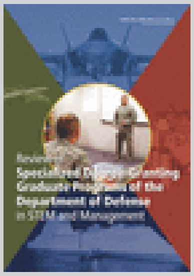

Review of Specialized Degree-Granting Graduate Programs of the Department of Defense in STEM and Management

ISBN
978-0-309-30339-2

160 pages
7 x 10
PAPERBACK (2014)

Committee on Review of Specialized Degree-Granting Graduate Programs of the DoD in STEM and Management; Division on Engineering and Physical Sciences; National Research Council

Review of
Specialized Degree-Granting Graduate Programs of the Department of Defense
in STEM and Management

Committee on Review of Specialized Degree-Granting Graduate Programs
of the DoD in STEM and Management

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS **500 Fifth Street, NW** **Washington, DC 20001**

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 competences and with regard for appropriate balance.

This is a report of work supported by Award HQ0034-10-D-0003, TO9 between the Department of Defense and the National Academy of Sciences. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-30339-2
International Standard Book Number-10: 0-309-30339-7

Cover: The Light Armored Vehicle–Upgrade Project (LAV-UP) image is courtesy of General Dynamics Land Systems.

Copies are available from:

The National Academies Press
500 Fifth Street, NW
Keck 360
Washington, DC 20001
(800) 624-6242 or (202) 334-3313
http://www.nap.edu

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, 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. Ralph J. Cicerone 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. C. D. Mote, Jr., 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 adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is 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. Ralph J. Cicerone and Dr. C. D. Mote, Jr., are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

COMMITTEE ON REVIEW OF SPECIALIZED DEGREE-GRANTING GRADUATE PROGRAMS OF THE DOD IN STEM AND MANAGEMENT

JACQUES S GANSLER, University of Maryland, *Chair*
THOMAS J. BURNS, ENSCO, Inc., *Vice Chair*
ROBERT A. CALICO, JR., Independent Consultant
RITA R. COLWELL, University of Maryland
EARL H. DOWELL, Duke University
JOHN V. FARR, U.S. Military Academy
BRENDAN B. GODFREY, University of Maryland
WESLEY L. HARRIS, Massachusetts Institute of Technology
MICHAEL L. HEIL, Ohio Aerospace Institute
ROBERT J. HERMANN, Hartford, Connecticut
WALTER F. JONES, Office of Naval Research
KATHRYN E. NEWCOMER, The George Washington University
LEIF E. PETERSON, Human Resources Concepts and Solutions
STEPHEN POLLOCK, University Michigan
STEVEN E. RAMBERG, National Defense University
CHARLES E. THORPE, Clarkson University

Staff

TERRY J. JAGGERS, Board Director
CARTER W. FORD, Study Director
MARGUERITE E. SCHNEIDER, Administrative Coordinator
DIONNA C. ALI, Research Assistant

Acknowledgment of Reviewers

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

Michelle Atchison, University of Texas System,
Lawrence D. Brown, University of Pennsylvania,
W. Peter Cherry, Ann Arbor, Michigan,
Paul G. Gaffney II, Monmouth University (emeritus),
Maryellen L. Giger, University of Chicago,
Paul J. Kern, The Cohen Group,
Louis J. Lanzerotti, New Jersey Institute of Technology,
Lester L. Lyles, The Lyles Group,
Charles E. Phelps, University of Rochester, and
James A. Voytuk, Annapolis, Maryland.

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

Preface

Recent National Research Council (NRC) reports on science, technology, engineering, and mathematics (STEM) and the Department of Defense (DoD) have focused on the quality of the DoD STEM workforce and the importance of ensuring an adequate number of people with the right STEM skill sets in the future.[1,2] This report is unique in that it addresses the need for relevant graduate STEM and management education for DoD military and civilians; assesses the cost, benefits, and organizational placement of DoD institutions that grant degrees in STEM and management; and evaluates alternative ways—for example, civilian institutions and distance learning—to ensure adequate numbers and high-quality education outcomes for DoD personnel.

TERMS OF REFERENCE

Section 245 of the National Defense Authorization Act for Fiscal Year 2013 (P.L. 112-239) directed the Secretary of Defense to enter into an agreement with the NRC to conduct a review of specialized degree-granting graduate programs of

[1] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce*, The National Academies Press, Washington, D.C., 2012.

[2] NRC, *Examination of the U.S. Air Force's Science, Technology, Engineering, and Mathematics (STEM) Workforce Needs in the Future and Its Strategy to Meet Those Needs,* The National Academies Press, Washington, D.C., 2010.

the DoD in STEM *and* management.[3,4] The NRC approved the terms of reference specified in the congressional language in May 2013, and funding for the study was received from the Office of the Secretary of Defense in July 2013. The president of the National Academy of Sciences appointed the committee in August 2013.[5] The terms of reference for the study include the following:

> 1. The need by the Department of Defense and the military departments for military and civilian personnel with advanced degrees in science, technology, engineering, mathematics, and management, including a list of the numbers of such personnel needed by discipline.
> 2. An analysis of the sources by which the Department of Defense and the military departments obtain military and civilian personnel with such advanced degrees.
> 3. The need for educational institutions under the Department of Defense to meet the needs identified.
> 4. The costs and benefits of maintaining such educational institutions, including costs relating to in-house research.
> 5. The ability of private non-Department of Defense institutions (public and private) or distance-learning programs to meet the needs identified.
> 6. Existing organizational structures, including reporting chains, within the military departments to manage the graduate education needs of the Department of Defense and the military departments in the fields of science, technology, engineering, mathematics (STEM) and management.
> 7. Recommendations for improving the ability of the Department of Defense to identify, manage, and source the graduate education needs of the Department in such fields.

COMMITTEE APPROACH

During four data-gathering meetings, the committee met with leaders and staff members from the Office of the Secretary of Defense, the Military Services, and various DoD-funded universities—including the Air Force Institute of Technology (AFIT), the Naval Postgraduate School (NPS), the Uniformed Services University of the Health Sciences, and the National Defense University—and representatives from civilian universities and industry. Additionally, the committee held smaller site visits with AFIT and NPS officials in Dayton, Ohio, and Monterey, California.

[3] For additional Information, see Bill Text Versions, 112th Congress (2011-2012), H.R. 4310, http://thomas.loc.gov/cgi-bin/query/z?c112:H.R.4310:, accessed March 4, 2014.

[4] A copy of the congressional tasking is provided in Appendix A.

[5] Biographies for the committee members are provided in Appendix B. The committee includes experts from academia, government, and industry with backgrounds in advanced education degree requirements for DoD military and civilian personnel, specifically in science, technology, engineering, mathematics (STEM) and acquisition, technology and logistics management; strategies associated with recruitment and retention of DoD military and civilian personnel requiring these types of advanced degrees; and an understanding of the abilities of both the public and private advanced-degree educational institutions to meet these DoD needs, either in residence or through distance learning.

The committee concluded its work during two 3-day meetings focused on finalizing its report, findings, and recommendations.

It was our great pleasure to work with the extremely dedicated and professional members of the committee during this study, and it is our hope that this report provides a useful service to DoD and the nation.

Jacques S. Gansler, *Chair*
Thomas J. Burns, *Vice Chair*
Committee on Review of Specialized Degree-Granting Graduate Programs of the DoD in STEM and Management

Contents

Acronyms

AETC	Air Education and Training Command
AFIT	Air Force Institute of Technology
AFMC	Air Force Materiel Command
AU	Air University
BOV	Board of Visitors
BRAC	Base Realignment and Closure
CNO	Chief of Naval Operations
CSAF	Chief of Staff of the Air Force
CUI	controlled, unclassified information
DAGSI	Dayton Area Graduate Studies Institute
DAWDF	Defense Acquisition Workforce Development Fund
DL	distance learning
DoD	Department of Defense
DSB	Defense Science Board
JPME	joint professional military education
MOOC	Massively Open Online Course

NDAA	National Defense Authorization Act
NDSEG	National Defense Science and Engineering Graduate Fellowship
NIH	National Institutes of Health
NPS	Naval Postgraduate School
NRC	National Research Council
NSF	National Science Foundation
OLI	Open Learning Initiative
PSM	Professional Science Master's
S&E	science and engineering
S&T	science and technology
SMART	Science, Mathematics, and Research for Transformation
SME	subject matter expert
STEM	science, technology, engineering, and mathematics
STEM+M	science, technology, engineering, mathematics, and management
UNM	University of New Mexico
USNWR	*U.S. News and World Report*
USUHS	Uniformed Services University of the Health Sciences
UT	United Technologies

Summary

Section 245 of the Fiscal Year 2013 National Defense Authorization Act (H.R. 4310) instructed the Secretary of Defense to enter into an agreement with the National Research Council (NRC) to conduct a review of specialized degree-granting graduate programs of the Department of Defense (DoD) in science, technology, engineering, mathematics, and management (STEM+M).[1,2] This report is the third in a series of recent NRC reports relating to STEM and DoD's workforce.[3,4] Its purpose is to address the need for relevant graduate STEM+M education for DoD personnel, both military and civilians; assess the cost, benefits, and organizational placement of DoD institutions that grant degrees in STEM+M; and evaluate alternative ways (e.g., the proper balance of DoD and civilian education sources and funding, distance learning delivery methods, and reporting structures of DoD-funded institutions) to ensure high-quality education outcomes.

---

[1] For additional Information, see Bill Text Versions, 112th Congress (2011-2012), H.R. 4310, http://thomas.loc.gov/cgi-bin/query/z?c112:H.R.4310:, accessed March 4, 2014.

[2] See Appendix A for the terms of reference and Appendix B for short biographies of the committee members.

[3] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce,* The National Academies Press, Washington, D.C., 2012.

[4] NRC, *Examination of the U.S. Air Force's Science, Technology, Engineering, and Mathematics (STEM) Workforce Needs in the Future and Its Strategy to Meet Those Needs,* The National Academies Press, Washington, D.C., 2010.

DoD is arguably the most intensely technological and complex enterprise in existence. When compared to the gross domestic product of other countries, DoD's budget ranks above all but about 20 nations. If DoD were a company, it would have the world's largest footprint and employee population. DoD maintains its edge over adversaries through continued investment in technology-enabled weapon systems. Each weapon, platform, vehicle, and person in an operating force is a node in one or more broadly distributed networks. Without STEM+M graduate education of sufficient quality and quantity, DoD's workforce will lack the understanding needed to acquire and operate these networked forces in support of U.S. security needs.

The committee could not determine how many advanced degrees are needed—or available—by STEM+M discipline, but because of globalization and the rapid pace of technological change, we know that more are needed overall. It is also apparent that a "one-size-fits-all" graduate education solution that meets DoD's growing STEM+M needs is not the correct solution. Students differ in their starting skills, academic interest, geographic location, time commitments, preferred learning style, and their ability to afford a quality education. It is therefore no surprise that the United States has more than 6,700 post-secondary schools, including many large state schools that each offer more than 100 STEM major and minor degrees.

DoD depends on these civilian institutions to educate the majority of its civilian workforce and military members. In addition to providing the opportunity to learn from world-renowned faculty members, civilian institutions offer degrees in disciplines not available at DoD-funded institutions, particularly in law, medicine, life sciences, and social sciences. The large number of civilian institution options creates a diversity of perspectives and ideas that strengthen the DoD workforce and military members, as well as the military and civilian faculty of DoD-funded educational institutions.

While a large number of DoD civilians and military members receive their graduate STEM+M education at civilian institutions, a not insignificant number are educated at specialized, DoD-funded degree-granting institutions, particularly the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS).[5] These schools offer valuable educational experiences typically not available at civilian institutions, which provide benefits that outweigh their costs. Notably, students attending AFIT and NPS possess the ability to readily conduct sensitive and classified research on campus alongside fellow students and faculty members. Their programs focus on militarily relevant problems, some of which might not

[5] From *The Armed Forces Officer*: "Broad continuous education—technical, conceptual, and moral-ethical—is the hallmark of a professional officer" (Congressman Ike Skeleton's Foreword, p. xii); "The profession itself, and the individual service in which one serves, must assume some of the burden of education and support for character formation" (p. 14); "The Services operate sophisticated education institutions to develop new officers, progressively through their careers" (p. 26) (U.S. Department of Defense, Potomac Books, Dulles, Va., 2006).

be welcome in civilian institutions (e.g., weapon system research). Their classroom environments allow for the free exchange of sensitive ideas. Their geographical and cultural proximity to Service laboratories create significant leverage for limited DoD research funds. In addition, the students have the opportunity to interact inside and outside the classroom with a cohort that shares a common interest in military culture and problems.

The majority of this report focuses on the graduate STEM+M education issues of the Air Force, Navy, and Marines, particularly those associated with AFIT and NPS—the two major specialized STEM+M degree-granting institutions in DoD. All three Services employ a similar graduate STEM+M education delivery model. These three Services identify, select, and fund a portion of their military officer graduate education pool from a central Service office. In addition, the Air Force, Navy, and Marine Corps send a significant number of their officers to AFIT and NPS and a smaller number to civilian institutions to obtain degrees not offered at AFIT or NPS and to broaden the intellectual diversity of AFIT, NPS, and Service Academy faculties.[6] Civilians and military members that fall outside this pool are funded predominately from local organizational budgets and tuition assistance programs, and they are nearly all educated at civilian institutions. In contrast to the partially centralized approach to graduate STEM+M education by the Air Force, Navy, and Marine Corps, the Army employs a decentralized graduate STEM+M education model that relies on subordinate organizations to identify and fund the graduate STEM+M education of its personnel. Also, as with the other services, the Army sends roughly an equal number of military officers to AFIT and NPS. The relative numbers of Army officers at these two institutions suggest that they send a larger percentage to civilian institutions. The Army's decentralized graduate education management approach presumably prevented the Army from responding to committee requests with sufficient information to allow the committee to make meaningful recommendations.[7] The apparent existence of an alternative graduate STEM+M education delivery model within the DoD suggests the need for a subsequent study of the Army's graduate education approach to determine if best practices of both centralized and decentralized education delivery models might be shared across the Services to enhance overall graduate STEM+M education outcomes. While all four Services appear to rigorously manage the graduate STEM+M education needs of their military personnel, they lack the enterprise-level ability

[6] The Marines require that officers who obtain STEM+M graduate degrees serve a "payback" assignment immediately following their degree program that requires their technical skill. This ensures the Marines achieve a return on their education investment. This requirement can be waived on a case-by-case base.

[7] Nancy Harned, Executive Director, Strategic Planning and Program Planning, Office of the Assistant Secretary of the Army (Acquisition, Technology, and Logistics), "STEM and Army S&T Enterprise," presentation to the committee on January 9, 2014.

to systematically manage their civilian workforce graduate education needs and sources. As a result, the committee was unable to determine if the Services are doing a good job of meeting the graduate education needs of their civilian personnel.

The increasing complexity and role of technology in new and future weapon systems provides sufficient evidence to demonstrate that DoD has a growing need for a workforce with graduate STEM+M degrees and a greater overall STEM+M literacy. Furthermore, this need can be satisfied using a holistic education strategy that offers a blended portfolio of graduate education choices that includes AFIT, NPS, and civilian institutions. Additionally, it is important that DoD recognize and continue to strengthen the value proposition of AFIT and NPS, particularly their research activities that are essential for achieving quality graduate STEM+M education outcomes and providing DoD with innovative capabilities. Following the examples of NPS and the Service Academies,[8] DoD can strengthen AFIT's value proposition by elevating its organizational placement to reflect its strategic importance. Finally, while DoD graduate STEM+M education programs for military members appear to be well funded and managed, a similar institutional commitment is required to manage the graduate STEM+M education needs of DoD's civilian workforce.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

The report's principal findings and recommendations align with six major themes. The themes, in priority order, are as follows:

1. Strengthen the STEM+M competencies of DoD's total workforce by placing greater emphasis on graduate STEM+M education.
2. Maintain a balanced portfolio of STEM+M graduate education sources consisting of DoD and civilian institutions.
3. Expand and adequately resource civilian workforce STEM+M graduate education initiatives.
4. Recognize and support the importance of STEM+M research at AFIT and NPS.
5. Enhance AFIT and NPS graduate education outcomes by increasing institutional collaboration through partnerships and effective distance learning methods.
6. Elevate AFIT's strategic priority.

[8] The Service Academies are Direct Reporting Units (i.e., they report to the headquarters of their respective Services), and the Uniformed Services University of Health Sciences reports to the Joint Chiefs.

Each theme is explained below and is then followed by supporting principal findings and recommendations. All report findings and recommendations, along with the evidence supporting each finding and recommendation, can be found in Chapters 1 through 4. Chapter 5 summarizes the contents of the report and provides the full text of the principal findings and recommendations.

1. Strengthen the STEM+M competencies of DoD's total workforce by placing greater emphasis on graduate STEM+M education.

The world's technical knowledge base and the technical complexity of modern warfare are rapidly increasing. By increasing its investments in graduate STEM+M education, even as the total workforce decreases in an increasingly constrained budget environment, DoD can continue developing and exploiting advanced technologies as key force multipliers. (Cf. Finding 1-1; Recommendation 1-1)

DoD leaders, regardless of background, will increasingly confront technical and technical management issues as the already rapid pace of technology change increases. DoD leadership could therefore encourage all graduate education programs to include technical and technical management-oriented components in order to send a strong signal of STEM+M's importance to the workforce and increase the STEM+M literacy of DoD decision makers. (Cf. Findings 1-2, 1-3; Recommendations 1-2, 1-3)

2. Maintain a balanced portfolio of STEM+M graduate education sources consisting of DoD and civilian institutions.

AFIT and NPS each have important value propositions that yield significant return on DoD investments. Value-added elements include graduate programs built around defense-based curricula and supported by military-relevant graduate research, the formation of multiservice and multinational intellectual networks that aid students throughout their military careers, and infrastructure and policies that facilitate sensitive and classified research. With recognition and full support of DoD, AFIT and NPS can contribute to a balanced STEM+M portfolio. Faculty members also form a body of technical and management experts that DoD acquisition and logistics professionals use to obtain independent opinions on challenging issues. (Cf. Findings 2-1, 2-5, 3-1, 3-4; Recommendations 3-2, 3-3, 4-1)

A significant portion of DoD's STEM+M graduate education needs could be met through civilian institutions. This is particularly important for degree programs in mission critical areas, such as life and medical sciences, which are not offered at DoD educational institutions in sufficient quantity to meet DoD needs. (Cf. Findings 2-3, 4-1; Recommendation 4-1)

3. Expand and adequately resource civilian workforce STEM+M graduate education initiatives.

DoD does much better strategically supporting the graduate education needs of its uniformed members than it does the needs of its civilian STEM+M workforce. This is true in terms of process, structure, opportunities, and funding. This issue could be addressed in three ways: (1) increase funding for civilian tuition assistance programs; (2) expand support for DoD's Science, Mathematics, and Research for Transformation program; and (3) aggressively use Defense Acquisition Workforce Development Funds (DAWDF) or "DAWDF-like" funds for the entire STEM+M workforce, by obtaining authorization from Congress either to expand existing DAWDF to include all STEM+M workforce professionals or to establish funding to educate those not covered by DAWDF. (Cf. Findings 1-5, 1-6, 2-6, 4-6, 4-7, 4-8, 4-9; Recommendations 2-2, 4-6, 4-7, 4-8, 4-9)

4. Recognize and support the importance of STEM+M research at AFIT and NPS.

An active research program is essential to quality graduate education. Active, high-quality DoD research programs

- Provide critical elements of the student's graduate education,
- Identify future education needs before requirements are specified,
- Expose students early on to emerging technologies and new scientific and engineering discoveries,
- Instill a culture of lifelong learning in the students,
- Attract and retain quality faculty for all DoD educational institutions,
- Enhance the national visibility of DoD institutions, and
- Result in cost savings and new capabilities for DoD.

Ensuring that AFIT and NPS are allowed to maintain active research programs and encouraging them to achieve international recognition in selected, DoD-relevant areas could lead to better education outcomes for students at and graduates of both institutions. (Cf. Finding 3-3; Recommendation 3-1)

5. Enhance AFIT and NPS graduate education outcomes by increasing institutional collaboration through partnerships and effective distance learning methods.

By jointly sponsoring research and teaching activities, and by continuing to maintain and broaden their partnerships with DoD laboratories and civilian research universities, AFIT and NPS can provide a wider range of degrees and problem-solving perspectives to their students and enhance the quality and relevancy of their research. (Cf. Findings 2-3, 3-1, 4-2, 4-3, 4-4; Recommendations 4-2, 4-3, 4-4)

Both AFIT and NPS understand the elements of effective, quality methods of distance learning (DL). For example, NPS has achieved a national reputation for its systems engineering programs via quality DL methods. In an era of rapidly developing DL technology and opportunities, DoD can actively leverage its proven DL approaches to connect students in residence at AFIT, NPS, and civilian institutions; broaden AFIT and NPS student bodies with more civilian DoD personnel; and expand the size of AFIT and NPS Ph.D. programs by offering a wider range of courses and research experiences. (Cf. Findings 2-2, 4-4, 4-5; Recommendations 2-1, 4-4, 4-5)

6. Elevate AFIT's strategic priority.

Many DoD organizations recognize the strategic importance of their educational institutions by having them report at the highest levels in the Services or Joint Staff. These institutions include the Service academies, the Uniformed Services University of Health Sciences, and NPS. AFIT currently reports to Air University, which reports to the Air Education and Training Command (AETC), where AFIT's graduate STEM+M education and research activities do not align well with AETC's Professional Military Education and training missions. By aligning AFIT with leadership that prioritizes its education and research mission, DoD can increase AFIT's strategic value and give it the authority and autonomy it requires to effectively interact with institutional peers, such as NPS. In accordance with the examples cited above, the best way to achieve this result is to have AFIT report directly to the Chief of Staff of the Air Force. (Cf. Findings 3-5, 3-7, 3-8, 4-4; Recommendation 3-2)

CLOSING REMARKS

Achieving success in modern conflicts is due in no small part to military forces that leverage technology enablers that connect mobile forces, create and accurately deliver smart weapons, hide from and defeat sensors, automatically detect threats from stand-off distances, allow small units to control large areas, and follow the commands of remote operators located outside the region of conflict. The increasing reliance on sophisticated technologies by friendly and adversarial forces to achieve force multiplier effects demands a technically competent workforce capable of buying, operating, maintaining, and, in some cases developing, technologies and technology-enabled systems. DoD leaders, regardless of their background, also require a basic understanding of technical concepts as they increasingly make decisions influenced by technical factors. One of the most effective ways to prepare DoD leaders and DoD's workforce to maximize the benefits of technology-enabled capabilities is through robust STEM+M graduate education. DoD has many graduate education options to choose from, including DoD schools, such as NPS and AFIT, as well as a wide range of civilian institutions.

No single source or class of sources meets all DoD graduate education needs, and not all needs are filled by technical degrees. Civilian and military professionals advancing their education in non-technical disciplines would augment their education with technical and management courses that would enable their decision making in an increasingly technical society. The committee's recommendations are designed to help DoD develop to retain a technically literate workforce through an appropriately blended portfolio of effective DoD in-house and civilian education options. A properly educated DoD workforce will help ensure DoD's ability to meet future challenges.

1

The Need for STEM and Management Graduate Education in the Department of Defense

TECHNOLOGY AND MILITARY OPERATIONS

The U.S. military is arguably the most intensely technological, complex enterprise in existence. When compared to the gross domestic products of other countries, the Department of Defense (DoD) budget ranks above all but about 20 nations. If viewed as a company, it would be the largest globally with the most employees. Major investments in weapons systems using advanced technologies provide an advantage over competing systems. Each weapon, platform, vehicle, and person in an operating force is a node in one or more advanced networks that provide the ability to rapidly form a coherent force from a large number of broadly distributed elements. DoD's ability to create and operate forces of this nature demands a competent understanding by its workforce of the composition, acquisition, and employment of its technology-enabled forces.

Military strategy, concepts, and tactics are greatly affected by particular technological capabilities available to the United States, its allies, and its adversaries. It is important that those who formulate, establish, and use these strategies, concepts, and tactics are capable of understanding the essential combination of technologies, weapons effects, and force dynamics that affect the nation's security. As an historical example, the advent of nuclear weapons and long-range missiles changed the nature of post-World War II (WWII) conflict and the adversary's military strategies. The United States responded to the change by placing greater emphasis on developing a more technologically advanced military corps. In retrospect, this emphasis played an essential role in the success of that era, producing a superior U.S.

technology base and a world-class science, technology, engineering, mathematics, and management (STEM+M) DoD workforce and industrial base.

The need to counter, deceive, and cope with adversary forces of competing technological characteristics is an essential part of the military equation. As a consequence, the intelligence function, which has seen significant technological advancement over the past few decades, provides the United States with a capability unmatched in the world today. Understanding the capabilities and limitations of intelligence, reconnaissance, and surveillance systems of adversaries, as well as our own, is key to deterring conflict and prevailing if deterrence fails. Success depends on sufficient understanding of the differences in capabilities, which, in turn, requires a deeper understanding of *all* capabilities. This deeper understanding requires a workforce competence and confidence that come only from broadly supported and readily available advanced education in STEM+M subjects.

For example, electronic warfare drives the struggle to dominate the signals environment. Understanding the technical details of electronic warfare is critical to understanding the nature of potential conflicts and using electronic warfare techniques to avoid or win conflicts. The technical breadth and depth of modern electronic warfare systems demands a DoD workforce with advanced technical understanding, largely achieved through graduate-level education and hands-on experience.

A second example requiring a DoD workforce competence in STEM+M is keeping pace with the performance, reliability, and survivability demands on networks, which form the basis of a coherent military force. Cyber operations require a deep technical understanding of the science and art of communications, storage, processing, network security, and the many forms of offensive and defensive actions. A highly skilled workforce capable of effectively designing, implementing, and managing this rapidly evolving domain is critical to modern military operations. Many of the required technical and management skill sets are best obtained through a strong mix of STEM+M programs in which graduate education is a fundamental keystone.

MANAGING THE DEFENSE INDUSTRIAL BASE

DoD acquires nearly all of its military combat systems from the private sector, where the collective defense industrial base performs most of the research, development, design, and production activities. However, the Armed Services and other DoD technical agencies are responsible for conceptualizing, specifying, contracting, testing, and accepting contractor-developed systems before military use.[1] The success of this approach requires competent contractors and a competent government buying entity that understands what it's buying and how what it's buying fits into the strategies and operational concepts governing its use. In all likelihood, the context within which a new system is used will differ from the context under which it was initially acquired. This requires that a growing fraction of the military and civilian workforce of DoD have access to relevant advanced STEM+M education in order to bring these two contexts closer and to effectively adapt to the inevitable differences.

Many private sector enterprises in DoD's industrial base have fewer business dealings with any entity other than DoD. As the overwhelming majority market for these businesses, DoD bears a major responsibility for maintaining the health of its industrial base. The ability to assess DoD's options for influencing its industrial base requires a sophisticated understanding of advanced technologies and industrial management, typically obtained through graduate education.

In addition to the need for in-house competence to specify and manage the acquisition of knowledge, technology, and systems from the private sector, there are special circumstances requiring government capabilities that advance knowledge, create technologies, and select system designs in an environment of secrecy, security classification, and selective need-to-know under the control of DoD in-house organizations. In particular, the constrained access required for many secure research projects makes it extremely desirable that DoD perform all phases of knowledge and technology creation within DoD technical education and laboratory institutions. Moreover, because the lives of military personnel are ultimately dependent on the ability of DoD personnel staffing these organizations to keep pace with continuously advancing weapon system technologies, they must periodically refresh their knowledge base through graduate education experiences. Chapter 2 provides an overview of DoD-funded and civilian institution graduate education sources.

LOOKING FORWARD

The current superiority of U.S. military forces is widely recognized as the result of the application of advanced technologies to military systems and operations for the past 50 years or more, together with a global dominance by the U.S. economy in the same time frame.

Finding 1-1. Looking forward to the next 50 years of greater leveling among the global economies and uncertainty about DoD budgets, the elements of superiority must be achieved in other ways. First among them is the need for a more, not

[1] Tim Coffey, *Chance Favors Only the Prepared Mind: The Proper Role for U.S. Department of Defense Science and Engineering Workforce,* National Defense University, Washington, D.C., August 2013.

the same or less, capable DoD workforce. This is likely to rest on individuals with greater knowledge, experience, and insight in STEM+M areas. This will be true for both military and civilian elements of DoD's workforce, as well as its industrial base. Relevant graduate education and a culture of lifelong learning are means to those ends.

Recommendation 1-1. The Department of Defense should increase its investments in graduate STEM+M education, even as the total workforce decreases in an increasingly constrained budget environment.

Today and for the foreseeable future, nation-states and non-state actors will challenge the United States with systems built from inexpensive, yet highly disruptive, commercially available technologies, such as the Digital Radio Frequency Memory.[2] The U.S. military will not overcome these challenges with large commitments of new resources, as was often the case in the past. Solutions will require a nimble and innovative DoD workforce capable of rapidly and creatively responding to the pace of technical change, which many believe is increasing exponentially with the proliferation of networks and inexpensive, yet highly capable, digital technologies.[3] Because trends indicate that future weapon and support systems will increasingly rely on complex technologies, military leaders will likely encounter situations where a basic understanding of technical principles is required to make quality performance, cost, and schedule decisions. Therefore, future military leaders, not just those with STEM+M degrees, would be well served to possess a basic familiarity with technical concepts.

This position is underscored by the recent decision of former Secretary of the Air Force James Roche and Chief of Staff General John Jumper to increase the Air Force leadership's literacy in and appreciation for STEM. Key Air Force leaders, including the Air Force Secretary, engaged airmen at all levels to emphasize that STEM literacy was a core competency of the Air Force. Going forward, DoD may wish to follow the Air Force example by promulgating a policy requiring military officers and non-commissioned officers to incorporate a basic technology literacy and technology management course in all degree-granting programs funded by DoD. As part of the policy, education monitors and supervisors responsible for reviewing and approving education funding requests would be held responsible for ensuring that those receiving education funds are properly counseled on the

[2] For additional information, see S.J. Roome, Digital radio frequency memory, *Electronics and Communication Engineering Journal* 2(4):147-153, http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=101420.

[3] Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*, Viking, New York, 1999, pp. 30 and 32.

policy and comply with it. Additionally, a waiver policy could be implemented for employees with truly unique circumstances where the cost of technology-related courses would yield little benefit to the individual or DoD.

Finding 1-2. The use of innovative technology solutions to address enduring DoD problems will not come simply by increasing the number of graduate degrees in STEM+M fields. Rather, it will require greater STEM+M "literacy" by all elements of the DoD workforce.

Recommendation 1-2. The Department of Defense should encourage greater inclusion of science, technology, engineering, and mathematics (STEM) and technically oriented management elements in all education programs in order to deepen the overall STEM literacy of the workforce.

Finding 1-3. The Air Force recently added STEM-related skills as an institutional competency for all military members and civilian employees. [4]

Recommendation 1-3. The Air Force's policy of instilling science, technology, engineering, and mathematics-related skills is one model the Department of Defense should emulate to further institutional competency for all military members and civilian employees.

MANAGEMENT COMPETENCE

DoD has a history of cost overruns, excessively long schedules, and performance shortfalls for complex programs that depend on high-technology goods and services. Improving in these areas requires management skills, as well as STEM+M literacy. Thus, leaders with advanced degrees in STEM+M are needed to achieve DoD's mission within the desired cost, schedule, and performance constraints. The proliferation of failed DoD programs and initiatives highlights the importance of

[4] *Air Force institutional competencies* are defined as the basic and essential knowledge, skills, and attitudes needed throughout one's career to operate successfully in a constantly changing environment. These education, training, and experiences provide the foundation upon which the Air Force's lifelong continuum of learning is built. The major categories are "Organizational" (employing military capabilities, enterprise leadership, managing organizations and resources, and strategic thinking), "People/Team" (leading people and fostering collaborative relationships), and "Personal" (embodies airman culture and communicating). Within the "employing military capabilities," competency is the "leverage technology" sub-competency that addresses STEM related behaviors. Institutional competencies apply to all members of the Air Force, military and civilian, and at all grades by proficiency levels. See U.S. Air Force, *Air Force Doctrine Document 1-1: Leadership and Force Development,* AFDD1-1, November 8, 2011, http://www.e-publishing.af.mil/.

astute management and leadership. DoD recognizes this need and places emphasis on identifying leaders with potential to make quality decisions and providing them with a broad range of training and educational opportunities, many of which lead DoD professionals to obtain a Master of Business Administration (M.B.A.) degree. The M.B.A. degree is popular among DoD military and civilian employees for several reasons. Employees recognize the importance of management skills and an understanding of how enterprises are managed across the spectrum of business sectors. The M.B.A. is popular in the civilian business world that interacts daily with DoD. The degree carries public credibility that is both attractive and useful. M.B.A. programs offer practical ways to obtain a graduate education while employed full-time. Many of these programs do not require a thesis. And unlike technical degrees, which generally require prior domain knowledge, M.B.A. programs require the type of skills and judgment often developed in the normal course of doing business. An M.B.A. provides value to the employee and DoD and is more accessible to many in the workforce than degrees demanding more technical depth. It is in DoD's interest to continue encouraging interested employees to seek M.B.A.s when technical graduate education is either impractical or irrelevant for DoD's and the individual's needs.[5]

ADVANCES IN TECHNOLOGY

The Defense Science Board (DSB) published a recent report that stated:

> The projected global technology landscape indicates that the U.S. should not plan to rely on unquestioned technical leadership in all fields…Future adversaries may be able to use [information on past asymmetric approaches] along with globally available technology to counter longstanding U.S. advantages and may, in isolated niches, be able to achieve capability superiority.[6]

These observations led the DSB to recommend that DoD continuously scan the technology horizon and establish a robust experimentation program to create and avoid surprise. The success of both recommendations depends heavily on increased competence in STEM+M areas.

A 2012 NRC report on DoD STEM needs identified rapidly evolving areas of science and engineering with a potential for high impact on future DoD opera-

---

[5] Caution should be given against treating M.B.A.s, or even graduate degrees in technical fields, as a "check-the-box" situation. DoD is better off with civilians and uniform personnel who receive graduate degrees from accredited and recognized institutions.

[6] Defense Science Board (DSB), *Technology and Innovation Enablers for Superiority in 2030,* Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C., October 2013.

tions.[7] This includes the areas of biotechnology and nanotechnology, which are areas of educational concern because they have grown rapidly since most current members of the military and civilian workforces received their STEM education. The rapid advances in biological and nanoscale materials science and technology (S&T), together with a growing array of applications, make it clear that militarily relevant capabilities can and will be created in the coming years. These emerging capabilities promise great opportunities for offensive operations but also present great threats to the nation and its forces. Currently, the level of investment in biotechnology and nanoscale materials by DoD beyond S&T is limited. Historically, DoD has had little engagement with the biological sciences except for its medical needs. Therefore, the number of DoD professionals with biological science expertise is low, and a strong internal advocacy for investment and education in this area has not developed. These are but two examples of emerging technologies DoD might leverage to improve its warfighting capabilities. Without the technical skills needed to understand the theory underlying these technologies, DoD employees will be unable to predict their warfighting impact. This level of understanding is primarily obtained through graduate STEM+M education.

WORKFORCE MANAGEMENT COMPETENCE

In 2008, DoD updated its policy governing graduation programs for military members. The revised policy, which represents a significant shift from earlier policies focused on graduate education to achieve specific competencies for anticipated assignments, emphasized the following:

> 4.2. Graduate education programs shall be established to:
>
> 4.2.1. Raise professional and technical competency, and develop the future capabilities of military officers to more effectively perform their required duties and carry out their assigned responsibilities.
> 4.2.2. Provide developmental incentives for military officers with the ability, dedication, and capacity for professional growth.
> 4.2.3. Develop or enhance the capacity of the Department of Defense to fulfill a present need, anticipated requirement, or future capability.[8]

DoD's updated policy governing graduate education is much broader than the previous policy and reflects not only a growing dependence on advanced educa-

[7] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce,* The National Academies Press, Washington, D.C., 2012.

[8] Department of Defense (DoD), Instruction 1322.10, DoDI 1322.10, April 29, 2008, http://www.dtic.mil/whs/ directives/, p. 2.

tion but also the need for skills to adapt to a more rapidly changing and uncertain future. In order to maintain the technical and management competence necessary to create, maintain, and operate DoD's systems, each of the Armed Services has developed its own internal processes for establishing how many DoD personnel are needed for a mission and what kind of advanced education they may need. Some of these processes are tied to the immediate need to fill current and anticipated skill shortages and have fairly specific specifications by specialty, degree, and rank. All are likely to be adversely affected by the ups and downs of current budgets as well as the operational tempo of the Service.

Other DoD education initiatives are tied to more general and strategic workforce education goals as called for in the 2008 policy.[9] For example, military personnel at both the officer and enlisted levels know their Service regards higher education as an important indicator for promotion. While not a requirement, a degree can be a key peer discriminator. A cadre of military officers are selected each year by the Air Force, Navy, and Marines to pursue graduate education at either civilian or DoD in-house universities. Others take advantage of DoD's military tuition assistance to advance their education in parallel with their full-time assignment. Still others pursue additional education and advanced degrees completely on their own time and with their own resources. The choice of institutions, as well as educational content, varies greatly as a consequence of these different initiatives and individual goals.

Finding 1-4. Tuition assistance should be equally important for the military and civilian workforces. But civilian workforce tuition assistance appears to be viewed by DoD as less important and is therefore poorly funded.

Recommendation 1-4. DoD should fund the civilian tuition assistance program at levels similar to the military program in terms of per capita outlay, factoring in an appropriate reduction for the fact that DoD can hire civilians with graduate degrees, whereas military members generally must earn their degrees after joining.

Science, Mathematics, and Research for Transformation (SMART) is a scholarship-for-service program designed to produce the next generation of civilian S&T leaders. Since 2005, the SMART program has helped to educate an average of nearly 100 STEM professionals each year. Roughly 30 percent of SMART scholarships are at the Ph.D. level, while 70 percent are at the master's level. Participation after 2009 appears to be limited more by budget than by either demand or opportunity. A scholarship recipient typically incurs a 3-year service obligation for each year of release time for education. Smaller but similar "home grown" STEM

[9] DoD, Instruction 1322.10, April 29, 2008.

graduate education programs can be found in many organizations throughout DoD, particularly at DoD laboratories. Although these numbers are not large in the overall workforce context, they are strategically important because they provide a substantial talent pool for securing DoD's future.

DoD's various military and civilian education programs have produced a current workforce with the education levels shown in Table 1-1. The committee's terms of reference (Appendix A) calls for a breakdown of the number of STEM+M degrees "needed by discipline." Other than the needs identified and funded by the Services' centralized offices for managing the graduate education of their military officers, the committee was unable to obtain needed data on the entire workforce broken down by STEM+M discipline, or, as Table 1-1 implies, holders of current graduate STEM+M versus other degrees. Creative attempts to deduce or infer current or needed STEM+M degrees in total or by discipline across the workforce resulted in unacceptable levels of uncertainty for drawing meaningful observations, much less actionable recommendations.

Finding 1-5. The Air Force, Navy, and Marines have a comprehensive and well-executed process for the career development of their military officers. Moreover, these Services track and support the graduate education of its officers quite well. The committee reviewed these processes and believes they provide a solid basis for tracking the evolution of the military workforce. The committee had inadequate information to reach a conclusion about the Army processes.

Recommendation 1-5. The expanding global knowledge base and increasing technological complexities of modern military systems and operations suggest the need

TABLE 1-1 Current Department of Defense (DoD) Workforce Broken Down by Degree Level and Major DoD Organization for Military and Civilian Employees

	Doctorate	Masters	Bachelors	Total
Army	10,720	24,585	48,119	83,424
Navy	2,884	15,830	15,259	33,973
Marine Corps	325	3,047	14,845	18,217
Air Force	7,601	31,429	22,855	61,885
Civilian agencies	11,904	94,486	182,341	288,731
Total	33,434	169,377	283,419	486,230

NOTE: A detailed analysis was not done to determine the correctness of the outcomes in Table 1-1. These outcomes are embedded in a much larger context of strategic, financial, and personnel decisions made by each institution in support of its workforce needs.

No attempt was made by the source of this data to break out degrees related only to STEM+M disciplines.

SOURCE: Office of the Secretary of Defense (Acquisition, Technology, and Logistics), Washington, D.C.

for a sustained and increased number of graduate STEM+M degree recipients in the future, even if the total workforce decreases. This expansion should be sourced by a combination of DoD-funded graduate schools and civilian institutions (both public and private).

The U.S. military, especially the Army and its Air Corps, undertook a significant training and education effort between WWI and WWII that prepared midgrade officer corps during a period when promotions and operations were limited. This enabled leadership to more rapidly adapt to the mobilization and leadership challenges at the outset of WWII. Such a need and opportunity may lie ahead for the broader DoD.

Growing demands within the civilian element of DoD's workforce for STEM expertise are evident from recent hiring trends. Comparing 2012 hires to those in 2000 reveals that while the total number of civilians hired is down (31,336 to 29,731), both the number and the STEM ascensions as a fraction of all employees are up: 1,780 to 2,483 individuals, and 5.6 percent to 8.3 percent.[10] This trend is significant and consistent with views taken in a pair of earlier NRC reports and a recent forecast by the President's Council of Advisors on Science and Technology that predicts the U.S. workforce will require approximately 1 million more STEM graduates in the next decade than the current pipeline is likely to produce.[11,12,13] There are some counterarguments on the future demand for actual STEM jobs in the U.S. civilian workforce; however, the vectors for STEM+M degrees and for competency in these fields are clearly heading up.[14] Both the military and civilian components of DoD's workforce must keep pace with these education and hiring trends if they intend to compete with the private sector for their share of the highest-quality graduates. Although the tracking of civilian graduate education needs and degrees are rudimentary at present (e.g., degree levels only, not degree

[10] Laura Stubbs (Senior Executive Service), Director, S&T Initiatives and STEM Development Office, OASD(R&E)/Research Directorate, "SMART 101," presentation to the committee on November 8, 2013. Based on DoD S&E occupations under the STEM taxonomy. The subject of a standardized taxonomy/ontology was addressed in the 2012 NRC report. Recommendation 3-2a from that report, which is provided in Appendix D, deals specifically with the need for a standardized DoD taxonomy.

[11] NRC, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* The National Academies Press, Washington, D.C., 2007.

[12] NRC, *Rising Above the Gathering Storm Revisited: Rapidly Approaching Category 5*, The National Academies Press, Washington, D.C., 2010.

[13] Executive Office of the President, *Report to the President: Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*, Washington, D.C., February 2012, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-executive-report-final_2-13-12.pdf.

[14] Ibid.

fields), the framework is now available to better track special expertise and degrees by field.

Finding 1-6. A strategic mechanism to track and manage the overall civilian workforce is emerging in the inaugural DoD *Fiscal Years 2013-2018 Strategic Workforce Plan Report.*[15] It appears to be a comprehensive effort to manage the civilian workforce.[16]

Military and civilian workforces in DoD are constituted in very different ways. For example, unlike the civilian workforce, which can hire a senior Ph.D. scientist off the street, the military workforce is built only at the entry level. Thus, individual career development is the only mechanism to grow military workforce skills and experiences. In contrast, the civilian workforce evolves at all levels and competes in a larger marketplace for its members at all levels.

DoD's civilian workforce is divided into 22 "functional communities" that comprise 93 percent of the civilian population, as shown in Figure 1-1 from DoD's Strategic Workforce Plan.[17] It is estimated that STEM positions can be found in 10 of these functional communities, representing up to 44 percent of the total DoD civilian workforce. This number may be somewhat misleading given that skills and experiences of civilian science and engineering (S&E) personnel assigned the same civil service label vary between and within functional communities. For example, there are about 130,000 DoD S&E employees. One-third of them work in DoD laboratories. The remaining two-thirds mostly work in the major range and test facilities, operational test facilities, logistics and maintenance centers, and system acquisition centers. The skill sets, experiences, and graduate education needs of these employees are quite different, despite the fact they are classified with overlap-

---

[15] DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report,* Fall 2013, http://dcips.dtic.mil/documents.html.

[16] From DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report* (2013):

> The plan incorporates the requirements of section 115b of title 10, United States Code (U.S.C.) and builds on lessons learned from previous efforts, which provide a unified process for workforce planning across the Department. The workforce planning process is guided by DOD Instruction (DODI) 1400.25, Volume 250, DOD Civilian Personnel Management System: Volume 250, Civilian Strategic Human Capital Planning, November18, 2008. This DODI establishes DOD policy to create a structured, competency-based human capital planning approach to the civilian workforce's readiness (p. ii).
>
> [It responds to] Section 935 of the NDAA FY 2012 amended section 115b of title 10, U.S.C. as follows:
>
> - Biennial Plan Required: The Secretary of Defense shall submit to the congressional defense committees in every even-numbered year a strategic workforce plan to shape and improve the civilian employee workforce of the Department of Defense; and
> - An assessment of the critical skills and competencies of the existing civilian employee workforce of the Department and projected trends for five years out (vice seven years) in that workforce based on expected losses due to retirement and other attrition (p. 12).

[17] DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report,* 2013.

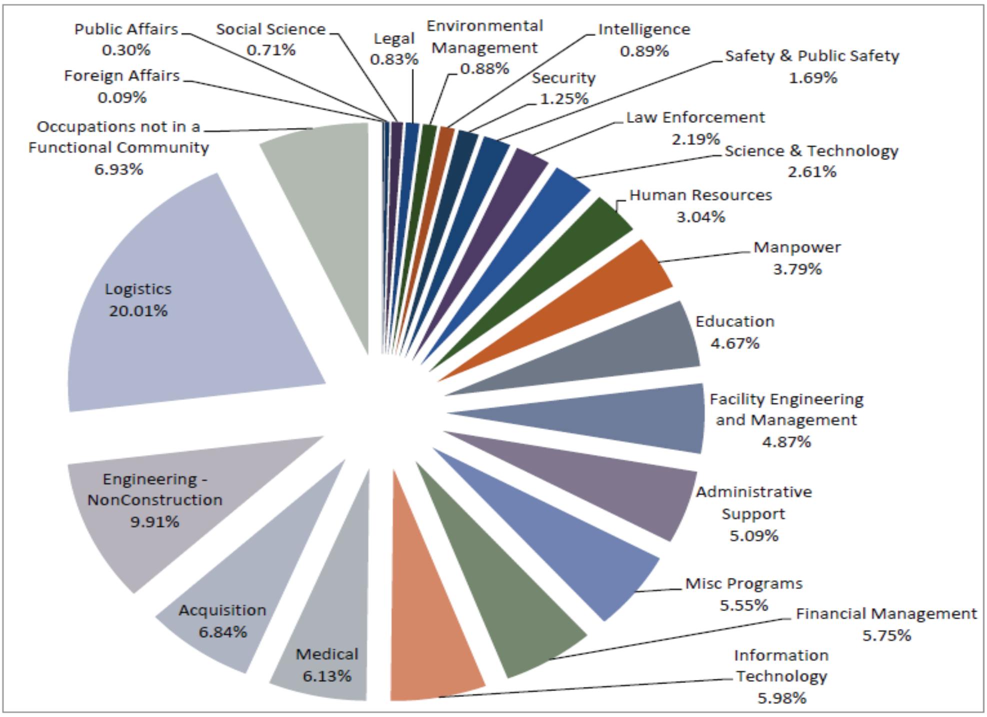

FIGURE 1-1 The Department of Defense (DoD) civilian workforce is divided into 22 "functional communities" that comprise 93 percent of the civilian population in 2012. SOURCE: DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report*, http://dcips.dtic.mil/documents.html, Fall 2013.

ping labels of the Civil Service System and may be grouped within the same DoD Strategic Workforce Plan functional area.

The need for a more detailed taxonomy within the S&T functional community was identified by a community report (Appendix 7 of DoD's Strategic Workforce Plan[18]) and would likely lead to better information on expertise and degree fields for the workforce. To illustrate the point, an S&E employee in a DoD laboratory might choose to cross-train into an acquisition career field while retaining the same Civil Service job series designation and possibly the same functional community. Civilian workforce managers have many marketplaces to use in order to make such transitions within a given billet count and overall workforce. Moreover, STEM careers tend to be a local matter rather than a department- or Service-wide priority. DoD's Strategic Workforce Plan offers a framework to have a strategic view

[18] DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report*, 2013.

for DoD for its civilian workforce and a means to achieve it, even if the implementation is largely local. If executed correctly, this action will significantly improve DoD's visibility into, as well as ability to manage, the graduate education needs of its civilian STEM+M workforce.

ORGANIZATION OF THE REPORT

The remainder of the report is structured as follows: Chapter 2 provides an overview of current DoD STEM+M graduate education and provides working definitions for the relevant terms used in the report. Chapter 3 provides the value proposition for the two primary DoD institutions offering advanced degrees in STEM+M: AFIT and NPS. Chapter 4 provides a broad discussion on alternative ways to enhance graduate education outcomes. Finally, Chapter 5 consolidates recommendations with the six major themes described in the Summary.

2

Overview of Current Department of Defense STEM and Management Graduate Education

STEM+M GRADUATE EDUCATION PROGRAMS WITHIN THE COMMITTEE'S PURVIEW

For the purpose of this report, "graduate education" is defined to be an educational program at a post-baccalaureate level that (1) uses previous academic preparation and performance as one of the admission criteria; (2) is either individually accredited or provided by an accredited educational institution; and (3) leads to an advanced degree which, in accordance with the terms of reference, is defined to be at the master's degree level or higher (e.g., Ph.D.).[1]

Therefore, although clearly critical to the Department of Defense (DoD), as outlined in Chapter 1 and presented in various reports, many important postgraduate, nondegree educational and training programs taken every year by DoD military and civilian personnel are outside the scope of this study. [2,3] Thus, this report does not examine or evaluate the large number of excellent certificate-granting, Intermediate Development Education, or training and short-course programs. For the reasons mentioned above, this report does not include detailed analysis or assessment of the following:

---

[1] See Appendix A for the terms of reference.

[2] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce*, The National Academies Press, Washington, D.C., 2012

[3] Government Accountability Office (GAO), *Joint Military Education: Actions Needed to Implement DoD Recommendations for Enhancing Leadership Development,* Washington, D.C., October 2013.

- The many nondegree programs offered by the Services' various war colleges (their degrees are not STEM-specific);
- The non-master's and non-Ph.D.-granting programs at the Joint Counterintelligence Training Academy, Defense Acquisition University, and at the various institutions comprising the National Defense University;
- Programs that do not fall within the definition of science, technology, engineering, and mathematics (STEM) and management (+M) for the purposes of this report—for example, in military leadership, operations, strategy, doctrine, etc.; and
- Academic programs that are explicitly labeled as certificate programs or those that have as the sole purpose the preparation of personnel to undertake a specific responsibility that arguably would require recertification in the future.

Similarly, because the Uniformed Services University of the Health Sciences (USUHS) has the extremely focused, unique, and critical mission of educating military doctors and other medical personnel, this report does not include an assessment of its nationally and internationally respected postgraduate degree programs. For the purposes of this report, STEM+M programs are considered to be those that grant master of science (M.S.) and doctorate of philosophy (Ph.D.) degrees having the designations (or similar ones) shown in Table 2-1.

It should be noted that life science and social science disciplines are not included in Table 2-1. This is not an indication of the lack of regard for those disciplines. Indeed, life sciences and social sciences are growing in importance to the military and belong in any reasonable compilation of STEM+M disciplines. However, other than to confirm that DoD fills its need for graduate life and social science degrees through civilian institutions, the committee's sources were unable to provide data pertaining to specific needs, sources, current numbers of degrees, and degree levels, among other factors. Because AFIT and NPS, which do not offer life and social science programs, were the only DoD institutions capable of providing quantitative education data, the committee was unable to substantively address life and social science education issues in this report.

In accordance with the terms of reference, postgraduate programs in management are addressed only to the extent that they relate directly and explicitly to the effective and efficient operation of STEM-driven enterprises, such as laboratories, technical systems, life-cycle planning and operation, complex systems acquisition, strategic and tactical activities and logistics, and contract management. For this reason, such programs are referred to as "STEM+M."

TABLE 2-1 M.S. and Ph.D. Degree Designations Defined as "STEM+M" for the Purposes of this Report

STEM+M M.S. and Ph.D. Degree Designations	
Aeronautical engineering	Industrial engineering
Aerospace engineering	Industrial hygiene
Air logistics	Information sciences
Applied mathematics	Information technology management
Applied physics	Information/electronic warfare systems engineering
Applied science	Logistics and supply chain management
Astronautical engineering	Materials science
Bio engineering	Materials engineering
Bio sciences	Mathematics
Chemical engineering	Mechanical Engineering
Chemistry	Meteorology
Civil engineering	Network operations
Combating weapons of mass destruction	Nuclear engineering
Computer engineering	Oceanography
Computer science	Operations analysis
Cost analysis	Operations research
Cyber operations	Optical science and engineering
Cyber warfare	Physics
Earth sciences	Project/program management
Electrical engineering	Remote sensing intelligence
Engineering management	Software engineering
Engineering science (mechanical engineering)	Space systems
Environmental engineering and science	Statistics
Human systems engineering	Systems analysis
Human systems integration	Systems engineering

Academic credentials, typically represented by college degrees, are normally considered to be "valid for the lifetime of the person to whom they are issued,"[4] although to remain proficient, the knowledge required to obtain the degree must be periodically refreshed and updated. Other professional and/or training certifications are "normally valid for a limited number of years, based on the pace of change in the certified profession, and require periodic recertification through reexamination (to demonstrate continuing competency as occupational standards of practice evolve) or continuing professional development (to demonstrate continually enhanced competency)."[5]

STEM+M GRADUATE EDUCATION DELIVERY MODELS IN THE DEPARTMENT OF DEFENSE

The Air Force, Navy, and Marine Corps share many common characteristics in the way they provide STEM+M graduate education to their military and civilian personnel. [6,7,8,9] STEM+M graduate education needs for military officers are collected and prioritized by centralized, enterprise-level organizations. These organizations also select military officers for graduate education programs, determine where the officer will obtain his or her education, and provide funds for the officer's education.[10] A significant number of military officers selected by these offices for graduate STEM+M education programs are sent to AFIT and NPS. A much smaller number are sent to civilian institutions. The criteria for determining if an officer will be sent to a DoD-funded or a civilian institution include the availability of

[4] Institute for Credentialing Excellence website, http://www.credentialingexcellence.org/p/cm/ld/fid=14, accessed April 23, 2014.

[5] Ibid.

[6] Col Jeffrey White, Chief, Air Force Learning Division, AF/A1DL, "Air Force Education Requirements Board," presentation to the committee on September 10, 2013.

[7] Pat Hogan, Chief, Acquisition Career Management and Resources Division, Office of the Assistant Secretary of the Air Force for Acquisition, "Advanced Academic Degrees (AADs) for Military Scientists & Engineers," presentation to the committee on September 11, 2013.

[8] CAPT Michael Davis, Director, Information, Analysis and Development Division (N15), and CMDR Paul Acquavella, Head, Education Branch (N153), "Navy's Specialized Degree-Granting Graduate Programs," presentation to the committee on September 10, 2013.

[9] Col Lawrence Miller, U.S. Marine Office of Manpower and Reserve Affairs (M&RA), H.Q. U.S. Marines, personal communication with the committee on May 29, 2014.

[10] Although the Marines have a centralized office for selecting officer graduate education candidates, the Department of the Navy pays for the Marine officer's tuition and fees. A large majority of Marine officers selected by this office for graduate STEM+M education attend NPS.

degree programs in the required discipline, the desire to broaden the intellectual diversity of the workforce, and cost.[11]

AFIT and NPS do not offer degree programs in several militarily vital disciplines, including law, medicine, and the life and social sciences. In fact, AFIT and NPS leaders insist that none of their sponsors have stated a need for life science curricula. Hence, students selected for these degree-granting programs are largely sent to civilian institutions. Officers are also sent to civilian institutions to increase the intellectual diversity of DoD's workforce. In this regard, civilian institutions are heavily used to educate future members of the AFIT, NPS, and Service Academy faculties. The cost to send an officer to a civilian institution includes indirect costs factored into tuitions and fees. Many indirect costs to maintain AFIT and NPS are paid for by other organizations. For example, building construction and maintenance are typically funded out of military construction and base operating budgets, respectively. Because these costs are not included in AFIT and NPS tuition rates, the centralized graduate education management offices typically pay less to send an officer to AFIT and NPS than to a civilian institution. However, as discussed in Chapter 3, the cost to send officers to AFIT and NPS from a "total DoD cost perspective" are generally no less than civilian institutions.

Enlisted members of the Air Force, Navy, and Marines; military officers not selected for graduate education programs by their centralized Service offices; and all Service civilians either pay their own costs to attend graduate school while they hold full-time jobs, or they take advantage of various DoD and Service programs that fund all or portions of their educational expenses. These include the military tuition assistance programs and the DoD Science, Mathematics, and Research for Transformation program discussed in Chapter 1 and Chapter 4. Nearly all students who fall into these categories are educated at civilian institutions. Unlike the data available from the centralized military officer graduate education management offices, the committee was unable to find anyone in DoD responsible for aggregating and analyzing data associated with graduate education and needs for all employees in these categories, which constitute the vast majority of military and civilian employees pursuing and holding graduate STEM+M degrees.[12] This may not be true for the Marines, where unlike the Air Force and the Navy, more military members hold graduate STEM+M degrees than their civilian counterparts.[13] It was therefore

[11] The Marines require that officers who obtain STEM+M graduate degrees serve a "payback" assignment immediately following their degree program that requires their technical skill. This ensures the Marines achieve a return on their education investment. This requirement can be waived on a case-by-case base.

[12] This may not be true for the Marines. Anecdotal evidence suggests more Marine military members hold graduate STEM+M degrees than do Marine civilians.

[13] Col Lawrence Miller, U.S. Marine Office of Manpower and Reserve Affairs (M&RA), H.Q. U.S. Marines, personal communication with the committee on May 29, 2014.

impossible to satisfactorily address the terms of reference requiring analyses of the need for and sources of graduate STEM+M education across DoD's workforce.

Finally, with the exception of a single, high-level presentation offered by one of many Army organizations responsible for meeting the graduate STEM+M education needs of their assigned employees, the committee did not have the opportunity to learn or offer substantive observations about the Army's graduate STEM+M education delivery model.[14] From the single briefing the committee received, it appears that the Army employs a model that differs in two major ways from the other Services. First, it appears that the Army does not have a centralized, enterprise-level office for managing the graduate education needs of its military and civilian workforces. Instead, the Army model is decentralized, relying on an individual organization (e.g., the Corps of Engineers) to define graduate education needs and select and fund employees to meet these needs. As a result, the committee was unable to find someone in the Army capable of addressing graduate education approaches for the entire Service. And the Army did not offer representatives to discuss alternative approaches beyond those offered by the organization briefed to the committee.

Second, as shown in Chapter 3, the Army sends nearly as many officers in absolute numbers to AFIT and NPS as do the other Services. However, given the relative size of the Army, the committee was left with the impression that a much larger percentage of the Army officer population attends civilian institutions than the other Services. Later in the report, the committee recommends that the DoD conduct a subsequent study of the Army graduate education deliver model(s) to determine if sharable best practices exist between the various Service approaches. The next two sections briefly discuss civilian and DoD-funded (AFIT and NPS) graduate STEM+M education sources.

STEM+M GRADUATE PROGRAMS FOR DEPARTMENT OF DEFENSE PERSONNEL AT CIVILIAN INSTITUTIONS

The majority of DoD civilian and military personnel holding graduate STEM+M degrees have obtained them at civilian education institutions, both on-campus and by distance learning. These institutions vary in geographical diversity, cost, and educational quality. For example, NPS sends students for degrees they do not offer to universities ranging from major Tier I schools to emerging research universities, as well as highly specialized institutions. Benefits of degree programs offered at civilian institutions compared to those offered at AFIT or NPS include

[14] Nancy Harned, Executive Director, Strategic Planning and Program Planning, Office of the Assistant Secretary of the Army (Acquisition, Technology, and Logistics),"STEM and Army S&T Enterprise," presentation to the committee on January 9, 2014.

greater course diversity, exposure to a diverse student body, and exposure to best practices from industry, with its broader perspectives than DoD. Chapter 3 contains a fuller discussion of the trade-offs inherent in a degree from a civilian institution as compared to one from AFIT or NPS.

What is most striking about DoD's attitude toward civilian universities in providing graduate education for DoD military and civilians is the lack of availability (within DoD and the individual Services) of consistent and comprehensive data on the number of graduate degrees granted, the specific types of programs (e.g., STEM+M or not), and the identity of the granting institutions, among other factors. Yet, outstanding military leaders have pursued—and current potential leaders will continue to pursue—graduate degrees in civilian universities, although not necessarily in STEM+M. For example, of the past 15 current and recent chiefs of staff of the Air Force, Navy, and Army, 11 have earned master's degrees, but only one was granted by a DoD graduate institution.

STEM+M GRADUATE DEGREE PROGRAMS AT THE AIR FORCE INSTITUTE OF TECHNOLOGY AND THE NAVAL POSTGRADUATE SCHOOL

DoD currently depends on two educational institutions to provide the bulk of DoD "in-house" postgraduate STEM education for active duty military personnel: AFIT and NPS. Both of these institutions

- Enroll students outside their own military departments, as well as from the U.S. Coast Guard, DoD civilians, foreign military, the U.S. Army, and other agencies;
- Have management and monitoring responsibilities for many DoD military members who pursue postgraduate STEM degrees at civilian institutions;
- Offer STEM-related management degree programs; and
- Have academic components of master's and Ph.D. programs (e.g., admission requirements, foundational courses, credit hour requirements, completion time limits, academic performance evaluation processes, research projects, qualifying examinations and procedures for candidacy, and thesis and dissertation defenses consistent with those used in civilian institutions.

These factors, which are critical to providing quality educational experiences, are discussed further in Chapter 3.

The NPS mission statement is: "[to provide] high-quality, relevant and unique advanced education and research programs that increase the combat effectiveness of the Naval Services, other Armed Forces of the U.S. and our partners, to enhance our national security,"[15] and AFIT's is: "Advance air, space, and cyberspace power for the Nation, its partners, and our armed forces by providing relevant defense-focused technical graduate and continuing education, research, and consultation."[16] Within the context of the terms of reference for this study, these mission statements make clear that graduates of their postgraduate (STEM+M) programs are expected to use their new knowledge, experience, and skills to improve the effective and efficient operations of STEM-driven DoD enterprises. The STEM+M graduate degree programs offered by AFIT, with 3-year averages of degrees granted per year, are shown in Table 2-2 (master's degrees) and Table 2-3 (Ph.D. degrees). The STEM+M graduate degree programs offered by NPS, with 3-year averages of degrees granted per year, are shown in Table 2-4 (master's degrees) and Table 2-5 (Ph.D. degrees).

Tables 2-6 and 2-7 show the number of graduate degrees granted by NPS in 2009 to 2013 with theses/dissertations that were either classified or CUI (controlled but unclassified information).[17] Tables 2-8 and 2-9 show the number of graduate degrees granted by AFIT in 2009 to 2013 with theses/dissertations that were either classified or CUI. Because both NPS and AFIT adhere to the academic norm of requiring Ph.D. students to publish their theses/dissertations, the percent of classified or CUI Ph.D. theses/dissertations, although not broken down in these tables, is extremely low.

A number of interesting observations can be made from the preceding tables, as well as other information provided by AFIT and NPS.

- There are no STEM-specific graduate degrees offered in NPS's National Security Affairs department or its Department of Defense Analysis.
- The only graduate degree granted in the NPS Department of Oceanography is a joint program with Meteorology.
- The mathematics departments at both NPS and AFIT are used primarily as "Service course" providers.
- AFIT and NPS Ph.D. programs are small (typically around 30 Ph.D.s per year are awarded in all STEM+M fields for AFIT and around 14 per year for NPS), compared to the roughly 10,000 Ph.D. degrees awarded in the United States each year in engineering alone, or compared to the 50-60 Ph.D.s awarded per year by a typical midsize civilian university.
- Over the past 3 years, 5 of AFIT's 23 STEM+M master's programs provided more than 50 percent of its degrees, whereas 9 programs in total provided

[15] NPS mission statement, see http://www.nps.edu/academics/generalcatalog/701.htm, accessed May 23, 2014.

[16] AFIT mission statement, see http://www.afit.edu/ABOUT/index.cfm, accessed May 23, 2014.

[17] CUI is defined to be "products containing unclassified information that requires safeguarding or dissemination controls, pursuant to and consistent with applicable laws, regulations and government-wide policies" (NPS "Combined Responses," p. 27).

TABLE 2-2 Air Force Institute of Technology STEM+M Master's Degrees Granted (Averaged over AY 2010-2011, 2011-2012, and 2012-2013)

Master's Degree Program Name	Delivery	Department	Military Graduates (3-Year Average)	Civilian (3-Year Average)	Total
Department of Aeronautics and Astronautics					
Aeronautical Engineering	R	Aeronautics and Astronautics	33.7	4.3	38.0
Astronautical Engineering	R	Aeronautics and Astronautics	14.3	1.0	15.3
Space Systems	R	Aeronautics and Astronautics	3.7	0.0	3.7
Materials Science[a]	R	Aeronautics and Astronautics/ Engineering Physics	1.3	0.0	1.3
			53.0	5.3	58.3
Department of Electrical and Computer Engineering					
Electrical Engineering	R	Electrical and Computer Engineering	38.0	2.7	40.7
Cyber Operations	R	Electrical and Computer Engineering	11.3	7.3	18.7
Computer Engineering	R	Electrical and Computer Engineering	8.0	1.7	9.7
Computer Science	R	Electrical and Computer Engineering	5.0	1.0	6.0
			62.3	12.7	75
Department of Engineering Physics					
Nuclear Engineering	R	Engineering Physics	15.3	0.7	16.0
Applied Physics	R	Engineering Physics	9.7	2.0	11.7
Combating Weapons of Mass Destruction	R	Engineering Physics	1.7	0.3	2.0
Optical Science and Engineering	R	Engineering Physics	0.0	1.7	1.7
			26.7	4.7	31.4
Department of Mathematics and Statistics					
Applied Mathematics	R	Mathematics and Statistics	1.3	0.7	2.0
Department of Operational Sciences					
Operations Research	R	Operational Sciences	20.7	3.0	23.7
Air Logistics	R	Operational Sciences	13.7	0.3	14.0
Logistics and Supply Chain Management[b]	R/DL	Operational Sciences	13.3	0.0	13.3
Logistics	R	Operational Sciences	7.0	0.7	7.7
Operations Analysis	R	Operational Sciences	5.0	0.0	5.0
			59.7	4.0	63.7

Department of Systems Engineering and Management					
Systems Engineering	R/DL	Systems Engineering and Management	30.0	1.7	31.7
Engineering Management	R	Systems Engineering and Management	14.3	0.3	14.7
Cost Analysis	R	Systems Engineering and Management	6.7	0.3	7.0
Environmental Engineering and Science	R	Systems Engineering and Management	4.0	0.0	4.0
Industrial Hygiene	R	Systems Engineering and Management	2.3	0.0	2.3
			57.3	2.3	59.6
Total of all departments			260.3	29.7	290

[a] Joint program.
[b] DL program starts January 2014.
NOTE: AY, academic year; DL, courses via distance learning; R, courses in residence; STEM+M, science, technology, engineering, mathematics, and management.
SOURCE: Data from the Air Force Institute of Technology.

TABLE 2-3 Air Force Institute of Technology STEM+M Ph.D. Degrees Granted per Year (Averaged over AY 2010-2011, 2011-2012, and 2012-2013) by Department

Ph.D. Program (All in Residence)	Department	MIL 3-Year Average	All CIV 3-Year Average
Aeronautical Engineering	Aeronautics and Astronautics	7.0	0.3
Applied Physics	Engineering Physics	3.3	0.7
Applied Mathematics	Mathematics and Statistics	0.3	1.7
Astronautical Engineering	Aeronautics and Astronautics	0.3	0.3
Computer Engineering	Electrical and Computer Engineering	0.7	0.0
Computer Science	Electrical and Computer Engineering	0.3	1.0
Electrical Engineering	Electrical and Computer Engineering	7.7	2.0
Electro-Optics[a]	Electrical and Computer Engineering/Engineering Physics	0.7	0.3
Logistics[b]	Operational Sciences	0.0	0.3
Materials Science	Aeronautics and Astronautics/ Engineering Physics	0.0	0.0
Nuclear Engineering	Engineering Physics	0.7	0.0
Operations Research	Operational Sciences	2.3	0.7
Optical Science and Engineering	Engineering Physics	0.0	0.7
Space Systems	Aeronautics and Astronautics	0.0	0.0
Systems Engineering	Systems Engineering and Management	0.3	0.0
TOTALS		23.6	8.0

[a] Program closed in 2011.
[b] Program began in 2012.
NOTE: AY, academic year; STEM+M, science, technology, engineering, mathematics, and management.
SOURCE: Data from the Air Force Institute of Technology.

TABLE 2-4 Naval Postgraduate School STEM+M Master's Degrees Granted Per Year (Averaged over AY 2010-2011, 2011-2012, and 2012-2013)

Degree by Department	Delivery	3-Year Average
Computer Science		
Computer Science (M.S.)	R	40
Modeling Virtual Environments and Simulation (M.S.)	R	12
Software Engineering (M.S.)	DL	7
		59
Defense Analysis		
Defense Analysis (M.S.)	R	0.3
Defense Analysis (Financial Management) (M.S.)	R	0
Defense Analysis (Information Operations) (M.S.)	R	2
Defense Analysis (Irregular Warfare) (M.S.)	R	50
Defense Analysis (National Security Affairs) (M.S.)	R	0.3
Defense Analysis (Operations Analysis) (M.S.)	R	1
Defense Analysis (Terrorist Operations and Financing) (M.S.)	R	14
Information Operations (M.S.)	R	7
		74.6
Electrical and Computer Engineering		
Electrical Engineering (M.S.)	R/DL	46
Engineering Science (Electrical Engineering) (M.S.)	R/DL	.3
		46.3
Information Sciences		
Electronic Warfare Systems Engineering (M.S.)	R	8
Information Systems and Operations (M.S.)	R	4
Information Technology Management (M.S.)	R	22
Information Warfare Systems Engineering (M.S.)	R	12
Remote Sensing Intelligence (M.S.)	R	8
Systems Technology (Command, Control and Communications) (M.S.)	R	11
		65
Mathematics		
Applied Mathematics	R	6
Mechanical and Aerospace Engineering		
Astronautical Engineering (M.S.)	R	11
Engineering Science (Mechanical Engineering) (M.S.)	R	5
Mechanical Engineer (M.Eng.)	R	5
Mechanical Engineering (M.S.)	R	34
		55
Meteorology		
Meteorology (M.S.)	R	12
Meteorology and Physical Oceanography (M.S.)	R	13
		25
Oceanography		
Physical Oceanography (M.S.)	R	6
Operations Research		
Applied Science (Operations Research) (M.S.)	R	0
Human Systems Integration (M.S.)	DL	10
Operations Research (M.S.)	R	56
Systems Analysis [a] (M)	DL	31
		97

continued

TABLE 2-4 Continued

Degree by Department	Delivery	3-Year Average
Physics		
Applied Physics (M.S.)	R	23
Combat Systems Technology (M.S.)	R	3
Engineering Acoustics (M.S.)	R	6
Physics (M.S.)	R	7
		39
Space		
Space Systems Operations (M.S.)	R/DL	15
Systems Engineering		
Engineering Systems (M.S.)	DL/R	27
Systems Engineering Analysis (M.S.)	DL/R	9
Systems Engineering Management (M.S.)	DL	10
Systems Engineering (M.S.)	R	129
		176
Undersea Warfare		
Applied Science (Physical Oceanography) (M.S.)	R	0.3
Graduate School of Business and Public Policy		
Contract Management (M.S.)	DL	10
Management (M.S.)	R	30
Program Management (M.S.)	DL	22
		62
TOTAL STEM+M		720.2

[a] Possibly not STEM-related.

NOTE: AY, academic year; DL, all courses via distance learning; R, all courses in residence; STEM+M, science, technology, engineering, mathematics, and management.

SOURCE: Data from the Naval Postgraduate School.

TABLE 2-5 Naval Postgraduate School STEM+M Ph.D. Degrees Granted per Year (Averaged over AY 2010-2011, 2011-2012, and 2012-2013)

Degree by Department	3-Year Average
Computer Science	
Computer Science	1.0
Modeling Virtual Environments and Simulation	1.7
Software Engineering	1.7
	4.4
Electrical Engineering	
Electrical Engineering	0.3
Information Sciences	
Information Sciences	0.7
Mathematics	
Applied Mathematics	0.3
Mechanical and Aerospace Engineering	
Astronautical Engineering	1.3
Mechanical Engineering	1.3
	2.7
Meteorology	
Meteorology	2.6
Oceanography	
Physical Oceanography	1.7
Operations Research	
Operation Research	0.7
National Security Affairs	
Security Studies[a]	1
Physics	
Applied Physics	0.7
Physics	0.7
Engineering Acoustics	0.3
	1.7
TOTAL	16.0
TOTAL STEM	15.0

[a] Possibly not STEM-related.

NOTE: AY, academic year; DL, all courses via distance learning; R, all courses in residence; STEM+M, science, technology, engineering, mathematics, and management.

SOURCE: Data from the Naval Postgraduate School.

TABLE 2-6 Naval Postgraduate School Classified STEM+M M.S. Theses

	2009	2010	2011	2012	2013	5-Year Total	5-Year Average
Graduate School of Engineering and Applied Sciences							
Applied Math	1	0	0	0	0	1	0.2
Electrical and Computer Engineering	0	1	0	2	2	5	1
Mechanical and Aerospace Engineering	0	0	1	0	0	1	0.2
Meteorology	2	1	0	0	0	3	0.6
Oceanography	2	1	0	0	1	4	0.8
Physics	2	1	0	0	1	4	0.8
Space Systems Academic Group	3	2	2	0	4	11	2.2
Systems Engineering	0	1	1	1	0	3	0.6
Graduate School of Operational and Information Science							
Cyber Academic Group	0	0	0	0	0	0	0
Computer Science	1	1	1	0	4	7	1.4
Defense Analysis	2	2	0	1	3	8	1.6
Information Sciences	4	5	0	10	3	22	4.4
Operations Research	8	8	6	1	2	25	5
Graduate School of Business and Public Policy							
Graduate Business	0	0	1	0	0	1	0.2
School of International Graduate Studies							
National Security Affairs	3	0	1	0	1	5	1
TOTAL	28	23	13	15	21	100	20

NOTE: STEM+M, science, technology, engineering, mathematics, and management.
SOURCE: Data from the Naval Postgraduate School.

TABLE 2-7 Naval Postgraduate School STEM+M CUI M.S. Theses

	2009	2010	2011	2012	2013	5-Year Total	5-Year Average
Graduate School of Engineering and Applied Sciences							
Applied Math	0	0	0	0	0	0	0
Electrical and Computer Engineering	6	4	9	6	6	31	6.2
Mechanical and Aerospace Engineering	11	4	6	6	10	37	7.4
Meteorology	2	1	0	0	1	4	0.8
Oceanography	0	0	0	3	1	4	0.8
Physics	12	11	10	9	12	54	10.8
Space Systems Academic Group	1	1	2	7	5	16	3.2
Systems Engineering	3	9	10	10	21	53	10.6
Graduate School of Operational and Information Science							
Cyber Academic Group	0	0	0	0	1	1	0.2
Computer Science	3	9	6	3	9	30	6
Defense Analysis	11	4	5	11	10	41	8.2
Information Sciences	4	11	9	6	5	35	7
Operations Research	5	6	12	16	15	54	10.8
Graduate School of Business and Public Policy							
Graduate Management	7	12	18	17	20	74	14.8
School of International Graduate Studies							
National Security Affairs	9	8	19	17	17	70	14
TOTAL	74	80	106	111	133	504	100.8

NOTE: CUI, controlled, unclassified information; STEM+M, science, technology, engineering, mathematics, and management.
SOURCE: Data from the Naval Postgraduate School.

TABLE 2-8 Air Force Institute of Technology Classified M.S. Theses and Ph.D. Dissertations

Department	2009	2010	2011	2012	2013	5-Year Total	5-Year Average
Mathematics and statistics	0	0	2	2	0	4	0.8
Electrical and computer engineering	2	0	2	2	0	6	1.2
Engineering physics	0	0	1	0	0	1	0.2
Operational sciences	0	2	0	0	2	4	0.8
Systems engineering and management	4	0	1	1	0	6	1.2
Aeronautics and astronautics	0	2	1	4	2	9	1.8
TOTAL	6	4	7	9	4	30	6

SOURCE: Data from the Air Force Institute of Technology.

TABLE 2-9 Air Force Institute of Technology CUI M.S. Theses and Ph.D. Dissertations

Department	2009	2010	2011	2012	2013	5-Year Total	5-Year Average
Mathematics and statistics	1	1	0	2	0	4	0.8
Electrical and computer engineering	15	10	15	6	6	52	10.4
Engineering physics	3	4	2	2	8	19	3.8
Operational sciences	8	7	5	11	4	35	7.0
Systems engineering and management	3	14	16	7	8	48	9.6
Aeronautics and astronautics	9	6	12	19	12	58	11.6
TOTAL	39	42	50	47	38	216	43.2

NOTE: CUI, controlled, unclassified information.
SOURCE: Data from the Air Force Institute of Technology.

fewer than 10 percent of AFIT degrees. At NPS, 3 of the 14 STEM+M departments provided about 50 percent of its degrees, whereas 3 departments in total provided fewer than 10 percent of NPS degrees.

- Of the more than 700 STEM+M postgraduate degrees NPS granted per year, only around 20 theses—fewer than 3 percent of all master's degree theses—were fully classified, and around 80 (10 percent) were CUI.
- The percentage of NPS degrees granted to U.S. Navy personnel declined from 51 percent in 2010 to 42 percent in 2012, whereas the percentage of civilian degrees granted has gone up from 11 percent in 2010 to 29 percent in 2012.

Two rationales for having Ph.D. programs at AFIT and NPS are that they help in recruiting and retaining faculty and provide Services focused benefits to those master's degree students who interact with Ph.D. students. A potential trade-off is that these Ph.D. students, *per se*, would arguably have a richer and deeper research experience in a larger Ph.D. program at a civilian university.

Through an alliance between NPS and AFIT, which was established by the Navy and Air Force via a December 4, 2002, memorandum of agreement,[18] the size of AFIT and NPS Ph.D. programs can be expanded by offering a wider range of courses and research experiences.

Finding 2-1. AFIT and NPS are primarily master's degree-granting institutions because the number of Ph.D. degrees they confer is less than 3 percent of the number of master's degrees.

Recommendation 2-1. The Air Force Institute of Technology and the Naval Postgraduate School should proactively seek to expand the December 4, 2002, memorandum of agreement between the Navy and Air Force so as to increase collaboration with each other, as well as to partner with other selected universities to create a critical mass of Ph.D. students. This will enable a deeper and wider range of courses and research experiences, particularly for some of the smaller Ph.D. programs.

Finding 2-2. At both AFIT and NPS, STEM+M master's and Ph.D. students pursuing degrees on campus at AFIT or NPS, not explicitly in distance-learning pro-

[18] The Memorandum of Agreement Forming an Educational Alliance between the Department of the Navy and the Department of the Air Force, December 4, 2002, discussed in detail in Chapter 4, is available at http://www.nps.edu/WASC/Docs/WASC_ReferenceFiles/11-20/REF18.pdf?return=2/report/sect3.aspx.

grams, generally do not take for-credit courses via distance learning from either their sister institution or at civilian institutions.

Recommendation 2-2. In an era of rapidly developing distance learning technology and opportunity, the Department of Defense should seriously explore the possibility of combining the networking and bonding benefits of military officers in residence at the Air Force Institute of Technology or the Naval Postgraduate School with the benefits of exposure to other institutions and learning opportunities at civilian universities by using distance learning.

Finding 2-3. AFIT and NPS do not have complete control over their admission process and are asked to take students assigned to them by other elements of DoD. For this reason, the range of preparation of their students is wider than many civilian universities, particularly at NPS. Both schools provide remediation help to incoming students who have been away from school for an extended time period due to operational demands.

Finding 2-4. AFIT confers about 30 STEM+M Ph.D. students each year, while NPS achieves about half that number. This difference may reflect, to some extent, a difference in the perceived needs of the two Services, and possibly the closer proximity of AFIT to the substantial research sources of the Air Force Research Laboratory.

Finding 2-5. NPS appears to place an emphasis on admitting personnel with non-STEM undergraduate degrees. Via a sequence of intense noncredit remedial courses, these students are offered an opportunity to go on to pursue a STEM-related master's degree. On the other hand, AFIT normally requires an undergraduate degree in a STEM field for admission to their graduate programs.

CURRENT STEM+M GRADUATE EDUCATION PROVIDED TO U.S. ARMY ACTIVE DUTY MILITARY PERSONNEL

Although many U.S. Army active duty personnel clearly take advantage of various STEM+M postgraduate programs at AFIT and NPS (see Table 3-2), no detailed information about enrollments at civilian institutions—for example, identity, degree programs, nature of their delivery, numbers of degrees granted—was provided to the committee by the Army. Without this information, no meaningful recommendations relating to the current status of the Army's STEM+M graduate degree education could be made. [19]

[19] This situation is discussed further in Chapter 3 and Finding 3-2.

Finding 2-6. There is no centralized source, within DoD, of clear and consistent data on how many STEM+M degrees are being obtained by military and civilian DoD personnel at civilian universities.

Recommendation 2-3. The Department of Defense (DoD) should centrally collect clear and consistent data on science, technology, engineering, and mathematics and management (STEM+M) degrees being obtained by military and civilian DoD personnel at civilian universities and share it widely with those involved in planning and directing STEM+M education programs.

CONCLUDING REMARKS

This chapter presented an overview of the existing structure, scope, and availability of STEM+M graduate degrees currently available to DoD personnel, with a focus on the two major DoD institutions that provide the educational structure for delivery of these educational experiences. Definitions of basic terms and concepts were presented, along with a review of AFIT's and NPS' student populations, number of degrees granted, and the diversity of degree programs. These definitions and assessments were used to delineate the boundaries of the terms of reference for this study, to refine its scope, and to help identify unique features and opportunities to improve each type of institution. Chapter 3 provides a more in-depth discussion and evaluation of the value proposition for graduate programs at AFIT and NPS, along with more specific findings and recommendations for improving and strengthening these programs. Chapter 4 then offers suggestions for enhancing STEM+M graduate education outcomes for all members of DoD's workforce.

3

Value Proposition for Department of Defense Institutions Offering Advanced Degrees in STEM and Management

INTRODUCTION

All military Services need and depend on military and civilian personnel with advanced technical education across a broad array of academic disciplines. Technical capabilities have always been critical to military roles and missions and are likely to become more critical in the future as both the military and society enhance their focus on improving human performance through human-computer interactions, developing autonomous robots and vehicles, creating renewable energy sources, exploiting technology to increase safety and improve efficiencies in manufacturing processes, writing complex embedded software to spur growth in the "internet of things," and enabling defensive and offensive cyber capabilities. As described in Chapter 1, the defense of the United States is based solidly on a policy of technological superiority where needed.

The 2012 National Research Council (NRC) report on the Department of Defense (DoD) science, technology, engineering, and mathematics (STEM) workforce recommended that DoD expand its STEM workforce with technically qualified U.S. citizens and non-U.S. citizens and increase re-education of nontechnical employees in STEM disciplines:

> The DoD should ensure that the education and training, and the re-education and re-training, opportunities for its civilian STEM workforce are both commensurate with similar opportunities afforded career military personnel and tailored to the needs of the civilian workforce. [1]

With more than 30 percent of DoD civilians eligible for retirement, competition with private industry for qualified STEM candidates, and the increasing technical complexity of defense solutions, DoD requires an innovative and multi-pronged graduate education approach to ensure that it retains and enhances the quality of its technical workforce.

The Air Force and Navy established the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS), respectively, many decades ago to increase military-relevant STEM and management (STEM+M) graduate education options for DoD personnel. Today, each school is centrally funded by its respective Service, primarily to educate its own military workforce. Both institutions also educate a small number of military personnel from sister Services, a few civilian personnel, and significant numbers of international military personnel, whose education costs are born by the student's Service, organization, or country—i.e., on a reimbursable basis. [2] In addition, AFIT and NPS play a vital role in providing military-relevant education programs and developing military-to-military relationships between Service members and foreign allies. Like their civilian education counterparts, both institutions also have research programs and centers aligned with DoD needs to enhance their education missions and provide value beyond simply educating DoD's workforce.

This chapter examines how NPS and AFIT accomplish their education and research objectives. Focusing on value, the chapter examines details on the history, current status, research enterprise, costs, and value proposition of both institutions.[3] The chapter also addresses operational and organizational obstacles that impede mission quality and execution, particularly for AFIT.

---

[1] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce,* The National Academies Press, Washington, D.C., 2012, p. 11.

[2] Reimbursable funding is the name given to work that is requested and funded by another agency or organization. Interagency reimbursables within DoD are funded by Military Interdepartmental Purchase Requests (MIPR).

[3] Value proposition can best be defined as the sum total of benefits derived, both actual and perceived, from a service or product. This can include return on investment, quality, speed of service, among other factors. A good value proposition will produce convincing reasons for a customer to buy a service or product.

OVERVIEWS OF THE AIR FORCE INSTITUTE OF TECHNOLOGY AND THE NAVAL POSTGRADUATE SCHOOL

Overview of the Air Force Institute of Technology

AFIT grants graduate school of engineering and management degrees and offers technical, professional continuing education. AFIT is accredited by the North Central Association of Colleges and Schools of the Higher Learning Commission, a regional collaboration of higher education 4-year and graduate institutions. Located on Wright-Patterson Air Force Base (WPAFB), AFIT is synergistically collocated with the Air Force Research Laboratory (AFRL) and the School of Aerospace Medicine. Their geographic proximity allows all three institutions to share personnel, library, and laboratory facilities. Additionally, AFIT has strong ties with the National Air and Space Intelligence Center, the Air Force Life Cycle Management Center, and Air Force Materiel Command Headquarters, all located on WPAFB.[4] The history of AFIT, described on its website,[5] is given below.

AFIT began as the Air School of Application, established within the Engineering Division at McCook Field, Dayton, Ohio, by the War Department in November 1919. The school was designated the Air Service Engineering School following the creation of the Air Service in 1920. School operations ceased during World War II, then reopened in 1944 as the Army Air Forces Engineering School with the mission to conduct a series of accelerated 3- and 6-month-long courses to meet emergency needs in 1944. In 1945, a board of officers "recommended that the Army Air Force establish a technological school under the immediate supervision of the Commanding General, Air Technical Service Command, using the existing Army Air Force Engineering School as a nucleus for expansion to accomplish the recommended action." The Army Air Forces Institute of Technology was officially opened on September 3, 1946. The Army did not establish an equivalent institution when the Air Force became autonomous, but chose to rely on mainly civilian universities for their graduate education needs. The institute was "composed of two colleges: Engineering and Maintenance, and Logistics and Procurement."[6]

When the Air Force "became an autonomous unit in the military establishment during 1947," the institute was given its current name. On April 1, 1950, "command jurisdiction of the institute was transferred from Air Materiel Command to Air University. On August 31, 1954, President Eisenhower signed Senate Bill 3712," giving AFIT authority to grant degrees. In 1955, AFIT was accredited in aeronautical and electrical engineering. It awarded its first degrees the following year. AFIT was

[4] Taken mainly from the AFIT website at http://www.afit.edu.

[5] AFIT, "AFIT History," http://www.afit.edu/ABOUT/page.cfm?page=126, accessed June 6, 2014.

[6] Ibid.

granted institutional accreditation at the master's level in 1960. Its accreditation was extended to the Ph.D. level in 1965.[7]

Overview of the Naval Postgraduate School

NPS is accredited by the Senior Commission of the Western Association of Schools and Colleges of the Higher Learning Commission, a regional collaboration of higher education 4-year and graduate institutions. The university is operated by the U.S. Navy and is located in Monterey, California. NPS awards a full spectrum of master's and doctoral degrees in areas of interest to the Navy, a large percentage of which are STEM+M degrees. The history of NPS, described on its website, is given below.[8]

On June 9, 1909, the Secretary of the Navy opened a school of marine engineering at Annapolis, Maryland. This small program, "consisting of 10 officer students and two Navy instructors," would later become NPS. On October 31, 1912, it was renamed the Postgraduate Department of the Naval Academy with "courses of study in ordnance and gunnery, electrical engineering, radio telegraphy, naval construction, and civil engineering, as well as continuing the original program in marine engineering. In 1945, "Congress passed legislation to make the school a fully accredited, degree-granting graduate institution. Two years later, Congress authorized the purchase of the Hotel Del Monte and 627 acres of surrounding land for use as an independent campus for the school. In December 1951, the Postgraduate School moved to its current campus in Monterey."[9]

Enrollment, Accreditation, and Faculty

Table 3-1 contains a recent historical summary of AFIT and NPS faculty over the past 5 years. Although both school's faculties have trended upward in size between 2009 and 2013, the NPS faculty size is several times the size of the AFIT faculty. In addition, military members constitute a much larger fraction of the total AFIT faculty population than they do at NPS. And NPS has a much larger portion of its faculty funded on a reimbursable basis.

Finding 3-1. NPS and AFIT have student-to-faculty ratios, respectively, of 4 and 8. Based on *U.S. News and World Report* rankings, top engineering schools such as the Massachusetts Institute of Technology (MIT) and Stanford University main-

[7] Ibid.

[8] Much of this was taken from NPS, "NPS History," http://nps.edu/About/NPSHistory/History.html, accessed June 6, 2014.

[9] Ibid.

TABLE 3-1 Faculty Numbers at the Naval Postgraduate School and the Air Force Institute of Technology

	Naval Postgraduate School					Air Force Institute of Technology				
	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
Staff/faculty (direct funded)										
Military	107	94	101	102	105	87	88	98	99	89
Tenure track	256	261	277	270	262	76	76	77	79	82
Nontenure track	0	0	0	0	0	0	0	0	0	0
Staff	—	—	—	—	—	121	122	122	99	96
Staff/faculty (reimbursable funded)										
Tenure track	0	0	0	0	0	0	0	0	0	0
Nontenure track	446	482	573	614	595	2	3	3	9	12
Staff	—	—	—	—	—	37	44	59	100	124
Total staff/faculty										
Military	107	94	101	102	105	87	88	98	99	89
Faculty	702	743	850	884	857	78	79	80	88	94
Staff	525	635	678	658	469	158	166	181	199	220

NOTE: —, information not provided to the committee. In some instances the institutions provided us with data that was categorized differently or simply was not provided.

SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

tain ratios between 5 and 8. Therefore, it appears that both AFIT and NPS have sufficient faculty numbers to deliver accredited graduate master's degrees and certificates. Based on the committee's graduate STEM education expertise, to include leadership and evaluator roles with the Accreditation Board for Engineering and Technology (ABET) accreditation bodies, NPS and AFIT teaching and research methods are pedagogically consistent with other leading universities.

Both NPS and AFIT offer a wide variety of certificates, master's, and doctoral degrees. [10,11] Many of the engineering degrees are accredited by ABET at both universities.[12] They are leaders in graduate level engineering accreditation. With nine programs accredited at AFIT and four at NPS, they comprise more than 50 percent of the graduate engineering programs accredited by ABET. The Graduate School of Business and Public Policy programs at NPS are accredited by the Association to Advance Collegiate Schools of Business (AACSB). The Master of Business Administration program at NPS is accredited by the National Association of Schools of Public Affairs and Administration (NASPAA). AFIT does not have a business-focused program but does offer degrees in logistics management and engineering management, which are also ABET accredited. Table 3-2 contains a historical summary of accredited program enrollment numbers by student type for both schools. Table 3-3 shows the number of degrees as a function of time and delivery mode.

Table 3-2 indicates that while the Army relies on NPS and AFIT to educate a portion of its officer corps, the number is relatively small compared to the Navy and Air Force.[13]

[10] A list of degrees offered by NPS can be found at http://www.nps.edu/Academics/GeneralCatalog/701.htm#o197.

[11] A list of degrees offered by AFIT can be found at http://www.afit.edu/en/academicprograms.cfm?a=mastdoc.

[12] ABET is a recognized accreditor in the U.S. by the Council for Higher Education Accreditation for engineering, technology, and computer science programs.

[13] This observation, along with a request to comment on the need for an Army equivalent of NPS or AFIT, was posed by the committee to the presenter from the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology. Based on dialog with the Army presenter, there are two possible explanations for this situation: (1) unlike the Air Force and Navy, each of which has a centralized corporate graduate education fund for officers, the Army's decentralized funding approach requires each organization to fund graduate education from their own budgets. Consequently, there has never been a critical funding or sponsorship mass to advocate for a centralized Army equivalent of AFIT or NPS; (2) the AFIT and NPS curriculums are designed to focus on Air Force and Navy problems and technologies. AFIT and NPS credentials are therefore more valuable for officers in their respective Services. With the exception of a few programs, such as nuclear engineering and operations research, Army officers may not see the value of Air Force- and Navy-oriented graduate institutions. Without additional data from the Army to review, it is not feasible to draw any further conclusions on this topic.

TABLE 3-2 Enrollment Numbers by Student Type at the Naval Postgraduate School and the Air Force Institute of Technology

	Naval Postgraduate School			Air Force Institute of Technology		
	2010	2011	2012	2010	2011	2012
Resident degree (full-time)						
Navy	681	731	700	13	0	4
Air Force	166	145	132	592	509	514
Marine Corps	164	165	173	5	7	5
Army	165	182	215	22	18	32
Other	10	15	19	0	0	0
Civilian	127	174	223	103	129	118
International	224	235	248	35	26	22
	1,537	1,647	1,710	770	689	695
Distance degree (part-time)						
Navy	226	291	366	—	—	—
Air Force	17	20	22	—	—	—
Marine Corps	11	9	16	—	—	—
Army	4	4	5	—	—	—
Civilian	582	597	605	—	—	—
Certificates (part-time)	329	291	206	65	68	80
	1,169	1,212	1,220	65	68	80
Full-time versus part-time totals						
Full-time	1,537	1,647	1,710	770	689	695
Part-time	1,169	1,212	1,220	65	68	80

NOTE: —, information not provided to the committee.
SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

Finding 3-2. The Army manages and fulfills its STEM+M graduate education needs in a highly decentralized manner. It was therefore not possible to gain a holistic understanding of the Army's STEM+M graduate education needs and sources from the single Army presentation provided by the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology. In addition, it was not possible to determine, due to the lack of data provided by the Army, if the Army STEM+M graduate education model, which does not significantly rely on DoD education institutions like AFIT and NPS to educate its STEM+M workforce, offers a viable alternative to the blended DoD and civilian institution models used by the Air Force and the Navy.[14]

[14] Nancy Harned, Executive Director, Strategic Planning and Program Planning, "STEM and Army S&T Enterprise," presentation to the committee on January 9, 2014.

TABLE 3-3 Types of Graduate Degrees Awarded at the Naval Postgraduate School (NPS) and the Air Force Institute of Technology

	Naval Postgraduate School			Air Force Institute of Technology		
	2010	2011	2012	2010	2011	2012
Certificates	195	282	203	39	24	17
Masters	872	836	989	321	331	229
Doctorates	18	14	16	31	34	30
Other	9	11	5			
	1,094	1,143	1,213	391	389	276
Distance learning (DL)						
Certificates	756	846	983	17	16	52
Masters	289	343	369	11	11	11
	1,045	1,189	1,352	28	27	63
Total (all degrees)	2,139	2,332	2,565	419	416	339

NOTE: The NPS distance learning (DL) program enrolled 1,005 students for academic year (AY) 2012. With 624 civilians enrolled in the DL programs needed by the Department of Defense and a distributed campus worldwide, the NPS is a model for DL in higher education (NPS Provost update briefing to the Board of Advisors February 20, 2014).
SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

NPS offers numerous certificates and master's degrees online, including a Ph.D. in systems engineering.[15,16] The programs employ both asynchronous and synchronous modes of distance education delivery. Many of NPS's 26 certificate and 17 master's programs are taught both on-campus in Monterey and online. AFIT currently only offers two degrees and five certificate programs online. Neither school offers joint degree programs with other universities. Additional discussion of online, distance-learning approaches at both schools can be found in Chapter 4. Table 3-3 summarizes enrollment figures for on-campus and online programs at both institutions.

[15] See http://www.nps.edu/Academics/DL/DLPrograms/dlProgramSearch.html.

[16] The systems engineering (SE) program has the most robust distance learning (DL) program at either institution. With 406 in master's DL programs and 22 PhD students the DL programs in SE are significantly greater than the on campus program. Both the resident and DL SE programs are ABET accredited. The NPS DL program for SE is unique in that most of the faculty members are "embed-ded" close to major student concentrations, such as the National Capitol Region, NAS Patuxent River, and San Diego. All faculty members on the main campus teach in the DL program. All courses are the same, with the same faculty, texts, and syllabi for the DL and on campus program. Because of laboratory access issues, some specialization tracks are not offered to DL students.

TABLE 3-4 Research Funding and Sources at the Naval Postgraduate School (in millions of dollars)

Sources	2010	2011	2012
National Science Foundation	3.2	3.1	5.4
CRADA/Other	1.8	1.5	1.2
Navy	46.6	40.2	40.7
Air Force	3.2	5.5	6.4
Army	3.5	4.0	4.3
Department of Defense/Joint	25.9	29.2	34.8
Department of Homeland Security	0.5	1.6	2.4
Other federal	7.0	5.6	7.7
Total	91.7	90.7	102.9

NOTE: CRADA, cooperative research and development agreement.
SOURCE: Data from the Naval Postgraduate School annual reports provided on its website.

Research Enterprise

Consistent with their graduate level education mission, both AFIT and NPS maintain internally funded research programs in support of master's thesis and Ph.D. dissertation studies. Both schools also maintain externally sponsored research programs funded by a number of government sources. Tables 3-4 and 3-5 summarize the research funding sources and amounts for both universities. [17] The data shows that the number of externally funded, sponsored research programs at NPS is much larger than AFIT, as expected from the relative sizes of the school's non-tenure track faculty previously shown in Table 3-1. The difference is due in part to the larger student and research faculty populations at NPS. Based on data from the Center for Measuring University Performance, NPS annually ranks around 100th in the country in external research funding. [18] The Carnegie Foundation classifies AFIT as a Doctoral Research University.[19] For 2010, AFIT and NPS ranked 248th and 113th, respectively, in federal research funding for universities.[20]

Both AFIT and NPS maintain multiple research centers that bring together experts from diverse disciplines to focus efforts on specific interdisciplinary chal-

[17] The specifics are in the format of a pie chart, see http://www.afit.edu/EN/docs/Research/AFIT percent20Annualpercent20Reportpercent202011.pdf, p. 33. Numbers were also provided by NPS Office of Research.

[18] From http://mup.asu.edu/research2012.pdf.

[19] From http://classifications.carnegiefoundation.org/.

[20] From http://mup.asu.edu/research_data.html, accessed April 17, 2014.

TABLE 3-5 Research Funding and Sources at the Air Force Institute of Technology (millions of dollars)

Sources	2010	2011	2012
National Science Foundation	0.3	0.8	0.7
CRADA	0.5	0.7	0.4
Navy	0.3	0.6	0.5
Air Force	13.6	10.7	10.3
Army	0.2	0.4	0.4
Department of Defense/Joint	4.7	8.5	10.3
Department of Homeland Security	0.0	0.3	0.2
Other	0.3	0.1	0.5
Total	19.9	22.1	23.3

NOTE: Only totals given. CRADA, cooperative research and development agreement.
SOURCE: Data from the Air Force Institute of Technology.

lenges of relevance to DoD and the national security communities. The interdisciplinary approach combines people, facilities, and equipment required to solve complex problems. Research center projects are typically sponsored and funded by external government sources and, like civilian institutions, are key supplements to the university's operation and maintenance (O&M) budget. Research projects enhance the educational mission by contributing to the development of faculty and students, and by allowing "margin of excellence" activities not fully covered in the schools direct allotted funding. Examples of research centers found at both universities include the Centers for Cyberspace Research, Directed Energy, and Advanced Navigation hosted by AFIT, and the Centers for Asymmetric Warfare, Autonomous Vehicle Research, and Cyber Warfare hosted by NPS.

How sponsored research at NPS and AFIT centers might save DoD funding elsewhere, thereby possibly offsetting the costs of the institutions for the Services or DoD, was briefly examined. Many examples were provided by AFIT and NPS to provide concrete evidence of cost savings. A few examples from those submitted include a 2011 AFIT graduate research paper that studied airlift fuel loads on cargo missions to Afghanistan, resulting in changes that were adopted by Air Mobility Command Control Center in 2012 and now save the Air Force up to $111 million per year.[21] An NPS graduate education research paper studied the Air Tasking Efficiency Model (ATEM) that has been in use since 2006. As a result of this NPS thesis work, the ATEM was able to justify withdrawing six more C-130s from Iraq

[21] Walter J. Lesinski III, "Tankering Fuel: A Cost Saving Initiative," AFIT/IMO/ENS/11-06, May 2011, p. 37.

with no reduction to service levels; savings were estimated at $2.5 million in convoy mitigation costs and the potential, non-estimated reduction of personnel casualties. [22] Finally, a 2012 paper, which won the 2013 INFORMS Prize for outstanding military operations research, described a state-of-the-art design of experiments for simulation models using unmanned air vehicles (UAVs). A former director of the U.S. Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) estimates that the model harvested $6 billion in savings and 6,000 to 10,000 billets.[23] These examples are a small sample. It only takes a few actual savings of this magnitude to offset the cost of educating many students. AFIT and NPS provide a significant return on investment beyond the education that they provide to their students.

Many civilian universities have strong partnerships with university-affiliated research centers (UARCs) located on or near their campuses. UARCs create synergies between applied and classified DoD research and more theoretical, unclassified research conducted in the institution's research laboratories. There are several UARC research institutions, such as Lincoln Laboratories, the Jet Propulsion Laboratory, and Lawrence Livermore National Laboratory, located near top-tier civilian institutions, where classified academic research might be performed. This same capability exists in many government laboratories, such as AFRL, the Army Research Laboratory, and the Naval Research Laboratory, which also have several civilian university affiliations. However, because UARC laboratories are typically located on secured sites away from the affiliated university campus and are not formal academic institutions (e.g., different cultures, different goals), they pose an impediment to academic research. Given that most DoD students are under tight timelines to complete their coursework and theses, these additional impediments create risks and stress for DoD employees that do not exist at AFIT or NPS, where research facilities are located on campus or adjacent to campus, as is the case with AFIT and AFRL.

For example, AFIT currently enjoys a strong relationship with AFRL whose headquarters and five of its research directorates are within walking distance of the campus. Students can use laboratory facilities and leverage subject matter experts (SMEs) beyond available faculty. NPS's larger research enterprise enjoys similar synergies between its education arm and its research centers. However, its somewhat isolated location lacks geographical proximity to major Navy laboratories, although the breadth of research sponsors and partners is noteworthy.

[22] Brown, Carlyle, and Dell, "Optimizing Intratheater Military Airlift in Iraq and Afghanistan," *Military Operations Research* 18(3): 35-51, 2013.

[23] Design and Analysis of Experiments, Volume 3, *Special Designs and Applications* (K.Hinkelmann, ed.), Wiley & Sons, 2012.

The November 2012 report of the Naval Inspector General (IG) concerning the leadership of NPS, its mission, and its activities was reviewed during the course of this study.[24] The IG report stated:

> The focus on research by NPS management and faculty has detracted from the importance of educating naval officers. NPS has focused on increasing research funding and research positions at NPS, which is a component of becoming a larger research institution but not necessarily a top-tiered research institution. NPS can increase its status as a research institute by encouraging an increase in faculty achievement of recognized research accomplishments and creating a legacy of students that achieved research excellence.[25]

No views are presented herein regarding personnel and financial procedures; however, the committee differs with the report concerning the importance of research in graduate education at NPS and, by extension, AFIT. Research drives the activities and intellectual efforts of both professors and students by exposing them to emerging technologies that may enter the force or fleet by the time students enter senior decision-making roles. In addition, active research programs serve as a tool to teach students how to think more creatively and collaboratively to solve complex military problems. Immersing students in a research environment that challenges status-quo thinking and encourages innovative thought and broad discussion benefits them in their DoD careers. This research, which is often funded by government agencies such as the National Science Foundation, the Office of Naval Research, the Defense Advanced Research Projects Agency, and numerous other DoD and intelligence sources, cannot only lead to solutions that save DoD money, but can also offset direct university costs. Finally, research breadth and recognition serve as measures of excellence for leading universities and allows AFIT and NPS to attract the best and brightest educators from top U.S. schools who expect environments that facilitate the development of strong publication credentials. These educators are then readily available to DoD decision makers seeking technical advice about complex problems. In short, research plays a fundamental and necessary role in graduate-level education at AFIT, NPS, and all graduate-level institutions.

The leadership of NPS has chosen to compare itself to a number of leading universities throughout the United States, including MIT, Stanford University, and Carnegie Mellon University. While it would be a challenge for a DoD-funded school to completely emulate a premier civilian school, the benchmark of excellence set by seeking these comparisons is appropriate and desirable. DoD students deserve the best education possible—one that combines the academic excellence of leading civilian universities with military-relevant teaching and research activities.

---

[24] Naval Inspector General, letter with the subject "Command Inspection of Naval Postgraduate School," dated October 22, 2012.

[25] Ibid.

COSTS ASSOCIATED WITH THE AIR FORCE INSTITUTE OF TECHNOLOGY AND THE NAVAL POSTGRADUATE SCHOOL

Generally speaking, determining the cost of any DoD organization is difficult. Budgets often do not include all of true costs, which are distributed across several organizational budgets that contribute to a given organization. Consequently, government organizations are typically more focused on preparing and executing budgets than capturing actual costs. For example, the cost of military personnel and all facility-related costs are usually paid through separate accounts for multiple entities and are not part of the direct organizational or institutional budgets for each entity. The cost of DoD schools includes military personnel and other services not provided at a civilian institution. This fact makes it difficult to accurately estimate the true cost to educate students at AFIT and NPS at a level that would bear the close scrutiny of a trained accountant and serve as a comparison to other education providers. Therefore, the following paragraphs offer a simple analysis that provides very approximate but useful cost estimates for the purpose of assessing value propositions in the next section.

AFIT's major cost drivers are contained in its directly allocated budget provided by the Air Force, as well as military pay and facilities costs contained in other organization's budgets. Using fiscal year (FY) 2012 data provided by these organizations, AFIT's annual costs were as follows: $28.9 million of budget directly allotted to AFIT from the Air Force (includes fully loaded civilian pay), $15.5 million of military pay, and $3.8 million of facilities and host base support cost, for a total annual cost of $48.2 million. The Office of the Deputy Chief of Staff of the Air Force for Manpower, Personnel, and Services valued the research contribution at $38 million. Offsetting the total cost with the research contribution yields $19,800 per calendar year or $14,900 per academic year for each of the 514 students. Ignoring the research offset yields a worst-case estimate (to a first order approximation) of nearly $93,800 per calendar year and $70,300 per academic year.

Table 3-6 contains summary financial information for AFIT and NPS. Similar to civilian schools, research budgets supplement the tuition costs by charging some of the overall institutional costs to the research sponsor, thus spreading institutional costs over a larger base. This is notable for NPS where the direct allotted budget only accounts for about 29 percent of their $368.6 million total operating budget for FY2012. Supplemental research activities can also allow for a larger faculty in the sense that some fraction of the faculty salaries is borne by other sponsors, yet, these faculty members can be available on a part-time basis to teach, participate in governance, and oversee research.

Estimating military pay costs using budgets can also be challenging. For example, military personnel costs are available through the DoD Comptroller who

TABLE 3-6 Income for the Air Force Institute of Technology and the Naval Postgraduate School (millions of dollars)

	Naval Postgraduate School			Air Force Institute of Technology		
	2010	2011	2012	2010	2011	2012
Direct Allotted						
Direct allotted military pay	13.3	14.6	15.4	13.0	14.8	15.5
Direct allotted O&M, including civilian pay	107.9	96.0	113.6	33.8	32.7	28.9
Base support services	2.4	2.6	2.7	0.1	0.1	0.1
Maintenance, utilities, recapitalization, janitorial services, etc.	12.4	12.4	12.4	3.7	3.7	3.7
Reimbursable						
Reimbursable research funding	91.7	90.6	102.8	19.9	22.0	23.4
Reimbursable education funding	108.4	90.5	35.8			
Tuition—all sources	22.9	74.1	47.3	1.7	2.7	2.4
Other—gifts, endowment, etc.	57.4	3.8	74.1			
Total income—all sources	416.4	384.6	404.1	72.2	76.0	74.0

NOTE: Air Force Institute of Technology and Naval Postgraduate School provided military manpower by rank, operations and mainenance (O&M) including civilian pay, base support costs, present value of facilities, and reimbursements.
SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

annually publishes the DoD Composite Rate for each Service.[26] The rates are given by rank and include the cost of salaries, retirement and medical benefits, housing and subsistence payments, annualized permanent change of station (moving), and all special pay. These are significantly more than the budgeted salary cost of personnel by a factor that ranges from slightly less than 2.0 to around 2.5, which is comparable to fully burdened costs elsewhere when one does not include elements such as facility capitalization, bid and proposal, and independent research and development, and fee/profit costs.

The cost of construction of DoD facilities is usually funded through the military constructions budget. The maintenance, repair, and operation of facilities are contained in the budgets of base support organizations.[27] Determining the

[26] See Undersecretary of Defense (Comptroller), "Financial Management Reports, Department of Defense FY 2014 Reimbursable Rates," Military Personnel Composite Standard Pay and Reimbursement Rates (Tab K), May 9, 2013, http://comptroller.defense.gov/financialmanagement/reports/rates2014.aspx.

[27] 88th Air Base Wing for AFIT and Naval Support Activity, Monterey, for NPS.

TABLE 3-7 Reimbursable Tuition Rates

Institution	Range of Tuition Reimbursed
Air Force Institute of Technology	$16,900 - $24,600
Naval Postgraduate School	$19,400 - $36,000

NOTE: Both are annual rates for Fall of 2013-2014.
SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

appropriate assignment of these costs toward the annual cost of operating an organization or activity is difficult. For example, construction costs need to be spread over the lifetime of the facility, and frequently, utility costs are not monitored for individual units but for an entire base. Whitestone Research, under contract to DoD and other federal agencies, has developed life-cycle cost models for facilities that capture all facility costs and express them as a percentage of the current value of the facility. In a presentation given by Whitestone Research,[28] the estimated percentage for all DoD facilities in aggregate is given as 4.3 percent of replacement value per year. Table 3-6 summarizes the financial information for AFIT and NPS by broad income and expense categories.

All DoD graduate degree institutions, including AFIT and NPS, have established rates they charge for students not covered by their direct budgets. These students may come from other military Services, the civilian component of the DoD workforce, other U.S. agencies, the private sector, and foreign nations. AFIT and NPS provided the rate data contained in Table 3-7. Comparing these rates to the first-order total cost approximation shows that the published rates probably do not fully recover the total actual costs to educate additional students as estimated above.

Table 3-8 contains the published total tuition costs of obtaining graduate degrees of some peer institutions. These costs are also difficult to obtain because of cost-reduction agreements between the Services and the institutions, scholarships, and the fact many military take more than the required classes and often enroll during the summer, among other factors.

In summary, the cost differential between AFIT and NPS and civilian institutions is not sufficiently significant for cost to serve as a determining factor in any decision or strategy for graduate education. As will be discussed in the next section, value propositions, rather than costs, should be the primary consideration when determining where to educate DoD employees and military members.

[28] Peter Lufkin, Whitestone Research, "Life Cycle Cost Models for Federal Facilities," presentation to the National Research Council Committee on Predicting Outcomes from Investments in the Maintenance and Repair of Federal Facilities, February 18, 2010, http://www.whitestoneresearch.com/media/1353/predicting%20outcomes.pdf.

TABLE 3-8 Cost at Selected Civilian Institutions

Institution	Approximate Annual Tuition Cost
George Washington University	$43,200
University of Virginia	$22,380 (resident) $39,520 (non-resident)
Stanford University	$55,330
Ohio State University	$15,895 (resident) $40,183 (non-resident)

NOTE: Department of Defense schools are based solely on budgeted cost. The costs are based on 45 quarters or 30 semester hours and a full-time load of 12 hours per term.
SOURCE: Data provided by the respective institutions.

THE VALUE PROPOSITION OF DEPARTMENT OF DEFENSE GRADUATE SCHOOLS

Introduction

Although cost is certainly an important factor for many students, it is generally considered only as one part of a broader value proposition. Figure 3-1 offers a framework that captures the value provided by DoD and civilian graduate STEM degree-granting institutions in return for the ranges of costs described in the previous section. This framework provides a useful context when comparing the value of an AFIT or NPS graduate degree against the same degree obtained at a civilian institution. The value proposition offered in subsequent sections addresses the need for DoD to maintain in-house graduate institutions rather than educate its military and civilian employees solely at civilian institutions.

Comparing Value Propositions of the Air Force Institute of Technology, Naval Postgraduate School, and Civilian Institutions

The United States has many excellent public and private civilian universities. Many offer graduate programs in STEM+M areas relevant to DoD, and many do research sponsored by DoD. Indeed, a large majority of the graduate degrees held by military and civilian DoD personnel were obtained from civilian universities. Given the quality and availability of these universities, why does DoD need its own institutions? Table 3-9, which shows the benefits and trade-offs of DoD graduate education institutions, addresses this question. In short, neither the DoD in-house nor the civilian university option is optimal for all circumstances.

AFIT and NPS clearly offer many strategic benefits to DoD. Other DoD institutions might look to them, along with the Uniformed Services University of the

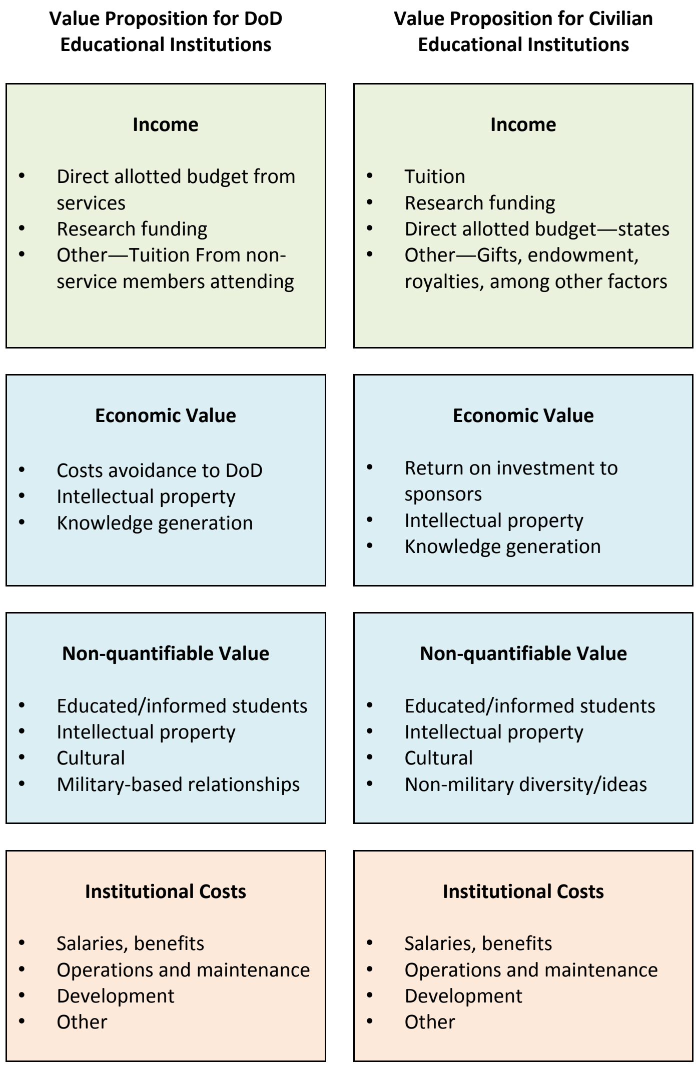

FIGURE 3-1 Value proposition for the Department of Defense and civilian universities.

Health Sciences (USUHS) for "best practices" of educational content and quality. However, when sending students to DoD in-house institutions, DoD must accept the trade-offs that follow from that decision. As mentioned earlier, the correct decision depends on the circumstances surrounding a particular educational need. Continued education of DoD military and civilian personnel at both DoD in-house and civilian institutions would optimize the benefits of both institution types across

TABLE 3-9 Summary of Strategic Benefits to Department of Defense (DoD) and Trade-offs of DoD-Funded and Civilian Institution Graduate Schools

	Strategic Benefit to DoD Graduate Education Institution	Potential Trade-off Compared to Civilian Institution
1	Tradition and culture building	May make DoD too inward looking
2	Creates the teamwork/networking that will help with future operations	Isolation from nonmilitary cultures and networks to international students; Might not be exposed to best practices from industry and academia
3	More predictable content and schedules	Civilian institutions are less predictable, but they may offer greater course diversity
4	Combines education with training	Lose education goals in favor of training outcomes
5	Education includes relevant research to foster lifelong learning skills	Innovation can be constrained by hierarchy within the students and the faculty
6	Coursework more adaptable to changing DoD priorities	Some coursework is difficult to link to fundamental studies and application to DoD needs.
7	Strong peer mentorship network and structured experience	Student mentoring and structured programs are subject to wide variations, creating uncertainty in quality and consistent of experience.
8	Easier to do classified/sensitive work	Classified/restricted research capacity and sharing is extremely limited.
9	Few intellectual property issues	Understanding of intellectual property challenges as key to doing business with DoD
10	Tackling any problem—even if socially unpopular or unacceptable	Lesser problem sets, more focused on nonmilitary areas, solutions might not capture all stakeholder and requirements
11	Leverage of unique facilities and subject matter experts—AFIT with AFRL, centers, and local program offices—NPS with laboratories and centers	Many universities do not have adjacent DoD research centers focused on military science and technology
12	Business processes mirror sponsors	Less hiring flexibility
13	Graduate focus frees faculty and administrators from dealing with the responsibilities of undergraduate programs.	Increases the difficulty of remediating students whose skills have eroded in the period bet. en their undergraduate and graduate experiences.
14	Provides avenues for students with marginal undergraduate grade point averages and non STEM+M degrees to obtain a relevant and connected STEM graduate experience, given a tailored remedial “catch up” to get up to speed as quickly as possible.	Top universities maintain their positions in part by controlling the quality of their incoming students. By lowering admission standards, DoD schools run the risk of lowering the quality of their education outcomes.
15	Provides a DoD environment where culture, processes, network, technology, among other factors, produces a more informed stakeholder/buyer	Limited exposure to private sector best practices.

NOTE: AFIT, Air Force Institute of Technology; AFRL, Air Force Research Laboratory; NPS, Naval Postgraduate School; STEM, science, technology, engineering, and mathematics; STEM+M, science, technology engineering, mathematics, and management.

the overall workforce. In the end, this is no different than DoD's undergraduate education strategy, where entry-level officers are commissioned through Service academies and Reserve Officer's Training Corp programs at civilian institutions.[29] Any marginal or even significant difference in the cost to achieve this mix of educational benefits should be a secondary consideration.

The strategic benefits of an AFIT and NPS education, along with the trade-offs listed in Table 3-9, are discussed below.

1. Instills tradition and culture building.

Strategic benefit. Faculty consists of officers or DoD-focused civilians with a strong Service knowledge base who often incorporate their military experiences and insights into the educational experience. Service military culture is reinforced by the fact that most students in a given cohort share similar backgrounds. A strong alumni network is formed that continues throughout the student's military career and beyond.

Potential trade-off. A homogenous military-oriented student body and culture limits exposure to non-military cultures, values, and viewpoints, creating an inward-looking atmosphere.

2. Creates teamwork/networking that will help future operations.

Strategic benefit. The student bodies at both Service schools consist of officers from all of the uniformed Services as well as officers from allied foreign countries. These students interact both socially and academically and develop a much deeper appreciation for their sister Services and for the political and cultural differences between the United States and its allies. They form bonds of friendship and trust by working together in accomplishing difficult academic goals that last a lifetime and provide the basis of a lasting network, which can be invaluable in solving Service-to-Service or nation-to-nation issues that may arise later in their respective careers. Teamwork and networking is increasingly international from a military perspective.

Potential trade-off. More exposure to civilian students and faculty could expand the size and future value of the military-oriented student's networks.

[29] The Army case bears further study.

3. Offers more predictable content and schedules.

Strategic benefit. All military Services transfer officers on a regular basis using well-developed assignment systems. Officer assignments are tightly scheduled, and unexpected changes in an assignment of an officer ripple through the system disturbing other assignments. Predictability in starting and ending dates of military officers enrolled in academic programs is essential. Both AFIT and NPS are structured so that all requirements for programs are offered and met within the time window available, and both have very high on-time completion rates.

Potential trade-off. Civilian institutions offer little or no control over the content and scheduling of their courses; however, larger civilian institutions may offer a greater diversity of course choices.

4. Combines education with training.

Strategic benefit. By law, officers who are part of the acquisition workforce or are seeking a joint assignment have training and education requirements beyond those found in traditional academic programs. For example, both AFIT and NPS offer programs that satisfy the Defense Acquisition Workforce Improvement Act for education and training.

NPS, and until recently AFIT, also provide Phase 1 Joint Professional Military Education (JPME) on campus. At NPS, JPME is offered through a partnership with the Naval War College. At AFIT, JPME was offered by a detachment from Air University Intermediate Service School. In both cases, the degree and certification requirements are met concurrently while the student is enrolled in their graduate education programs. This results in significant time and money savings to DoD. It also ensures both research and education objectives are aligned with the most recent military doctrine.

Potential trade-off. Given the structured time constraints at DoD institutions, the additional education requirements, in addition to the added training requirements of being stationed on a DoD installation, might lead to less time to devote to the pursuit of the graduate degree.

5. Conducts relevant research that fosters lifelong learning skills.

Strategic benefit. Master's and Ph.D. students are required to conduct and publish research results in a thesis.[30] Topics are typically developed through the research of faculty and their connection to the many Service, DoD, and national security agencies. Occasionally students bring a topic of interest from their field experience and work with a faculty member to define a thesis effort. The process is intense, and faculty is actively involved. Sponsors are routinely asked to evaluate both the quality and applicability of the work and to assess its value.

The thesis requirement ensures that a student has conducted an independent and original study of a problem relevant to national security, documented the results of that research, and presented the work both in writing and orally. These skills are essential throughout a student's career and provide qualities that coursework and training alone do not. The ability to frame a complex problem, develop the means to solve it, document the results—often for external peer review, and present the results in an academic forum for evaluation all develop self-confidence and prepare the student for lifelong learning.

Potential trade-off. The broader research scope and diversity of ideas at civilian universities may lead to more "out of the box" thinking and solutions.

6. Is more adaptable to changing DoD priorities.

Strategic benefit. As accredited universities, both AFIT and NPS have well-established procedures for modifying existing programs and establishing new ones. As small institutions, they can make changes quickly and have programs in place in a few months in response to DoD needs and priorities. There are numerous examples of quick-reaction course and program development at both AFIT and NPS.

Potential trade-off. Less structured processes for curricula development and approval may make AFIT and NPS more susceptible to short-term fads than civilian institutions.

7. Offers strong peer mentorship network and structured experience.

Strategic benefit. Students at AFIT and NPS have a very structured experience to include a chain of command among students. This provides mentorship

[30] Some systems engineering students in the distance learning program at NPS do a group project.

for academic and non-academic activities where the roles and responsibilities of a student are well defined. The structured environment facilitates students graduating within the allotted time—the Services only allow 3 years for Ph.D. completion. While there is wide variation in statistics by degree, full-time students average between 5-7 years for STEM-related Ph.D. completion. The current practices of AFIT and NPS align with the best practices described in the Ph.D. Completion Project report.[31,32]

Potential trade-off. At many civilian institutions, graduate students are expected to participate in many activities beyond coursework and research. For example, many programs require students to teach as part of their Ph.D. experience. This breadth of academic experience could provide a more diverse graduate experience.

8. Easier to do classified/sensitive work.

Strategic benefit. Classified and sensitive work are a routine part of curricula and research at AFIT and NPS. Each has extensive facilities to handle and store classified material through the Top Secret level. Sensitive Compartmented Information Facilities (SCIFs) are available on both campuses as are classified computer networks. Professional security staffs are available to maintain and operate the classified facilities. All faculty members have at least a Secret clearance, and many have Top Secret clearances with access to Sensitive Compartmentalized Information (SCI). A student thesis or capstone project need not be "extracted" to have a publishable, unclassified version. In summary, the environment, facilities, and personnel at both institutions support both classified course work and research. At most civilian STEM+M institutions, classification considerations can be a significant issue, particularly when a publishable thesis is required, unless the institution is already involved in classified research on campus in some fashion (e.g., UARCs and federally funded research and development centers).

Potential trade-off. Without the open scholarship focus that exists at many civilian universities, feedback and generation of ideas can have a more limited scope.

[31] Council of Graduate Schools, *PhD Completion Project: Policies and Practices to Promote Student Success*, http://www.phdcompletion.org/information/Executive_Summary_Student_Success_Book_IV.pdf, March 2010.

[32] See also National Science Foundation, "Time to Degree of U.S. Research Doctorate Recipients," InfoBrief NSF 06-312, available at http://www.nsf.gov/statistics/infbrief/nsf06312/, March 2006.

9. Avoids intellectual property issues.

Strategic benefit. Unless the work is considered sensitive or classified, research produced at AFIT and NPS is published in the public domain. As civilian universities strive to be more entrepreneurial, revenue in the form of royalties and licenses and for intellectual property is becoming a major issue that does not arise in a DoD institution.

Potential trade-off. DoD students would have limited exposure to the challenges of proprietary intellectual property considerations that are universal and key to doing business with DoD.

10. Tackles any problem—even if socially unpopular or unacceptable.

Strategic benefit. Essential military research, such as weapons research, has been discouraged by civilian institutions as inconsistent with their missions and culture. A more subtle challenge is the natural bias of civilian faculty who must build a career of publishable research in some areas that may not adapt well to military subjects of relevance to DoD and of interest to the student.

AFIT and NPS, as military organizations, readily offer programs or do research in any area of importance to national security or with potential military application. The faculties of these institutions also accept limitations on the publication or dissemination of their work due to classification restrictions.

Potential trade-off. Exposure to a broader array of socially relevant problems and perhaps future national security challenges is limited at the expense of clearer military relevance.

11. Leverages unique facilities and subject matter experts (AFIT with AFRL, centers, and local program offices, and NPS with NRL, laboratories and centers).

Strategic benefit. Both defense schools have internal, Service, and DoD centers of excellence with which to share personnel and facilities. By virtue of collocation with the AFRL, AFIT shares subject matter expertise, libraries, and laboratory facilities. AFRL Ph.D.s also often serve on dissertation committees and provide SME expertise and mentorship to AFIT students. Faculty members also form a body of technical and management experts that DoD acquisition and logistics professionals use to obtain independent opinions on challenging issues.

NPS, through its strong reimbursable research programs, has created numerous relevant centers in topical areas of national interest. It is immediately adjacent to a campus of the Naval Research Laboratory and the Fleet Numerical Center. These centers can provide the critical mass of faculty to tackle the complex problems that are challenges for DoD.

Potential trade-off. Most major civilian universities have extensive facilities across a broader array of subject areas, as well as more links to external organizations, particularly industry. Many complex problems affecting DoD and the nation are a combination of technical, political, and sociological attributes.

12. Business processes mirror research sponsors.

Strategic benefit. Few inside or outside the government consider the business processes and regulations governing operations as conducive to efficiency and entrepreneurship. Because NPS and AFIT are DoD institutions, a relatively simple Military Interdepartmental Purchase Request (MIPR) can be used to award funding versus a contractual instrument—often a cumbersome, competitive selection process. Service and other government agencies can process MIPR paperwork often within a week to obligate funding. NPS and AFIT can use this advantage to rapidly accept year-end funding on a project order for high-priority research efforts.

Potential trade-off. DoD procurement and contracting processes are changing and becoming increasingly inflexible. Business processes of universities may be more adaptive to these changes than DoD institutions whose business processes have been finely tuned over the years to match their sponsor's funding processes.

13. Applies graduate level focus on military-relevant problems.

Strategic benefit. AFIT and NPS only offer graduate-level programs. Faculty members are not encumbered with undergraduate responsibilities. Additionally, the research focus at both AFIT and NPS is largely driven by military needs. Many civilian university faculty members funded by DoD conduct high-quality research of interest to the military. However, when military funding shrinks or changes focus, university faculty typically seek funding elsewhere.

Potential trade-off. The difficulty of remediating students whose skills have eroded between their undergraduate and graduate experiences is increased.

Fewer opportunities for students to expand their knowledge and education experience in different disciplines are offered.

14. Provides avenues for students with marginal undergraduate grade-point averages and non-STEM+M degrees to obtain a relevant and connected STEM graduate experience.

Strategic benefit. Military officers often do not exercise their undergraduate STEM+M skills in subsequent assignments. The Navy provides the opportunity for military officers with receded skills, who might not be competitive for admission to the best civilian graduate university programs, to pursue post-graduate education at NPS. As a result, NPS provides a significant amount of remedial education for such students to enhance their STEM-related competencies prior to embarking on their graduate studies. This remediation program is also important for the retraining of students with non-STEM undergraduate degrees. The Air Force's selection process for officers pursuing graduate degrees requires those officers to meet typical admission criteria, and Air Force students require little remedial work while in residence. AFIT has, however, sent foreign officers, Naval officers, and students selected by the Army for nuclear engineering to take undergraduate courses at local universities to prepare them for graduate work. AFIT does offer a short refresher (approximately 1 month) to all entering master's students to help them adjust to life as a full-time student. Indeed, some at AFIT and NPS argue that they offer students who may be under-qualified for admission to the best civilian universities an education that would allow them to compete with graduates of the best universities upon graduation. While this may be an overstatement, AFIT and NPS provide a valuable service by making future DoD leaders notably more prepared for decision-making responsibilities that involve technological factors.

Potential trade-off. Top universities maintain their positions in part by controlling the quality of their incoming students. Metrics such as prior academic performance and standardized testing are used to assess student quality. These metrics drive peer perception and national rankings. By lowering admission standards, DoD schools might be perceived as lowering the quality of their educational outcomes. Also, most traditional graduate students follow a well-defined career path by proceeding directly from undergraduate to graduate school. Standardized testing might be a good assessment tool for traditional civilian students, but it probably does not reflect the ability of military students who have a break in formal education because of multiple deployments or command tours.

15. Provides an environment where culture, processes, network, and technology, among other factors, produces a more informed stakeholder/ buyer.

Strategic benefit. Acquisition is a complex interdisciplinary process involving numerous stakeholders. AFIT and NPS expose students to other students, professional development activities, coursework, and other factors that make them more informed buyers.

Potential trade-off. The DoD procurement arm has historically not performed as well as the civilian sector. Best practices from the civilian sector may not be taught in military-oriented graduate education programs.

The brief assessment of strategic benefits and trade-offs to an AFIT and NPS graduate education yields the following findings and recommendation.

Finding 3-3. AFIT and NPS are often viewed solely as education enterprises by their constituents. These institutions, however, are coupled research/education enterprises with productive research programs that improve the quality of student education, play an essential role in attracting and retaining top faculty, and generate valuable weapon system insights and technologies.

Finding 3-4. AFIT and NPS foster teamwork and facilitate the formation of intellectual networks that follow students throughout and beyond their military experiences. Developing military-to-military, joint, and interagency relationships can play a critical role as students work in future multi-Service and multi-national operations.

Recommendation 3-1. The Department of Defense (DoD) should recognize and support the comprehensive value proposition offered by the Air Force Institute of Technology and the Naval Postgraduate School. Measures of convenience, cost, and quality are not sufficient to meet the demand for a technically superior workforce. When viewed from a total value perspective, as described in the benefits column of Table 3-9, DoD's graduate science, technology, engineering, mathematics, and management enterprise is a tremendous asset to the respective Services, DoD, and the nation.

DoD's graduate education strategy could include a mix of graduate education options for its employees at both DoD and civilian institutions to realize all strategic benefits and minimize the trade-offs in the overall workforce. Based on the simple cost assessment described here, the difference in the costs of achieving this mix of educational outcomes and resulting overall workforce capabilities is of secondary importance compared to the strategic benefits offered by quality, DoD-funded institutions. The next section provides more detail on how best to assess the quality of AFIT and NPS educational outcomes.

ON THE QUALITY OF EDUCATION

Traditional measures of academic institutional quality in civilian universities generally rest on the quality of the students and the faculty. The widely cited *U.S. News and World Report* (USNWR) rankings use many factors for measuring inputs into the system: how good are the students, how much money is the university spending on them, and how strong is the faculty. For the quality of the faculty—at both undergraduate and graduate levels—traditional measures include the institutions where they received their degrees and the outputs of the faculty in three general areas: (1) intellectual activity (e.g., peer-reviewed publications); (2) scholarly activity (e.g., service on campus and on broader academic pursuits nationally and internationally); and (3) individual recognition (e.g., prestigious awards, national academy service and membership). This traditional view of institutional quality effectively assumes that the highest educational outcomes will follow from excellence in these metrics.

Direct measures of educational outcomes are becoming more widely used in terms of educational and learning objectives that can be quantified in some way to determine the eventual outcomes for the students. In this framework, the regional accreditation boards and the subject-matter accreditors are moving toward institutional assessments of colleges and universities to assure the desired performance for the public funding provided to these institutions as state and federal budgets become tighter. Accreditors require "learning outcomes" for each course of study, and a detailed description of the assessment of each outcome, to ensure graduating students have the knowledge and skills degrees promise. Both AFIT and NPS have well-established assessment processes and, when appropriate, have achieved accreditation at the program level.

The most frequently used source of information about reputational quality of master's programs for prospective graduate students, as well as in marketing by the universities themselves, is the USNWR graduate school rankings. All of the STEM graduate programs—for example, mathematics, biology, computer sciences, and statistics, except engineering—are ranked through collecting survey data every 3 years via a mail survey sent to all schools housing the program. Each university gets two votes, and the raters are asked to simply rate each university's program, including their own, on a 1 to 5 scale from poor to highest quality. The average across the entire sample of respondents is used to rank the programs. It is difficult to obtain response rates from USNWR, but it is highly likely that the response rates are not extremely high.

Engineering schools are ranked by USNWR using four sets of criteria, with indicators under each: (1) quality assessment, weight 0.40, measured by peer assessment on a survey with a 1 to 5 scale (0.25) and recruiter assessment (0.15); (2) student selectivity, weight 0.10, measured by mean graduate record exam quantitative scores of incoming students (0.0675) and acceptance rate (0.0325); (3) faculty resources, weight 0.25, measured by student-faculty ratio (0.0375), percentage of faculty in the National Academy of Engineering (0.0725), and number of doctoral degrees awarded (0.0625); and (4) research activity, weight 0.25, measured by total research expenditures (0.15) and average research expenditures per faculty member (0.10). A reputational survey, such as that described above, is used to rank the specialty programs—for example, aeronautical engineering.

While the process used by USNWR for deriving rankings of graduate programs is certainly not without flaws, the faculty raters typically are knowledgeable about the programs they rate. Perceptions about the quantity and quality of published research, the professional prestige of the faculty members, the total amount of external funding, and the prestige of the funding sources are taken into account, as well as the quality and accomplishments of the doctoral students that the program produces. Doctoral programs in STEM fields are also ranked by the NRC's Board of Higher Education and Workforce in their Assessment of Research Doctoral Programs, which it undertakes every 10 years. The NRC ranking process is much more labor-intensive and involves measuring the productivity of the alumni of the programs over many years, as well as the scholarly productivity of the faculty members in the programs. NRC rankings are not without criticism, much like the USNWR rankings, but they are based on more data.

The USNWR and NRC quality assessment methods are designed to rank and compare civilian institutions. As described in the previous section, in-house DoD education institutions possess unique characteristics that make them difficult to assess for quality using these conventional methods. The quality of DoD graduate degree-granting institutions should not be framed using only conventional methods for the following reasons:

- DoD institutions focus primarily on research-intensive master's level programs and less on doctoral programs, in contrast to most of the highest-quality civilian institutions.
- By and large, the student bodies of DoD institutions draw from a closed (military) population. DoD is constrained to train the population they recruited at the beginning of their careers; they do not have the option of hiring in new officers at mid-career.

- Most of the above traditional measures of quality based on enrollment and postgraduate career data simply have no bearing. The placement rate for graduates of AFIT and NPS is near 100 percent; the salaries are fixed by the military pay scale, and the list of hiring employers is limited to the sponsoring agencies.
- The publication record in peer-reviewed journals might be slightly lower than at comparable institutions because (1) some of the most important research results are classified; (2) with relatively fewer Ph.D. students, the kinds of research that can be performed by faculty and M.S. students may well limit the number of published journal articles; and (3) the ongoing limits on travel budget and conference presentations severely limit the number of conference papers the faculty can present. This lack of visibility at conferences can negatively affect peer evaluations of the universities/programs, which is the number-one factor in rankings such as the USNWR.

This is not meant to say that traditional metrics of academic quality should not be used to assess the quality of DoD institutions. In fact, traditional measures serve an important role in fostering broader educational credibility, as well as quality, in several key areas of institutional performance such as competitiveness in intellectual output and in success obtaining external research sponsors. The calculus for quality at these DoD institutions is different, however, than it is for civilian institutions. The most appropriate calculus likely comes closer to the emerging approaches for performance-based funding of state colleges and universities. With this view, quality should be measured and aligned with the value received from the primary stakeholders—students, Services, and DoD.

The value proposition and quality measures discussed above are not unique to AFIT and NPS. They are likely to be the same or at least quite similar for all DoD graduate-degree-granting institutions.[33] In a state with a large number of universities in its state system, one individual has budget and regulatory authority over the institutions. Such an individual or function in DoD could become the source for assuring the department of institutional performance and quality across all campuses and adherence to the desired value proposition at each campus and college. Indeed, such a function would probably have been able to undertake this study for DoD.

Such a chancellor function could use one of many approaches to assess the corporate governance needed for DoD graduate-degree-granting institutions, one of which assesses an organization's ability to change. Figure 3-2, depicts the complex set of factors that affect the ability of DoD to develop and support a well-prepared STEM+M workforce in order to achieve the desired outcomes of STEM+M educa-

[33] The lack of a single DoD voice that might be the keeper of this strategic view across DoD is noteworthy and a repository of data was difficult for the committee to obtain.

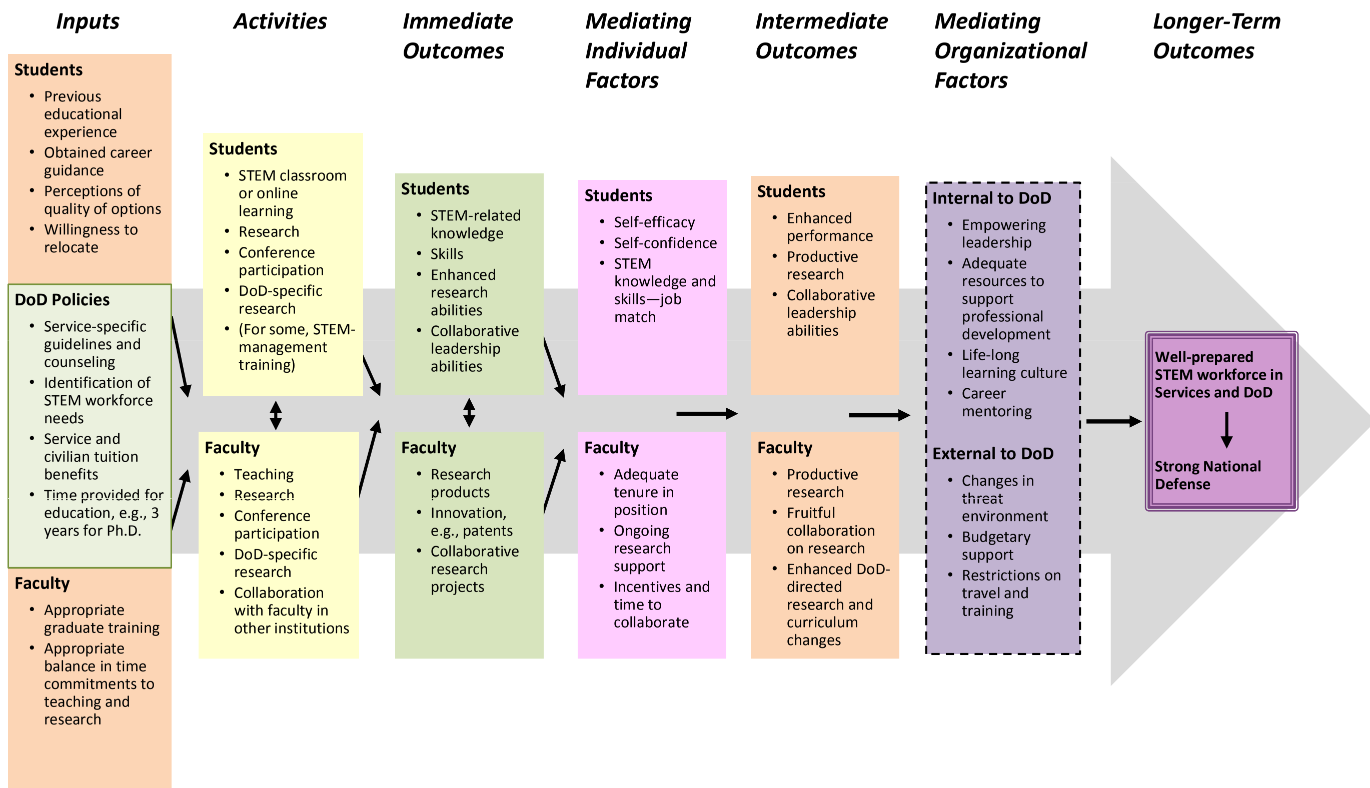

FIGURE 3-2 Theory-of-change model for STEM+M graduate education for the Department of Defense.

tion for DoD. A theory-of-change model can be used for evaluative purposes.[34] The model traces the path of intended policies and programs, from the components that support and shape the programs, to the intended outcomes. In this case, given existing DoD policies and resources together with educational experiences of DoD uniform and civilian personnel, this model identifies expected immediate, intermediate, and longer-term outcomes from DoD-managed graduate degree institutions. The model could be applied to all DoD institutions, going beyond STEM+M institutions.

Reading Figure 3-2 from left to right, the process flows from inputs—the people, resources, DoD policies and procedures—to the activities during a STEM graduate education. Activities include classroom or online learning as well as laboratory research and field research and other professional development experiences such as conference and workshop participation. These inputs and activities are expected to affect the trajectory of outcomes such as changes that occur in the students and faculty involved in the STEM education and, ultimately, the impacts within the organizations where graduates return to work. This report separates the faculty and student outcomes to indicate the specific intended aims of STEM education on both students and faculty. The longer-term outcomes are not separated between student and faculty, indicating the desired collaborative and integrated nature of these longer-term relationships. This education process is embedded in the overall DoD system in which there may be significant changes over time, such as new threats to national security and budgetary constraints. The continued collaboration between students and teachers promotes lifelong learning, for example, and provides a means to measure it.

The ability of DoD to achieve the desired outcomes, for both the careers of STEM graduate education graduates and the workforce, is shaped by many other factors that may be beyond the control of DoD leadership—e.g., salary scales, hiring flexibility. Such factors are labeled as mediating factors because they may shape or even block achievement of desired results. Between intermediate and longer-term outcomes lie additional, potentially important mediating factors both within and outside of DoD that may impede achievement of the longer-term DoD objective of ensuring a well-prepared STEM+M workforce, both military and civilian. DoD staff can use an assessment tool of this type to be more strategic in planning and assessing how well the desired educational outcomes and DoD outcomes are attained. The model identifies key mediating factors that affect achievement of short-term outcomes, as well as intended intermediate outcomes. Many of the mediating factors are under DoD control, and some reflect the underlying DoD culture. Research

[34] J.A. McLaughlin and G.B. Jordan, Using logic models, pp. 7-32 in *Handbook of Practical Program Evaluation,* 2nd edition (J.S. Wholey, H.P. Hatry, and K.E. Newcomer, eds.), Jossey-Bass, San Francisco, Calif., 2004.

has highlighted the importance of promoting a learning culture and risk-taking to enable achievement of desired longer-term outcomes from educational programs. Leaders must be empowering, creative, and support leadership development throughout an organization to ensure effective workforce development. [35]

The mediating factors identified in the model can also help to explain the extent to which STEM+M graduate education adds value to the students, organizations, and DoD as a whole. For example, despite gaining STEM+M knowledge and skills while in educational programs, military STEM+M graduates may not perform fully in their careers due to inevitable non-STEM+M assignments. Even if the STEM+M graduates—military or civilian—are successful in the workforce, organizational performance may not improve or not be measured appropriately. Note that one important component of the earlier value proposition model is Benefit 7—peer mentoring that occurs as part of an AFIT/NPS degree (see Table 3-9), which fosters improved organizational performance and provides a means to measure it.

The theory-of-change model for STEM+M graduate education can also help to explain why even high-quality curricula and outstanding instruction may not necessarily produce desired intermediate and longer-term outcomes for DoD's workforce.[36] Of significance, the model clarifies how DoD, and more generally federal rules, processes, and procedures may constrain development of a culture that supports life-long learning and career development in DoD's STEM workforce.

The committee considered important inputs and mediating factors identified in Figure 3-2 and identified several key influence points that seemed to be either weak or not apparent within existing DoD processes. These DoD inputs and mediating factors could be monitored to assess how to make STEM graduate education more effective in adding value to the DoD workforce and, ultimately, to national security. These observations are listed in Table 3-10.

To illustrate the assessments in Table 3-9, the currency of DoD career counselors' knowledge about offerings and the quality of educational programs within DoD institutions and in civilian institutions is one of the first key influence points about which more information is needed. STEM graduate programs differ along a variety of important dimensions, and the distinctions make the selection process even more critical for both the prospective students and the career counselors because they need to understand the relative advantages of the options available. Five key variables are (1) whether the program is offered within a civilian university or DoD-sponsored institution such as NPS or AFIT; (2) whether or not the student has an undergraduate degree in a STEM field or not; (3) whether or not

[35] J.E. Kee and K.E. Newcomer, T*ransforming Public and Nonprofit Organizations: Stewardship for Leading Change*, Management Concepts, Washington, D.C., 2008.

[36] E. Salas and J.A. Cannon-Bowers, The science of training: A decade of progress, *Annual Review of Psychology* 52:471-499, 2001.

TABLE 3-10 Illustrative Critical Influence Points Affecting Outcomes of STEM Graduate Education for DoD

		Military Workforce	DoD Civilian Workforce
Pre-Educational Experience			
1	Systematic analysis of needs for STEM-educated personnel.	Improving strategically	Locally well determined, but much less strategically visible until recent DoD SWP for 2013-2018
2	Career counseling to ensure correct match of student to appropriate educational programs	Appears weak	Done well locally (i.e., at home organization)
3	Appropriate preparation for students without STEM undergraduate degree to pursue STEM graduate degrees	NPS and AFIT well positioned for this, not for education at civilian institutions	Less of an issue unless sent to AFIT or NPS
During Educational Experience			
4	Well trained and research-active faculty	A challenge for AFIT, NPS and possibly all DoD institutions	Depends on caliber of civilian institutions used.
5	Educational experience match to subsequent DoD assignments	Inevitable challenge	Unclear if a problem
6	Adequate support for research, conference travel and other professional development activities	Problems due to budgets and process	Problems due to budgets and process
After Educational Experience			
7	Match of students' educational preparation to subsequent assignments	Inevitable challenge	Unclear if a problem
8	Ongoing professional support	Little or none	Local or none
9	Ongoing support of DoD collaboration about research and personnel needs with DoD educational institutions, e.g., Air Force and Navy panels advising on research and skills needs to AFIT and NPS	Excellent at both AFIT and NPS	Little or none at civilian institutions unless local

NOTE: AFIT, Air Force Institute of Technology; DoD, Department of Defense; NPS, Naval Postgraduate School; STEM, science, technology, engineering, and mathematics; SWP, strategic workforce plan.

the degree requires a thesis—i.e., an individual research project; (4) whether or not the master's degree is free-standing or is taken in conjunction with a doctoral program—i.e., combined M.S./Ph.D. programs; and (5) whether the Ph.D. program requires entering students to have completed a master's degree before entering the

TABLE 3-11 Distinctions Among STEM+M Graduate Programs

Relevant Distinctions	Potential Relative Advantages	
Civilian university or DoD-funded institution	*Civilian*— Larger faculties, higher nationally ranked programs, and broader range of research available	*DoD*— Cross service socialization; research DoD specific; high security research easier; faculty more likely to be vets and/or DoD knowledgeable
Undergraduate degree must be in a STEM field	*Yes*— Student may take more advanced coursework	*No*— STEM education is available to a larger pool of potential students
Thesis required	*Yes*— Student produces DoD relevant research	*No*— Degree may be shorter and easier to complete on time
Free standing master's or combined M.S./Ph.D. program	*M.S. only*— Time to complete the one degree is shorter	*M.S./Ph.D.*— Time to complete both degrees is likely shorter
Ph.D. program requires M.S. upon entry	*Yes*— Time to complete the degree is likely shorter	*No*— Time to complete degree may be longer since more coursework may be needed

NOTE: DoD, Department of Defense; STEM, science, technology, engineering, and mathematics; STEM+M, STEM and management.

program. To carry the example further, Table 3-11 presents these five options and suggests potential advantages as they might be provided when DoD offices provide counseling advice. The impression is that this is an area that could be improved for the overall benefit of the military workforce, particularly in STEM+M education.

While not under the influence of DoD policies, perceptions of quality of the STEM+M graduate programs and universities offering the programs also matter. As shown in Figure 3-2, it does matter how students view the relative merits of different educational options matters, and how DoD career advisors view the different programs' relative advantages to the students and to adding value to DoD's STEM workforce.

INSTITUTIONAL ORGANIZATION CONSIDERATIONS

Command Structure of the Naval Postgraduate School

The NPS president reports to the Chief of Naval Operations (CNO), as shown in Figure 3-3. This is also true of the Naval War College and the U.S. Naval Academy. Academic oversight is provided by the NPS Board of Advisors under the provisions

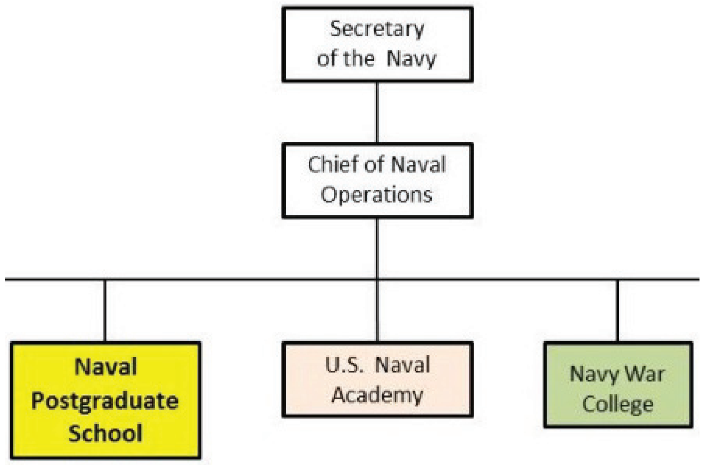

FIGURE 3-3 Organizational structure for the Naval Postgraduate School.

of the Federal Advisory Committee Act of 1972. Resourcing and budgeting actions flow through the Office of the Chief of Naval Personnel.

NPS made two significant points to the committee during its visit. First, research sponsors who invest with the Navy on issues involving intellectual property are becoming increasingly concerned about the composition of the NPS research team. Those outside DoD pose an ownership risk and make partnering more difficult. Second, NPS's "short" chain of command is key to their relevancy, flexibility, timeliness, and added value.[37] Their ability to rapidly move laterally with senior Navy leaders who have decision authority is critical to their success. NPS stated that the two most important changes at NPS were the Navy's decision to have NPS led by a civilian (continuity of leadership) and to have the school report directly to the Navy CNO (better resourcing and ownership of mission).[38] In short, "stability leads to innovation which drives capability."[39]

Command Structure of the Air Force Institute of Technology

The AFIT chancellor reports directly to the Commander, Air University (AU) who, in turn, reports to the Commander, Air Education and Training Command

[37] Dan Boger, NPS, presentation to the committee on November 6, 2012.
[38] RADM James Greene, USN (ret), discussion with the committee on November 7, 2012.
[39] Ibid.

(AETC), who, in turn, reports to the Chief of Staff of the Air Force (CSAF) (see Figure 3-4). The AFIT subcommittee of the AU Board of Visitors provides oversight.

In 1999, the AFIT Subcommittee of the Board of Visitors noted that AETC was the wrong advocate for AFIT. The minutes of the March 1999 AFIT Board of Visitors noted:

> Postgraduate education advocacy is the responsibility of the commander of Air Education & Training Command. This is among his smallest responsibilities and among his lowest priorities. From a priority perspective, the AETC commander is driven to meet the training syllabus. . . . When money is short in an AETC area to meet a field need, education is an obvious resource target; there is no immediate measurable operational impact if not met. There is no immediate mission or readiness impact nor is there a senior stakeholder noting a shortfall. . . . Accordingly, AETC is adjudged to be the wrong functional advocate for AFIT. AFIT is not important to AETC's metrics nor success, nor is there a united user community to advocate for it.

They recommended that AFIT remain within AU, but that the Air Force realign AU as a direct reporting unit to the Air Force Chief of Staff. In 2000, the AFIT Board of Visitors stated that if moving AFIT under the CSAF was not feasible, then AFIT should realign with its largest single customer, the Air Force Materiel Command (AFMC), which would return AFIT to a chain of command similar to what it had

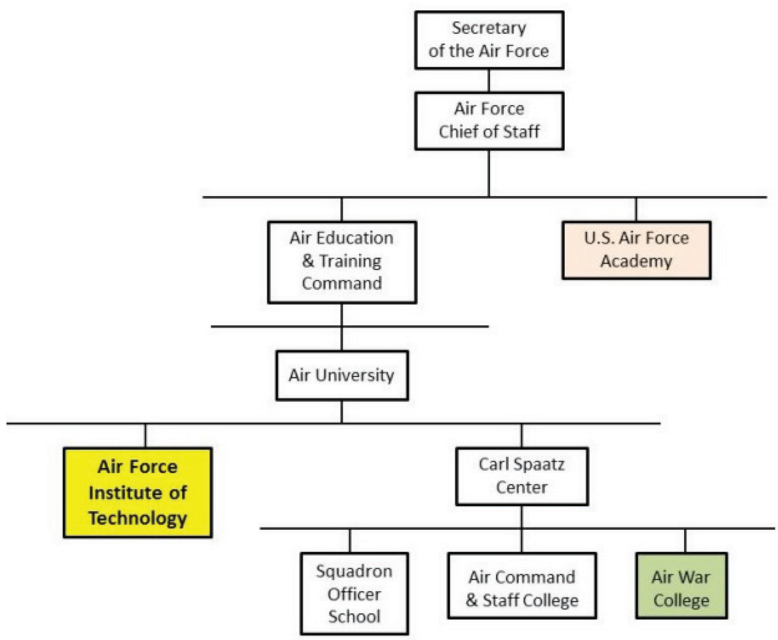

FIGURE 3-4 Organizational structure for the Air Force Institute of Technology.

between 1919 and 1950. At the time, the commander of AFMC was prepared to accept the organizational assignment and advocate for AFIT. However, AU was opposed, and nothing happened to the recommendation.

The issue was raised again with the enactment of the National Defense Authorization Act of 2001 (P.L. 106-398) that called for the Secretary of the Air Force to study and make recommendations with respect to AFIT's chain of command. The resulting report generated internal debate within the Air Force, whose leadership concluded that the command arrangement should remain the same.[40] Several observers continued to note that AFIT was a questionable fit even within AU. In 2007, a team of four higher education professionals reviewed the organization and general condition of AU.

> AFIT is located hundreds of miles distant [from AU] and actually is accredited by a different regional agency (the North Central Association of Schools and Colleges) than AU, which is accredited by the Southern Association of Schools and Colleges (SACS)…. This distance means that the AFIT leadership and its faculty and student body do not often interact in the same room with comparable AU personnel located in Montgomery.[41]

AU views and manages AFIT as a college of AU, not as a separate, autonomous institution reporting through the university.[42] As a result, AU's president, not the AFIT chancellor, is the final authority on faculty hiring, faculty promotion, and tenure decisions. AFIT's lack of autonomy is extremely unusual, if not unprecedented, for a regionally accredited institution and could represent a serious challenge to future accreditation.[43]

As stated earlier, military-focused, graduate STEM+M education and research conducted at DoD-funded institutions plays a strategically vital role in educating the DoD workforce. DoD invests heavily in maintaining an extensive education portfolio across a wide range of STEM+M programs. How the Services organize to leverage this investment matters. Based on budgetary consequences of prior post-conflicts, it is anticipated that there will be reductions in funding for education, training, and travel, which are often the first programs cut during challenging budget environments. Education, however, is unique in how budgets impact their

[40] Report of Air Force Institute of Technology (AFIT) Study For Senate and House Armed Services Committees, submitted to Congress on February 25, 2002.

[41] James L. Fisher, Ltd., *Air University Review,* February 2007-April 2007.

[42] As confirmed by the commander and president of Air University during presentations to the committee.

[43] AFIT has been continuously accredited by the Higher Learning Commission for more than 50 years. In 2004, Air University received institutional accreditation through the Commission of Colleges of the Southern Association of Colleges and Schools. As currently structured, AFIT is managed by AU as one of its several colleges and, as such, may in the future be ineligible for separate institutional accreditation.

programs, both near and long term. Reductions taken as a "percent" across the board, sometimes referred to as "peanut butter" cuts, have a short shelf life for an educational institution. They are quickly faced with cutting entire programs, such as graduate education at civilian institutions. In addition, the impact of significant budget cuts to education are typically not seen with the normal Program Objective Memorandum cycle, perhaps several cycles. Said another way, if you want to increase the number of general officers with a STEM+M degree, you may not realize the full benefits of your efforts for 20 years or more.

AU controls AFIT's faculty personnel decisions, including hiring, promotion, tenure, and annual appraisals and salary adjustments. Even if the process usually confirms AFIT's recommendations, it requires time and effort that could be better spent by both AFIT and AU leaders. Furthermore, it is essential that AFIT continue to have a strong research program and expand its student base to include more sister Service personnel, international officers, and DoD civilian personnel—primarily through reimbursements. AFIT has made significant progress establishing a reimbursable program for both research and tuition, despite difficulties caused by the fact AFIT is the only component in its current chain of command requiring such a program. The difficulties arise from the length required to staff recommendations through both AU and AETC, and by the lack of experience or expertise in such matters within either organization.

The characteristics and implications of education and training are quite different. In an era characterized by the value of intellectual property, organizational agility, and rapid innovation, AFIT may experience "drag" created by a parent organization focused on Air Force-wide readiness issues. This is especially true of budget cuts that tend to get larger as they "roll downhill" through a rather extensive chain of command. The difference in reporting structures of AFIT and NPS is indicative of the difference in strategic priorities each Service assigns its respective school.

Finding 3-5. From an organizational structure and chain of command perspective, AFIT is at a disadvantage in comparison to the other graduate-degree-granting DoD organizations. This disadvantage was highlighted in the organization of the alliance between AFIT and NPS. While the alliance was purported to be between AFIT and NPS, responsibility for oversight of the alliance was given to the NPS Board of Advisors and the AU Board of Visitors. To ensure a connection between those boards, the NPS superintendent was appointed to the AU Board of Visitors and the AU commander, not the AFIT commandant, was appointed to the NPS board.

Finding 3-6. In recognition of the importance of education and the key roles DoD-funded graduate education institutions play in delivering education to the uniformed component of the workforce, many of these institutions report at the highest levels in the Services, the profession, or the Joint Staff—e.g., the Service academies, USUHS, and NPS. This is appropriate to insure a strategic oversight that is not deterred by other priorities of interim organizations. However, this placement is not true for all DoD degree-granting institutions. In particular, AFIT organizational issues have come up several times in the past 20 years without meaningful resolution of these challenges.

Finding 3-7. AFIT's current command structure requires it to advocate for initiatives to maintain and strengthen its research-based graduate education programs via a lengthy chain of command that has limited graduate education expertise, virtually no technical research expertise, and a focus on immediate training and professional military education requirements.

Recommendation 3-2. The Air Force Institute of Technology's (AFIT's) chain of command should be changed, perhaps to resemble the Naval Postgraduate School, with its own board, budget, accreditation, and program authority, in order for AFIT to maximize its value to the Department of Defense and the nation.

If DoD does not wish to have AFIT report directly to the CSAF, it might choose to align AFIT with AFMC, its largest customer—a solution the AFIT Board of Visitors recommended in 2000. AFIT cannot achieve its full potential as a subordinate organization to AETC or AU. AETC's training mission, AU's accrediting body and accreditation process, and the education and research mission of AFIT create significant culture and priority mismatches. As DoD continues to "bend the technology curve," it will become increasingly import that AFIT and NPS, in partnership, move forward in a manner that allows both to be agile, value added, and innovative. AFIT organizational challenges have arisen several times in the past 20 years without meaningful resolution. DoD needs to resolve this longstanding issue.

Department of Defense Policies

DoD has been damaged by sequestration, furloughs, pay freezes, lack of professional development opportunities, unstable funding, reductions in retirement benefits, increased oversight, and decreased contracting and hiring flexibility, among other factors. This is not unique to DoD in the federal government but arguably has more direct impact on national security readiness than others may have for their missions.

One of the major findings of the 2012 NRC report addressed NPS and the erosion of its independence—i.e., travel, publication restrictions, hiring/personnel constraints, and new and immature business processes.[44] That report also states "meeting the workforce needs associated with emerging technologies in the light of existing workforce trends and DoD policies could be problematic."[45] Another major finding of the 2012 NRC report was "*flexibility*, *capability,* and *relevance* in the DoD STEM workforce are the essential characteristics sought."[46] Current DoD processes and practices are inhibiting the hiring, development, and retention of a competent workforce.

Seemingly small, the current limitations on travel, increased travel regulations, funding constraints, and approval authority for conferences strikes at the heart of a robust graduate educational system and experience for the students. The constraints, mainly driven by short-term funding limitations, severely constrain faculty and students from participating in critical peer reviews and network opportunities, with potentially long-term ramifications. [47] Without the opportunity for immersive interaction with peer communities, AFIT and NPS relevancy and credibility are undermined in the technical communities. Conferences for disciplines such as computer science, cyber warfare, computer-based STEM, and other key competencies for DoD are the primary outlets for learning what others are doing, publication, and peer assessment of research, including educational pedagogy. This is severely limiting DoD educational institutions on many fronts, including perceived quality (not visible among their peers), as well as the ability to remain at the leading edge of rapidly advancing technical fields.

Finding 3-8. Sequestration, furlough, pay freezes, and limitations on travel, among other factors, have hampered the ability of AFIT and NPS to provide the required educational experience needed by its students, particularly its uniformed students. Further, it is vitally important for faculty and students at these institutions to be able to attend scientific conferences to present research to their peers, network, receive feedback, and remain current. To this end, the Services would be well served to implement DoD Conference Guidance Version 2.0, dated November 6, 2013, from the Office of the Deputy Chief Management Office that states that for

[44] NRC, *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce,* The National Academies Press, Washington, D.C., 2012.

[45] Ibid., p. 83.

[46] Ibid., p. 7.

[47] Office of the Deputy Chief Management Officer, "DoD Conference Policies and Controls," available at http://dcmo.defense.gov/products-and-services/conference-policies-controls/, accessed April 17, 2014.

most conferences, "approval authority at their discretion to General Officers/Flag Officers/Senior Executive Service members in their organization."[48]

Finding 3-9. When viewed from a total value perspective, DoD's graduate STEM+M enterprise is a tremendous asset to the respective Services, DoD, and the nation. Because the Services and DoD are the consumers, research, cultural benefits, and a clear value proposition could be employed for the students in the oversight, management, and operation of these institutions, particularly in times of increasing budget constraints. One can argue that education is among the highest priorities for an investment in preparation for an uncertain future and, once neglected, is extremely difficult to remedy at almost any cost.

Recommendations 3-3. A senior-level panel should be formed composed of former senior military and Department of Defense (DoD) civilians with leadership experience in civilian educational institutions to recommend specific means to (1) remove or reduce the impediments cited in Finding 3-8; (2) advance the value of DoD science, technology, engineering, mathematics, and management (STEM+M) education institutions; and (3) assess the mission impact these impediments, and others that may develop, have on the STEM+M workforce. Such a panel should examine how the whole STEM+M education enterprise aligns programmatically and by research competencies with key DoD science and technology thrusts and make recommendations with regards to programs, people (faculty and students), and, especially, business processes.

CONCLUDING REMARKS

AFIT and NPS are quality educational institutions with relevant and robust research enterprises that enhance their educational missions. They are intellectual assets to their respective Services, DoD, and the nation. Their broader value proposition, as described in this chapter, deserves the recognition by and full support of DoD.

[48] DoD, Memorandum: Implementation of Updated Conference Oversight Requirements, November 6, 2013. For additional information, see http://dcmo.defense.gov/products-and-services/conference-policies-controls/DoD%20Conference%20Guidance%20-%206%20November%202013.pdf.

4

Alternative Ways to Ensure High-Quality Graduate Education Outcomes

INTRODUCTION

As discussed in the preceding chapters, the single most important way to ensure high-quality Department of Defense (DoD) graduate science, technology, engineering, mathematics, and management (STEM+M) education outcomes is to preserve a blended portfolio of education sources that includes the Air Force Institute of Technology (AFIT), the Naval Postgraduate School (NPS), other military education institutions, and civilian institutions. Chapter 3 describes the educational value proposition offered by AFIT and NPS. The first section of this chapter emphasizes the need for and benefits of graduate STEM+M education from civilian institutions.

GRADUATE EDUCATION AT CIVILIAN INSTITUTIONS

Historically, military Services have used a combination of Service schools and civilian universities to educate its officer corps. The Army, which does not have its own graduate STEM+M educational institution, primarily uses civilian universities for graduate officer education, although it does use NPS and AFIT for a portion of its officers. In each of the past 3 years, an average of approximately 210 U.S. Army personnel have been enrolled in these schools (see Table 3-2 in Chapter 3). The Navy and the Air Force rely primarily on their respective graduate schools for the majority of their STEM+M-related graduate officer education needs. However, both Services also use civilian universities graduate programs if, for example, a required degree program is not offered by their Service schools. Both AFIT and NPS are responsible for managing officers enrolled in civilian institutions. Graduates for each Service from fiscal year (FY) 2010 through 2013 are shown in Table 4-1.

The Navy uses civilian universities to cover specific areas not offered at NPS, such as facilities and ocean engineering, operational oceanography, petroleum management, Naval construction and engineering, and nuclear engineering. Almost all of the degrees are master's degrees, with Ph.D.s representing just over 1 percent of the total. The Air Force also uses civilian institutions in areas not covered at AFIT at the master's level in numbers similar to the Navy. However, the Air Force also sends a significant number of officers for Ph.D. programs to civilian

TABLE 4-1 Institutions That Have Conferred Degrees to SMART Scholars

Doctoral Degree Institutions		Master's Degree Institutions	
University of Florida	12	Georgia Institute of Technology	12
Georgia Institute of Technology	9	University of California, San Diego	12
Purdue University	8	Virginia Polytechnic Institute and State University	11
Texas A&M University	7	Stanford University	10
Virginia Polytechnic Institute and State University	7	Utah State University	8
Arizona State University	6	University of Central Florida	7
North Carolina State University	6	Brigham Young University	6
Pennsylvania State University	6	Columbia University	6
University of Central Florida	6	University of Florida	6
University of Michigan, Ann Arbor	6	University of Maryland, College Park	5
University of Washington	6	University of Utah	5
Auburn University, Main Campus	4	University of Wisconsin, Madison	5
Clemson University	4	Auburn University, Main Campus	4
Rensselaer Polytechnic Institute	4	Rensselaer Polytechnic Institute	4
University of California, Santa Barbara	4	Stevens Institute of Technology	4
University of Illinois, Urbana-Champaign	4	University of Michigan, Ann Arbor	4
University of Maryland, College Park	4	University of Pennsylvania	4
University of Texas, Austin	4	University of Texas, Austin	4
Vanderbilt University	4	Air Force Institute of Technology	3
Brigham Young University	3	Massachusetts Institute of Technology	3
Carnegie Mellon University	3	Pennsylvania State University	3
Massachusetts Institute of Technology	3	Purdue University	3
Naval Postgraduate School	3	San Diego State University	3
University of Connecticut	3	Texas A&M University	3
University of New Mexico, Main Campus	3	University of California, Berkeley	3
University of Wisconsin, Madison	3	University of Colorado, Boulder	3
		University of Illinois, Urbana-Champaign	3
		University of Kansas	3
		University of Southern California	3
		Worcester Polytechnic Institute	3

SOURCE: Laura Stubbs (Senior Executive Service), Director, S&T Initiatives and STEM Development Office, OASD(R&E)/Research Directorate, "SMART 101," presentation to the committee on November 8, 2013.

universities. In fact, the number of Air Force officers sponsored for doctoral education at civilian universities historically has exceeded that at AFIT. A significant number of these officers are slated for faculty positions at either AFIT or the Air Force Academy. Both institutions, as well as their respective Service academies, while valuing AFIT and NPS graduates on their faculties, seek to have faculty with backgrounds from a number of institutions. Indeed, most quality universities draw the vast majority of their faculty from numerous other quality universities to avoid becoming too ingrown.[1]

Civilian universities play an important part in educating military officers from all Services. Even though the Navy and the Air Force operate their own graduate schools, they rely on civilian schools to provide quality education, particularly in areas not covered by DoD institutions; in the case of the Air Force, civilian schools provide a breadth of background for faculty at both AFIT and the Air Force Academy.

Finding 4-1. Quality civilian universities are a valuable source of STEM+M graduate education for all civilian and military DoD employees. For officers, they provide education in disciplines not covered by AFIT and NPS, as well as education for prospective military faculty at AFIT, NPS, and the Service academies. Because few DoD civilians attend AFIT or NPS, civilian universities are essential for their graduate education. DoD would be well served to continue to rely heavily on civilian institutions for its graduate STEM+M education needs.

Recommendation 4-1. The Department of Defense should continue and expand support for science, technology, engineering, mathematics, and management graduate education of its officers and civilian employees at civilian universities.

[1] The symbiotic link described between AFIT, NPS, and their respective Service academies led the committee to consider the possibility of integrating these institutions, much like the way the vast majority of public and private civilian universities operate. This option was posed to speakers and debated during committee meetings. The overwhelming majority of those asked argued against combining the institutions out of concern that appending a graduate school focused on research and education would potentially compromise the unique training and education mission of the academies. Therefore, the committee did not seriously consider this option. Conversely, university faculty members liked the idea of graduate-level-only institutions and the corresponding reduction/increase in their teaching/research responsibilities. However, they pointed out that undergraduate programs typically subsidize graduate programs, which in many cases are money-losing propositions. AFIT and NPS are subsidized by Service budgets.

AIR FORCE INSTITUTE OF TECHNOLOGY AND NAVAL POSTGRADUATE SCHOOL COLLABORATIONS

The Navy and Air Force established an alliance between NPS and AFIT via a memorandum of agreement dated December 4, 2002.[2] The goals of the alliance, as stated in the agreement, were as follows:

> It will:
>
> - Ensure officers continue to receive high-quality, relevant, and responsive graduate education aligned to defense needs,
> - Prevent unnecessary duplication, while sustaining excellence at NPS and AFIT,
> - Ensure efficient operation of both institutions, while maintaining each as a "world-class" higher education institution underpinned by its unique Service heritage and character,
> - In combination, provide a Joint educational environment in which officers from all of the Services will engage in education and research programs.

The alliance was to be overseen by the NPS Board of Advisors and the Air University's Board of Visitors (BOV). The agreement suggested that, over time, these two boards might be replaced by a single BOV that could serve as the governing board for both NPS and AFIT. The agreement further stipulated that, as initial actions, NPS would terminate its aeronautical engineering curriculum in favor of sending officers to AFIT's program, and that AFIT would terminate its meteorology and acquisition (management) curricula and send the students to NPS. These joint curricula were to be overseen by joint oversight boards, each headed by a general officer of the Service losing the program.

The 2002 agreement also stated that the Air Force and the Navy should, after seats were filled at either NPS or AFIT in a particular field of study, give priority to sending their students to the other institution before sending those students to civilian universities.[3] To implement this policy, AFIT and NPS, in coordination with the staffs of the other Services, to include the Marine Corps, Army, and Coast Guard, were directed to form a joint admissions and quota control process.[4] Following establishment of the agreement, NPS and AFIT closed the designated programs and began sending students to the other school. Joint oversight boards were formed and met to ensure that transitioned curricula met Service needs, and the superintendent (later, president) of NPS was added to the Air University (AU) BOV and the commander of AU (later, the AU president) became a member of the NPS BOV. The suggestion in the agreement that these two boards might merge at

[2] Memorandum of Agreement Forming an Educational Alliance between the Department of the Navy and the Department of the Air Force, December 4, 2002.

[3] Ibid.

[4] Ibid.

a future date did not happen. Further, it appears that the Air Force gave priority to sending students to NPS in areas such as foreign area studies and business, where NPS offered curricula and AFIT did not. Whether a joint admission and quota control process involving all Services was formed is not clear. In the committee's discussions with both the Navy and Air Force personnel responsible for the quota process within their respective Services, neither mentioned any interaction with the other Services in determining their quotas.

In 2004, 2 years after the agreement was signed, AFIT had 47 Navy students enrolled in its master's program in aeronautical engineering, and NPS had 87 Air Force students enrolled in a variety of programs, including 76 master's students in STEM+M programs. Despite initially positive trends, other than initial actions both schools took to close programs at AFIT and NPS, it appears little was accomplished to complete the goals of the alliance. Oversight of the alliance, which was to come from the AU BOV and the NPS BOV, was ineffective in moving the alliance along. Establishing a successful alliance may have been difficult under the best of conditions, but it is important to note that the difference in the institutional nature of AFIT and NPS certainly made it more difficult. That is, as was mentioned in Chapter 3, NPS is a stand-alone institution, while AFIT is considered by AU, and governed, as a college of AU. Thus, responsibility and authority for oversight of the alliance was vested with AU, not AFIT. In effect, the alliance was between AU and NPS. Many argue that the inability of AFIT and NPS to work as equal partners impaired the alliance from its start.

In 2005, the Base Realignment and Closure (BRAC) Commission considered options of privatizing or realigning (combining at one location) AFIT and NPS. The commission, in rejecting the options to privatize or combine the institutions, noted that "such actions could potentially degrade the military value of both institutions and the quality of their program graduates."[5] The commission also discussed the alliance between AFIT and NPS, stating:

> The Commission finds that, under its present charter, the joint service Educational Alliance has no authority to impose change regardless of the findings of its study groups. As a result, the tough issues mentioned above that could result in significant savings and improvement remain unaddressed. The Commission believes that rather than continuing as two schools focused on individual service needs, they can and need to be transformed into a joint program with two schools working together to meet joint needs. The Commission finds that an empowered Board free from individual service branch and school institutional pressures could address issues facing the schools and provide the non-service focused direction needed to transform the Naval Postgraduate School and Air Force Institute of Technology into a truly joint system of education.

[5] Defense Base Closure and Realignment Commission, *2005 Defense Base Closure and Realignment Commission Report*, Vol. I, submitted to President George W. Bush on September 8, 2005, http://www.brac.gov/docs/final/Volume1BRACReport.pdf, pp. 188-189.

The BRAC Commission then recommended the creation of

> A new and permanent oversight board responsible for curriculum review and approval, and program development for the resident and non-resident degree-granting programs at both schools. This Board, consisting of an equal number of members from the governing boards of each school, civilian education authorities recommended by the U.S. Secretary of Education, and other education officials as designated by the Secretary of Defense, will be chartered by the office of the Secretary of Defense and will provide a formal report of its actions and accomplishments to that office bi-annually. The Board's duties will consist of those actions listed as "Goals" in the Memorandum of Agreement that formed an Educational Alliance between the Secretaries of the Air Force and Navy on December 4, 2002. This Board will be located in the National Capital Region. By this recommendation, the newly formed board will also have the authority to:
>
> - Take action to eliminate unnecessary curricula and program duplication;
> - Identify, approve, and implement programs of collaboration in research and instruction between the schools; and,
> - Expand nonresident programs and arrangements with private institutions of higher learning to meet common curriculum and non-Department of Defense focused class requirements.[6]

During visits to NPS and AFIT, there was little evidence of a working alliance between the schools, or of the oversight board required by the BRAC recommendation. Each school indicated interactions with the other, primarily in research, but there was no indication that it was due to any formal alliance. Neither institution appears to have reinstituted programs that were moved as part of the agreement, but the Navy's requirements in aeronautical engineering have dropped dramatically: only four (two in aeronautical engineering) Navy students were enrolled at AFIT in 2013. In contrast, 112 Air Force students were enrolled at NPS in 2013. The administrations of both institutions were aware of the dramatic change in student numbers but did not offer explanations. They also stated that the alliance had received little attention for a number of years. Both schools also mentioned they were addressing the issue and had been meeting with the goal of revitalizing the alliance but offered no vision of what they hoped to accomplish or of any concrete progress.

Finding 4-2. The effectiveness and efficiency of AFIT and NPS can be increased by significantly enhanced collaboration and building on the strengths of the two organizations. This was recognized by the Air Force and Navy in the December 4, 2002, memorandum of agreement "Forming an Educational Alliance between the

[6] Ibid., p. 189; also Appendix Q, Sec. 197, p. Q-96.

Department of the Navy and the Department of the Air Force" and also by the findings and recommendation of the 2005 BRAC Commission, which called for establishing a "permanent oversight board responsible for curriculum review and approval, and program development for the resident and non-resident degree-granting programs at both schools,"[7] which would be chartered by the Office of the Secretary of Defense and have substantial authority.

Recommendation 4-2. The Department of Defense should implement the recommendation of the 2005 Defense Base Closure and Realignment Commission (Appendix Q, Section 197) to establish an empowered oversight board for the Air Force Institute of Technology and the Naval Postgraduate School, reporting to the Office of the Secretary of Defense.

Collaborations with Civilian Institutions

AFIT, the University of Dayton (UD), and Wright State University (WSU) formed the Dayton Area Graduate Studies Institute (DAGSI) in 1995 to provide master's- and doctoral-level students at each institution, with access to engineering and computer science courses of study offered at any partner school.[8] A student entering one of these institutions can apply for a DAGSI scholarship, is encouraged to cross-register for courses at one of the other partners, and may get involved in collaborative research with other institutions. Table 4-2 provides data on the courses taken by AFIT and non-AFIT studies as part of DAGSI starting in academic year 2008.

According to the DAGSI website: "All DAGSI students are graduate-level and must be degree-seeking"[9] and "DAGSI itself is not a degree-granting institution. Each graduate engineering student is enrolled at and will receive a degree from one partner institution, AFIT, UD, or WSU, referred to as the home institution. Each partner is fully accredited in its M.S. and Ph.D. programs."[10] Broad guidelines are given in part as follows:[11]

- Each DAGSI student must meet all requirements of the Home Institution that would pertain to any other graduate student enrolled in a similar program.
- Each DAGSI student must complete at least 50 percent of the courses in his or her approved program of study at the Home Institution.

[7] Memorandum of Agreement, 2002.
[8] For additional information, see the DAGSI website at http://www.dagsi.org/index.html, accessed April 22, 2014.
[9] DAGSI, "General Program Information," http://www.dagsi.org/, accessed February 14, 2014.
[10] DAGSI, "General Program Information," accessed February 14, 2014.
[11] DAGSI, "General Program Information," accessed February 14, 2014.

TABLE 4-2 Graduates of Civilian Universities via Air Force Institute of Technology and Naval Postgraduate School Civilian Institutions Programs

	FY2010		FY2011		FY2012		FY2013	
	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.
Air Force	72	32	65	26	72	29	68	28
Navy	71	1	71	0	68	1	73	1
Total	143	33	136	26	140	30	141	29

NOTE: The civilian institutes over this time period awarding the largest number of Ph.D. degrees are the Naval Postgraduate School, the Massachusetts Institute of Technology, the University of Washington, and Rice University. AFIT counts NPS as a civilian institute. FY, fiscal year.
SOURCE: Data from the Air Force Institute of Technology and the Naval Postgraduate School.

- Thesis or dissertation credits always will be taken at the Home Institution, and the chairperson or principal advisor of the DAGSI student's advisory committee will be appointed from the faculty of the Home Institution. However, any member of the graduate faculty of DAGSI's partner institutions may be appointed as a full voting member to a thesis or dissertation committee.

Evidently, participation in DAGSI enhances both AFIT's capacity and its range of capabilities. It also strengthens ties between Wright-Patterson Air Force Base (AFB) and the Dayton community.

AFIT also has agreements with the University of New Mexico (UNM) and Loyola Marymount University, according to its website.[12] UNM has had a long history of providing Kirtland AFB personnel with quality STEM+M graduate education degrees. AFIT and UNM signed an agreement that encouraged each university to offer programs with up to one-half of the course credits coming from the other school. The first program offered under those provisions was a UNM M.S. in electrical engineering, which contained 16 credit hours of systems engineering course work from AFIT (offered through distance learning). NPS also has agreements with other universities. It is unclear to what extent any of these agreements, aside from DAGSI, are used by either institution.

Objectively, AFIT and NPS are small institutions with limited capacity and single geographic locations. Partnerships with other capable universities would allow them to better serve military personnel who have educational requirements that cannot be met at AFIT and NPS or who are unable to attend classes on the AFIT or NPS campuses. University partnerships might complement collaborations

[12] For additional information, see Air Force Institute of Technology, "Distance Learning Programs," http://www.afit.edu/en/dl/distancelearning.cfm?a=programs, accessed February 13, 2014.

with DoD laboratories located far from AFIT and NPS but close to local universities, as discussed in the next section. Such partnerships might leverage both schools' distance learning capabilities, also discussed in this chapter. For instance, one could imagine a graduate program in high-power microwaves delivered in partnership by AFIT and UNM, with some or all of the AFIT courses delivered by distance learning and the thesis research performed at the Air Force Research Laboratory (AFRL) at Kirtland AFB.

Finding 4-3. AFIT effectively uses its partnership with universities in Dayton, Ohio, to enhance its capacity and capabilities. Both AFIT and NPS have partnerships with other universities, but little evidence has been offered that they are used extensively.

Recommendation 4-3. The Air Force Institute of Technology and the Naval Postgraduate School should establish and use a limited number of partnerships with quality universities located near Department of Defense (DoD) installations or that otherwise possess unique partnering benefits. They should leverage distance learning tools and methods to exploit these partnerships, and in conjunction with DoD laboratories, provide a wider range of quality degrees that are available at remote locations (i.e., not Dayton or Monterey) and accessible to additional military personnel.

Collaborations with Department of Defense Laboratories

AFIT and NPS have, as part of DoD, the advantage of access to a wide variety of excellent DoD laboratories. The variety and quality of these facilities represents an opportunity to enhance the research at the schools and increase their outreach to the larger DoD community. AFIT takes great advantage of the AFRL laboratories at Wright-Patterson AFB, and to lesser extent AFRL laboratories at other locations, most notably the high-energy laser facilities at Kirtland AFB. NPS appears to take little advantage of other Naval laboratory facilities. Conducting thesis research at DoD and, conceivably, other laboratories could enhance degree quality in some disciplines while increasing AFIT and NPS capacity. To the extent students are able to perform thesis research in the locale to which they would next be assigned, the quality of the research and the impact of the student in his or her assignment would be enhanced. Recent Rand Corporation studies emphasized the value to the Air Force and Navy of promptly using officers newly graduated with advanced STEM+M degrees.[13,14]

Finding 4-4. AFIT effectively uses the Wright-Patterson AFB component of AFRL to strengthen its graduate education program, employing its experimental facilities for thesis research and its technical staff as adjunct professors. AFIT's collaborations with other components of AFRL, however, are not as robust. Finally, it appears that NPS does not significantly collaborate with DoD laboratories.

Recommendation 4-4. The Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS) should permit their graduate students to conduct thesis research at Department of Defense laboratories and other suitable locations when doing so provides a quality education. AFIT and NPS should also involve adjunct professors drawn from those organizations to help guide and supervise graduate students. Effective distance learning tools and methods should be leveraged to reduce costs and enhance the education experience.

DISTANCE LEARNING

The terms of reference for this study specifically ask for "the ability of private[15] non-Department of Defense institutions or *distance-learning programs* to meet the needs identified" [emphasis added] (see Appendix A). In addition to non-DoD institutions, distance-learning (DL) programs within the military, specifically at AFIT and NPS, were examined, including the ability of these programs to contribute to meeting identified educational needs.

Distance learning is, of course, not a new topic; "correspondence courses" date back to the early 1700s. Both computer-aided instruction and educational video started in the 1960s. But the pace of adoption of DL has exploded in the past decade with the rise of Internet-based education and the continued pressures to meet the needs of more students, more efficiently and more effectively. There is no generally accepted taxonomy of DL strategies and methods, and there is a wide range of practice. Box 4-1 provides two examples to illustrate the diversity of DL.

[13] T.L. Terry, A.A. Robbert, J.E. Boon, Jr., P. Shameem Firoz, and S.C. Moore, *A Methodology for Determining Air Force Education Requirements Board (AFERB) Advanced Academic Degree (AAD) Requirements,* RAND Corporation, Santa Monica, Calif., http://www.rand.org/pubs.html, 2013.

[14] K.N. Kamarck, H.J. Thie, M. Adelson, and H. Krull, "Evaluating Navy's Funded Graduate Education Program," monograph, RAND Corporation, Santa Monica, Calif., http://www.rand.org/pubs.html, 2010.

[15] "Private" is interpreted to mean both public and private civilian institutions, as opposed to those institutions maintained by DoD, such as the Naval Postgraduate School and the Air Force Institute of Technology.

BOX 4-1 Examples of Distance Learning

Example 1: A remote student participates in a live class via video link.

This style of distance learning is:

- *Synchronous*—happening live, in real time, with the interaction with other students and the professor.
- *Blended*—a mix of students taking the whole course in person, and other students taking the whole course by distance.
- *Relatively low technology*—no special preparation tasks for the professor.

Example 2: A student participates via a MOOC (Massively Open Online Course) with fully automated computer-based instruction.

This style is:

- *Asynchronous*—students able to take the course at their own schedule.
- *High technology*—considerable effort given to preparing courseware, setting up automated grading and assessment, perhaps creating forums for class discussions.

Other possibilities include the following:

- *Hybrid*—the entire class meets in person one or more times, for example, at the beginning to form a cohort and start the class. The rest of the class proceeds by distance.
- *Flipped*—asynchronous technology for students to watch lectures and otherwise prepare before class, with in-person class time used for collaborative problem-solving.
- *Computer-based tutoring*—the Open Learning Initiative (OLI) at Carnegie Mellon University[1] has built tutors that model the cognitive processes of the students. If the student gets a particular wrong answer, the OLI tutors know at which step of the problem the student made an error, and can provide more examples of that particular step.

[1] M. Lovett, O. Meyer, and C. Thille, The Open Learning Initiative: Measuring the effectiveness of the OLI statistics course in accelerating student learning, *Journal of Interactive Media in Education,* May 2008.

A DL course designer need not always pick a single alternative; often, the course delivery uses a mixture of methods. For example, a student taking a blended course in person may refer to the online archive to review the lecture later; a live professor may use very sophisticated technology to illustrate particular points; and students in a hybrid class may meet with each other in small cohorts between the in-person meetings of the entire class.

There is no single format that creates the "best" DL experience. Synchronous courses are the closest to an in-person experience; but the convenience of an asynchronous format may make it easier for a student to complete the course. Personal interaction with a professor or teaching assistant works best for some students; others prefer the anonymity (and patience!) of a computer tutoring interface. The field continues to evolve rapidly. However, the key to any distance program, as in any educational program, is assessment: How do individual students receive feedback on their learning and guidance on how to improve? How does the course designer receive feedback on the progress of the students and guidance on how to improve the course?

Massively Open Online Courses (MOOCs), in particular, have received an increasing amount of attention, both for their potential to reach more students at a reduced cost, and for the level of effort that will be required to ensure quality. For example, the President's Council of Advisors on Science and Technology released a letter to the President in December 2013 on MOOCS.[16] In their judgment:

> To be truly successful in promoting both expansion of access and improvement in the quality of education, the MOOCs and their relatives will need to (1) employ excellent technology, (2) foster excellent pedagogy, (3) apply the results of learning science, (4) deploy new techniques of big data analysis to provide rapid feedback to teachers and learners, and (5) cultivate an online social ecosystem to enhance peer-to-peer learning and teaching. Although the jury is out, and there are legitimate reasons to be skeptical, PCAST believes that all of these conditions for success can potentially be met.[17]

In a distance setting, assessment of an individual student is somewhat more complicated than in person. For a formal credit-bearing course, it is important to ensure that the student is the one doing the work, turning in assignments, and taking the tests. A small cottage industry has sprung up of testing centers, conveniently located near where students live, that will check the students' identification and proctor exams. More generally, the feedback the student receives may be the same as in a classroom (papers graded by the instructor or graders), through interactions with other students (peer assessment), or fully automated (computer-based testing).

Assessment feedback to the professor takes several forms and may consider the following questions: Have the students achieved their learning objectives? What percentage of students actually completes the course? What are the most difficult parts of the course for them? These are the same questions for a traditional in-person course, but the remedies for any difficulties uncovered may be much different. Given proper assessment and careful course design, the literature supports claims that distance education can be as effective as in-person education. Studies

[16] Executive Office of the President, President's Council of Advisors on Science and Technology (PCAST), "Letter Report on Education Technology," December 2013, http://www.whitehouse.gov/administration/eop/ostp/pcast/docsreports.

[17] Executive Office of the President, PCAST, "Letter Report on Education Technology," 2013.

such as Means et al.,[18] which surveyed 1,000 independent studies, find that blended, hybrid, and online learning can all be as effective as face-to-face instruction.[19,20,21,22]

Both AFIT and NPS offer courses by distance. From 2005 to 2013, the average on-board enrollment in NPS DL STEM programs rose steadily from 227 to 662. Similarly, the enrollment in NPS DL management programs increased from 240 to 342. The DL programs offer degrees in 7 fields of information science, 11 engineering disciplines, and 6 specialties in management. Over the past 5 years, 1,524 DL degrees have been conferred in STEM+M. Some of the DL students working on degrees from NPS have the advantages of cohorts of students working together, with synchronous interactions with the faculty. Navy sites at China Lake and Point Mugu in California and in Patuxent River, Maryland, all have enough distance students to have cohorts of students and visits from faculty in a "hybrid" distance model. Other students, such as those deployed on submarines, can work asynchronously, with the courses sent to them ahead of time on compact disk or made downloadable over the Internet. However, studies show that under these circumstances, degree completion is more difficult, and the dropout rate is higher.

NPS spends significant effort to enable its distance cohorts to succeed. It reports that there is more variation cohort-to-cohort than distance-to-residential. AFIT also offers master's degrees by distance, but on a much smaller scale. Over the past 4 years, it averaged 14 new students enrolled in distance education M.S. degrees each year. Both NPS and AFIT offer many non-credit distance courses for certificates or for continuing education. While those courses are beyond the scope of this study, they do provide evidence of economies of scale for building the in-house capabilities (human and equipment) for distance education.

As implied by the above examples, distance education is better used in some settings than in others. Course-based master's degrees or professional master's degrees (discussed at the end of this chapter) are more easily delivered by distance than are thesis-based or research-based degrees. A research-based degree may take special efforts to find a way to supervise and evaluate the research remotely;

---

[18] U.S. Department of Education, Office of Planning, Evaluation, and Policy Development, *Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies,* Washington, D.C., 2010.

[19] W.G. Bowen, M.M. Chingos, K.L. Lack, and T.I. Nygren, *Interactive Learning Online at Public Universities: Evidence from Randomized Trials,* ITHAKA S+R, New York, N.Y, May 22, 2012.

[20] I.E. Allen and J. Seaman, *Changing Course: Ten Years of Tracking Online Education in the United States*, Babson Survey Research Group and Quahog Research Group, LLC, January 2013.

[21] J. Beckem and M. Watkins, Bringing life to learning: Immersive experiential learning simulations for online and blended courses, *Journal of Asynchronous Learning Networks* 16(5):61-70, 2012.

[22] N. Xiaopeng, S.S. Diomede, and S.R. Rutland, Effects of using the quality matters (QM) programme as an intervention for online education. *International Journal of Social Media and Interactive Learning Environments* 1(1):93-105, 2013.

although, as discussed earlier, research performed at DoD laboratories is a viable option. Any organization offering distance education would, ideally, stay current on new developments in distance technology and techniques. For example, Georgia Institute of Technology's recently announced M.S. in computer science, borrowing tools from the MOOCs, is an experiment that will inform the whole distance education community on what works and what needs refinement in reaching hundreds of M.S. students.[23] Carnegie Mellon University's OLI pushes further into intelligent interactive tutoring software.[24] It is not clear yet how these tools will evolve. All that can be said for certain is that more change is coming, and AFIT and NPS will need to stay alert to make sure they have access to the best methods as they develop. AFIT and NPS understand this context and already provide quality DL programs.

Finding 4-5. Distance education is rapidly expanding in the number of courses offered and in the quality of education provided. NPS has successfully taught many of its degree programs by distance education; AFIT has offered more certificate programs and fewer degree programs. Increased use of distance courses will offer much more flexibility to DoD personnel to attain advanced degrees, especially for those unable to relocate to AFIT or NPS.

Recommendation 4-5. The Department of Defense (DoD) should increase the use of distance education for science, technology, engineering, mathematics, and management degrees. Specifically, the Air Force should invest in converting some Air Force Institute of Technology (AFIT) M.S. degrees to be offered by distance learning, face-to-face, or any of the varieties of blended and hybrid delivery. In addition, AFIT and the Naval Postgraduate School (NPS) should consider offering joint degrees, or joint courses, taught in person on one campus and by distance learning on the other. Finally, NPS and AFIT should use distance offerings to enable their students to be in residence at one of the DoD laboratories for their research while taking courses from their home universities.

MILITARY TUITION ASSISTANCE

Military tuition assistance is designed for military personnel, which is administered slightly differently by each Service, pays for part-time education for those not selected to attend one of the full-time sponsored education programs. The bulk of military tuition assistance funds go to enlisted men and women for completing undergraduate degrees. In FY2012, 538,000 people (Service members and their families) participated in the Voluntary Education Program, resulting in the award

[23] For additional information, see http://www.omscs.gatech.edu/, accessed March 19, 2014.
[24] For additional information, see http://oli.cmu.edu/, accessed March 19, 2014.

of 33,000 associate degrees, 9,600 bachelor's degrees, 5,800 master's degrees, and 27 doctorates.

There are many advantages to military tuition assistance for graduate education. For example, military tuition assistance is an employee benefit, paying for education and therefore attracting and retaining military personnel who want to further their education. It is also a way to fund a master's degree for those who wish to become career officers. It appears to be the practice, although not a stated requirement, that military officer promotion to field grade rank requires a master's degree (often funded by military tuition assistance), without any specification of degree subject. Finally, military tuition assistance provides an avenue for education for those who cannot be selected for full-time study because of their specialty—e.g., pilots who cannot leave their flying career for a year for full-time study.

There are three major drawbacks to military tuition assistance, as currently configured. First, the limited funds available per course (currently $250 per semester credit hour) are much less than the tuition charged by top-ranked programs, whether from private or public institutions. This encourages military personnel on limited budgets to pursue lower-cost alternatives, which are not usually the best programs. Second, military tuition assistance does not align tuition benefits with military needs. There is no incentive given to officers to complete a graduate degree in a field that would benefit the Services. Of course, any ongoing study produces a better-educated individual. But, if DoD needs more STEM+M-educated officers, there is no military tuition assistance mechanism to encourage STEM+M programs. Third, AFIT and NPS can accept military tuition assistance funds but cannot retain them and, therefore, are unable to support students using military tuition assistance funds. As long as military tuition assistance is considered a benefit, those courses are not viewed as "job related" and therefore fall outside the scope of the charters of AFIT and NPS. Without access to the Services' graduate schools, students' access to classes that are tailored to military needs, use military-relevant examples, and are taught by military faculty is limited. This combination of drawbacks creates a large gap between the education of those using military tuition assistance and of those selected for full-time sponsored study at AFIT, NPS, or a civilian institution.

A modest change to military tuition assistance procedures could yield great benefits for the military, as well as for military personnel seeking STEM graduate degrees. It would start by defining a set of fields of study that are most relevant to the military. These would certainly include STEM+M fields, but may also include foreign affairs and other areas. The program would then create a category of "Priority Military Tuition Assistance" for those fields. For the Priority Military Tuition Assistance areas, the program would (1) increase the tuition amount per credit hour; (2) encourage, where possible, cohorts of students to take the same program together; (3) provide, as needed and feasible, high-bandwidth Internet connections that enable high-quality interaction for distance courses; (4) encourage, where possible, release time for students to take courses synchronously or at a minimum to keep pace with their classmates weekly; (5) allow military tuition assistance funds to be used at AFIT and NPS, and give AFIT and NPS incentive to compete for those resources and students; and (6) assess the achievements of the students during their study, and their contributions to DoD over their careers.

These changes to military tuition assistance would more closely align the military with the best practice of leading corporations. United Technologies (UT), for instance, has for more than a decade paid for any accredited degree program taken by its employees.[25] UT supervisors counsel employees on which degrees will enhance their career paths. Employees receive a tax break if the degree matches their job assignment, although they are allowed to study other areas if they prefer. UT allows the employees release time to attend classes. For example, an employee taking a 3-credit-hour course is automatically allowed 3 hours release time per week. UT reports that the employees taking advantage of this program have a 15 percent higher retention rate than employees across the company as a whole.

Finding 4-6. Military tuition assistance is a highly valuable military benefit. DoD spends some $560 million per year to support students under military tuition assistance, including nearly 5,800 master's degree students. Although data are not available on what percentage of these students are active-duty officers seeking STEM+M degrees, it seems likely that this percentage is small. Encouraging more of these officer students to seek STEM degrees could help significantly to reduce DoD's need for more STEM+M officers.

Recommendation 4-6. The Department of Defense (DoD) should create a new category of Priority Military Tuition Assistance for science, technology, engineering, mathematics, and management graduate education and do the following:

- Significantly increase the maximum tuition payment per credit hour.
- Encourage, where possible, cohorts of students to take the same program together.

[25] Michael Winter, Chief Engineer for Technology, Pratt & Whitney, United Technologies Corporation, "United Technologies' Approach to Graduate Education Needs," presentation to the committee on December 5, 2013.

- Provide, as feasible, high-bandwidth connections to enable high-quality interaction for those courses.
- Encourage, where possible, release time for students to take courses synchronously or at a minimum to keep pace with their classmates weekly.
- Allow military tuition assistance funds to be used at the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS), to allow access to those courses and to give AFIT and NPS an incentive to compete for those resources and students.
- Assess the achievements of the students during their study and their contributions to DoD over their careers (see Figure 3-2 and associated discussions in Chapter 3).

This present large gap between the education of those using military tuition assistance and of those selected for full-time sponsored study could be reduced significantly by these actions.

COMPETITIVELY SELECTED EDUCATION AT CIVILIAN INSTITUTIONS

As described in previous chapters, civilian graduate education programs appear to receive less funds and management attention than programs for the military, at least at the strategic level. This section outlines two existing funding programs designed for civilian education—the Science, Mathematics, and Research for Transformation (SMART) program and the "Section 852" funds—and discusses the possibility of achieving cost savings and therefore expanding the candidate pool through tuition negotiation.

Science, Mathematics, and Research for Transformation Program

The SMART program is particularly effective for attracting and developing civilian STEM talent within DoD. SMART enables students pursuing graduate or undergraduate degrees in STEM disciplines to receive a full scholarship (tuition, living expenses, book allowances, summer internships, health insurance, and other benefits) and be gainfully employed after degree completion. Upon selection, awardees are assigned to a DoD organization where they serve as a paid summer intern and later complete a 1-year period of post-graduation employment as a DOD civilian. The retention rate following completion of the service agreement is a very respectable 82 percent.[26]

[26] Laura Stubbs (Senior Executive Service), Director, S&T Initiatives and STEM Development Office, OASD(R&E)/Research Directorate, "SMART 101," presentation to the committee on November 8, 2013.

TABLE 4-3 Courses Taken by Air Force Institute of Technology (AFIT) and Non-AFIT Students as Part of the Dayton Area Graduate Studies Institute (AY2008-AY2013)

	AY2008	AY2009	AY2010	AY2011	AY2012	AY2013	Total
AFIT student courses taken at other institutions	61	48	23	13	3	7	155
AFIT courses taken by students from other institutions	17	27	25	7	2	0	78

NOTE: The numbers reflect the total number of courses taken. In other words, if one AFIT student took three different courses in 2012, that would account for the "3" in the first row in table. By that same token, if there were two non-AFIT students who took one AFIT course in 2012, that would be reflected by the "2" in the second row of table. AY, academic year.
SOURCE: Data from the Air Force Institute of Technology.

Over the past 9 years, SMART has supported 1,456 students in aeronautical and astronautical engineering; biosciences; chemical engineering; chemistry; civil engineering; cognitive, neural, and behavioral sciences; computer and computational sciences; electrical engineering; geosciences; industrial and systems engineering; information sciences; materials science and engineering; mathematics; mechanical engineering; naval architecture; ocean engineering; nuclear engineering; oceanography; operations research; and physics. Of these, 348 were master's degree students, and 462 were Ph.D. students. Students attend a range of quality graduate schools.[27] Table 4-3 provides the number of graduate degrees conferred under the SMART program.

The fact that graduation rates for SMART graduate students average about 94 percent, far higher than national averages, testifies to the quality and determination of these students. These numbers appear to be limited by budgets, not demand. Both prospective and current DoD employees are eligible for SMART, although only about 12 percent are the latter. Not surprisingly, 90 percent of current DoD employees enrolling in SMART are seeking graduate degrees. Thus, SMART also serves as an effective means for retaining and enhancing the contributions of many of the best DoD scientists and engineers. The 2012 National Research Council report recommended:

> DoD should continue as well as expand broadly available scholarship programs (such as SMART) that are aimed at improving the quality of its current and potential employees

[27] Ibid.

> and are tied to a commitment to service. We believe this action would be valued by the employee and would demonstrate the priority DoD places on the employee.[28]

Recently, though, some DoD laboratories have been slow to place SMART graduates to whom they have made prior commitments. Such behavior wastes money, does not show that employees are valued, and calls into question DoD's ability to honor commitments. The SMART program is small in size but provides a stream of well-qualified scientists and engineers with up-to-date knowledge and skills. Continuity of purpose is essential for its success.

Finding 4-7. SMART is achieving the purpose outlined for it in USC Title 10 Section 2192a. It offers full scholarships and post-degree employment in DoD laboratories to well-qualified, competitively selected students pursuing undergraduate or graduate degrees in STEM disciplines. SMART graduation and retention rates are high compared to national averages.

Recommendation 4-7. The Department of Defense (DoD) should continue and expand support for the Science, Mathematics, and Research for Transformation (SMART) program and should provide a blanket exemption to current and future hiring freezes, as well as placement priority, to ensure SMART graduates are placed promptly and effectively employed. Furthermore, DoD should ensure the candidate selection process continues to be conducted on a competitive basis.

Funding for Civilian Graduate STEM Education

Several factors limit DoD's ability to provide graduate education opportunities for its civilian STEM workforce. Not surprisingly in today's budget-constrained environment, one of the limiting factors is funding, both in terms of amount and predictability. This issue has been pointed out in previous studies[29] and has been addressed by DoD for its acquisition workforce through the use of Defense Acquisition Workforce Development Funds (DAWDF), also called "Section 852" funds.[30]

DAWDF are used to ensure DoD's acquisition civilian workforce has the capacity, in both personnel and skills, needed to properly perform its mission, provide

[28] National Research Council (NRC), *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce,* The National Academies Press, Washington, D.C., 2012. This committee concurs with all related findings and recommendations (especially Recommendation 5 [p. 11], Finding 4.1 [p. 96], Recommendation 5.2 [p. 111], and Finding 6.4 [p. 117]). Relevant findings and recommendations from that study are reprinted in Appendix D of this report.

[29] Ibid.

[30] National Defense Authorization Act (NDAA) for Fiscal Year 20088, H.R. 4986, Section 852. DAWDF funding is multi-year money.

TABLE 4-4 Actual and Budgeted (Statutory) Defense Acquisition Workforce Development Fund (DAWDF) Profiles (millions of dollars)

	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
Current Statutory Levels	500	800	700	600	500	400

NOTE: The Secretary of Defense may reduce an amount specified for a fiscal year (FY) if the secretary determines that the amount is greater than is reasonably needed for purposes of the fund for such fiscal year. The secretary may not reduce the amount for a fiscal year to an amount that is less than 80% of the amount otherwise specified (U.S. Code 1705). In FY2013 the amount credited to the fund was reduced to $400 million (80%) as allowed in the statute.

appropriate oversight of contractor performance, and ensure that the DoD receives the best value for expenditure of public resources (U.S. Code 1705). DAWDF are for the recruitment, training, education, and retention of DoD acquisition personnel. These funds can also be used for tuition assistance, long-term and full-time study, and back-filling positions behind students attending school and transitioning back after graduation. DAWDF is a critical enabler for the Defense Acquisition Workforce improvement strategy. The fund is managed by a senior official of DoD designated by the Under Secretary of Defense for Acquisition, Technology, and Logistics. Table 4-4 provides the current statutory DAWDF levels.

DAWDF can only be used on acquisition-coded positions across DoD. Qualified STEM personnel occupy some of these positions, but not all DoD civilian STEM personnel are acquisition-coded.[31] DoD and the Services have issued specific written policies regarding the management and usage of DAWDF. Reduced funding between FY2014 and FY2018 reflects the fact that original hiring initiatives are wrapping up and that education funds are under attack as DoD budgets are decreasing.[32]

Finding 4-8. DoD does a much better job of supporting the graduate education needs of its uniformed members than it does the graduate education needs of its civilian STEM workforce. This is true in terms of process, structure, opportunities, and funding. AFIT, NPS and many civilian institutions have the capacity to better support civilians. DoD needs to find a sufficient and predictable funding source for all STEM professionals.

[31] Discussions with a Service representative indicated that more than half of DoD's S&E community are on acquisition-coded positions and already have access to these funds.

[32] Defense Acquisition Workforce Development Funds (DAWDF) FY 2012 Annual Report to Congress, 10 U.S.C. 1705(f), April 2013.

Recommendation 4-8. The Department of Defense (DoD) should aggressively use Defense Acquisition Workforce Development Funds (DAWDF) for the existing covered science, technology, engineering, and mathematics (STEM) workforce members for graduate-level education through current long-term, full-time education provisions. Further, DoD should obtain authorization from Congress either to expand existing DAWDF to include all STEM workforce professionals or to obtain "DAWDF-like" funding, backfilling positions behind students attending school and supporting their transitioning back to their former jobs after graduation.

Negotiating Civilian Institution Tuition Costs

Because universities typically offer significant financial aid packages to their STEM Ph.D. students, the actual tuition rates these students pay are often substantially less than the published rates. It is estimated that DoD funds Ph.D. graduate education for hundreds of personnel at civilian universities each year at a cost of many tens of millions of dollars, not including salary and living costs.[33] Programs include the Air Force Civilian Institutions Program, managed by AFIT; students sponsored by military installations; and the graduate portion of SMART, described earlier in this chapter; as well as many local organizational programs (e.g., DoD laboratories). Additionally, it supports about 185 Ph.D. students not employed by DoD through the National Defense Science and Engineering Graduate Fellowship (NDSEG) program at an annual cost of almost $35 million.

In general, DoD pays published tuition rates. The U.S. Military Academy is a notable exception. It has negotiated tuition reductions averaging 50 percent with a number of leading universities. If DoD as a whole followed a similar practice, it might achieve substantial savings while not compromising the quality of graduate education. These savings could be used to educate additional DoD personnel at top-quality universities or to enhance the STEM capabilities of its members in other ways. An alternative approach is taken by the National Science Foundation (NSF), which provides a cost-of-education allowance of $12,000 to universities in lieu of tuition as part of its Graduate Research Fellowship Program.[34] Use of a flat rate eliminates the need for negotiation with numerous universities and avoids any perception of favoritism toward particular universities. The National Institutes of Health (NIH) employs a similar approach.[35]

[33] The committe was unable to obtain exact numbers.

[34] Graduate Research Fellowship Program (GREP) Program Solicitation, NSF 13-584, http://www.nsf.gov/pubs/2013/nsf13584/nsf13584.htm, accessed March 19, 2014.

[35] Ruth L. Kirschstein, National Research Service Award (NRSA) Stipends, Tuition/Fees and Other Budgetary Levels Effective for Fiscal Year 2012, NOT-OD-12-033, http://grants.nih.gov/grants/guide/notice-files/NOT-OD-12-033.html, accessed March 19, 2014.

Finding 4-9. Through the Civilian Institutions Program, NDSEG, SMART, and other graduate education programs, DoD provides both adequate stipends and full tuition for the graduate students it supports. In contrast, NSF and NIH provide adequate stipends at uniformly reduced tuition rates, which universities usually accept, for the Ph.D. students they support. West Point, NSF, and NIH have negotiated reduced tuition rates for Ph.D. students sent to civilian institutions. Adopting these practices across DoD would help the department stretch limited graduate education funds to support more graduate students.

Recommendation 4-9. The Department of Defense should provide a flat rate cost-of-education allowance to universities in lieu of tuition for Ph.D. students it supports, similar to allowances provided by the National Science Foundation and the National Institutes of Health.[36]

Professional Science and Engineering Master's Degrees

The Professional Science and Engineering Master's degree, hereafter called the Professional Science Master's (PSM) degree for consistency with standard terminology,[37] was developed in response to the need for broader technical talent for many science and engineering positions. It is designed to provide solid training in and understanding of science and the ability to communicate about science for professionals in industry, government, and advocacy organizations, providing the equivalent of an M.B.A. in science. Until about 20 years ago, this kind of career training was not available. Schools of engineering had, however, developed programs in engineering management, most often in collaboration with schools of business administration. What has been developed is the PSM, essentially management-trained professionals in science and engineering. The PSM is not the traditional master's degree in chemistry, physics, or biology, but rather programs that educate people to enter careers in management of science and technology programs, with the master's degree viewed as the terminal degree for the professional. Some PSM graduates do go on to the Ph.D., but the program is aimed at developing a scientist (and more recently, an engineer) for nonacademic settings, indeed, for the "real world."

The PSM was designed to address employer's needs for staff trained in the natural sciences at the master's degree level. The landscape of master's education was reviewed in a report published by the NRC in 2008. An important finding stated that:

[36] NSF, for instance, currently pays $12,000 per year.
[37] For additional information, see http://www.sciencemasters.com/, accessed January 28, 2014.

> These programs are attractive to students who want to work in nonacademic sectors, interdisciplinary careers, team-oriented environments, managerial or other professional level positions, or emerging areas of science and scientific discovery. They appeal to students who are seeking career advancement, are looking to gain a competitive edge, or are reentering the workforce in order to refine professional and technical skills.[38]

The report also showed that students and employers had increasingly found a master's education a valuable pursuit, with education at the master's level growing faster than other sectors of postsecondary education in the United States. In 1970-1971, higher education institutions had awarded 230,509 master's degrees, and by 2004-2005, a total of 574,618 master's degrees were awarded, an increase of approximately 150 per cent.[39] According to the National Center for Education Statistics, there were 730,635 master's degrees awarded for 2010-2011 and 754,229 master's degrees awarded for 2011-2012, the last year for available data.[40] In fact, the rate of growth of master's degrees has been significantly higher than for professional degrees in law, medicine, and dentistry.[41] Career-oriented fields now dominate master's degree programs, with the degree no longer considered an intermediate degree that follows the baccalaureate and preceeds the doctorate. Of course, this is also reflected in the emphases of both AFIT and NPS graduate programs.

The natural sciences have been more traditional with respect to the master's degree. However, the marketplace now demands workers with skills that include the following:

- Communication in writing,
- Making presentations,
- Contributing as members of interdisciplinary teams,
- Managing projects effectively,
- Understanding and working toward organizational goals,
- Understanding legal, regulatory, and international dimensions of science- and engineering-based work,
- Understanding the commercialization process and how to translate knowledge into product or process innovation, and
- Understanding and applying ethical considerations.[42]

[38] NRC, *Science Professionals: Master's Education for a Competitive World,* The National Academies Press, Washington, D.C., 2008.

[39] Ibid.

[40] National Center for Education Statistics. For additional information, see http://nces.ed.gov/programs/coe/indicator_cvc.asp, accessed May 8, 2014.

[41] NRC, *Science Professionals*, 2008.

[42] Ibid.

These new demands have changed the master's degree into a highly professional education with many opportunities. As noted in the 2008 NRC report, evolving science and technology have both enabled and created fields and opportunities within industry.[43] For example, discoveries in physics led to advances in data storage; the creation of new fields of business intelligence and the concomitant growth in computing power; and the fields of bioinformatics, computational finance, and computational linguistics.[44] Clearly, new talent with advanced science education and practical workplace skills has been created through PSM programs. PSM programs now number more than 300 at well more than 120 institutions. As noted in the 2012 NRC report, these programs are generally cross-disciplinary, and new programs of this type:

> Could be configured to meet the broad skills specified as needed by DOD management. . . . So far, most employers involved in PSM programs have been corporate; DOD has not been involved to any significant degree. However, if DOD agencies could describe PSM programs that would meet their projected needs, possibly in concert with large procurement programs, PSM degrees would likely be configured to meet DOD's needs by a number of universities that are actively expanding their PSM offerings.[45]

In line with this recommendation, DoD agencies could help university faculty plan such degrees, offer PSM students internships, and provide financial support to PSM students in return for appropriate DoD service, for instance, through the SMART program described later in this chapter.

Finding 4-10. PSM degree programs have been expanding around the country and now number more than 300 at some 120 institutions. These programs have created a distinctive approach to articulating curricular design, with scientific and engineering workforce needs specified by employers. Often these programs are cross-disciplinary, and new programs of this type could be configured to meet the broad skill set specified as needed by DoD management.

Recommendation 4-10. The Department of Defense should use Professional Science Master's (PSM) degree programs at civilian universities to educate some of its officers and civilians in science, technology, engineering, and mathematics disciplines, augmented with appropriate management courses. PSM degrees are particularly appropriate for managers who will oversee acquisition programs with substantial technical content.

[43] Ibid.
[44] Ibid.
[45] NRC, *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce*, 2012.

CONCLUDING REMARKS

Education is a complex process. Students differ in their starting skills, academic interest, geographic location, time commitments, preferred learning style, and ability to pay. It is no surprise that there are many different ways to address graduate education needs. The United States has more than 6,700 post-secondary schools,[46] and a big state school such as Ohio State University offers more than 175 different undergraduate majors, many of which are in STEM+M fields.[47] The Air Force, the Navy, and the rest of DoD have significant educational needs of their own, both because of the breadth of their mission and because of the variety within their own personnel across those same dimensions. While AFIT and NPS, as currently configured, can meet many of the most mission-critical needs for graduate education, there is a wealth of opportunities to expand the current offerings. This chapter outlined some of those possibilities: expanding offerings at NPS and AFIT with new degrees, new partnerships, and new distance learning modes; and expanding options for DoD personnel with civilian institutions, including various funding mechanisms. Chapter 5 aggregates the committee's key findings and recommendations from all chapters.

[46] National Center for Education Statistics, http://nces.ed.gov/fastfacts/display.asp?id=84, accessed February 13, 2014.

[47] For additional information, see http://majors.osu.edu/, accessed February 13, 2014

5

Principal Findings and Recommendations

INTRODUCTION

To summarize the content of the preceding chapters, Chapter 1 addresses the Department of Defense's (DoD's) need for military and civilian employees with graduate-level science, technology, engineering, and mathematics (STEM) and management (STEM+M) education, and assesses DoD's graduate education organization structure. Chapter 2 analyzes various DoD-funded and civilian university STEM+M graduate education sources. Chapter 3 concentrates on the value proposition of DoD's two primary in-house STEM+M graduate education sources: the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS). In concert with its value proposition analysis, Chapter 3 reviews specialized DoD degree-granting graduate programs in STEM+M, including costs and benefits of maintaining DoD in-house graduate educational institutions. Chapter 4 offers alternatives to current graduate education solutions designed to ensure high-quality graduate education outcomes for DoD employees and military members. Finally, Chapter 5 summarizes the contents of the report and consolidates principal recommendations under six themes. References are provided for principal findings and recommendations related to each theme.

The importance of STEM+M graduate education for both uniformed and civilian components of the DoD workforce cannot be overstated. Underemphasizing it in times of constrained budgets will imperil DoD's future and the security of the United States. The basis for this view is given in Chapter 1, where the differences between management practices for the two workforce components—military and civilian—are also explored. The military workforce is essentially a closed population after admission at the entry level, whereas the civilian component sits in the overall marketplace with arrivals and departures at all levels of a career. This difference appears to be reflected in overall management and tracking of the two workforce components, with the civilian component largely managed locally with strategic oversight provided via the inaugural DoD Strategic Workforce Plan.[1] Although rudimentary today, it is encouraging to note that the plan offers a framework for the future.

Education is distinguished from training in this report in accordance with the adage, "Train for the known, educate for the unknown."[2] Unlike training, quality graduate education outcomes require robust support by research programs, a requirement sometimes overlooked by DoD decision makers. This difference should be recognized and valued across the department. The committee took a narrow view of the management element in STEM+M, not because the broader area is less important, but simply to reflect the STEM emphasis in the study's terms of reference (provided in Appendix A). Indeed, graduate education in "+M" is also of great importance to DoD, particularly in regard to business practices and theories outside of government that help DoD obtain what it needs.

The committee sought data from all DoD graduate-degree-granting institutions, with limited success. Ultimately, the committee focused on the two primary DoD STEM+M institutions—AFIT and NPS—together with a brief look at the Uniformed Services University of the Health Sciences (USUHS) and the Information Resources Management College (iCollege) of the National Defense University. The path of this focus is discussed in Chapter 2. AFIT, NPS, and the USUHS constitute the jewels in the crown of DoD graduate-degree-granting institutions in general, and clearly with regard to STEM+M degrees. Indeed, this status follows from their dedication to the goals and standards of leading civilian institutions.

The committee took a limited look at civilian institutions for similar reasons of scope and time. However, the committee did explore a few "best practices" of civilian institutions and benefitted greatly from committee members with strong credentials in the academic community. Because the vast majority of DoD in-house STEM+M education is provided by AFIT and NPS, Chapter 3 examines their value propositions in detail. As noted, accurately estimating the cost of DoD in-house education is elusive. Even costing civilian institution education programs is less obvious than accepting the published "face values" for tuition rates. Accordingly, Chapter 3 provides a "first order" cost analysis of AFIT and NPS education and

[1] Department of Defense, *Fiscal Years 2013-2018 Strategic Workforce Plan Report,* Office of the Secretary of Defense, Washington, D.C., 2013.

[2] Variously attributed to Art Cebrowski and VADM Rodney Rempt.

then focuses on the value that DoD, students, and sponsoring organizations receive for that investment.

The quality of AFIT and NPS offerings cannot be measured in ways common to civilian institutions (exclusivity of admissions, research reputation of students and faculty, etc.), and Chapter 3 explores how such quality might be viewed in comparison to state university systems. Chapter 3 also offers an illustrative "change model" to improve governance of AFIT and NPS for its military students, which may have merit for overall management of all DoD graduate degree programs. Lastly, Chapter 3 describes the committee's perceptions of AFIT's strategic priority within DoD relative to other DoD educational institutions and recommends an organization construct designed to enhance its priority.

Chapter 4 explores several ways to enhance the quality and quantity of DoD's graduate education outcomes. The committee's recommendations do not call for replacing AFIT or NPS with civilian institutions, nor the reverse (i.e., achieving all military graduate education objectives through AFIT and NPS). Rather, it is the diversity and a combination of education sources that will ensure national security in the future, in the face of large uncertainties. AFIT and NPS add significant value, particularly for the military component of DoD's workforce. At the same time, civilian institutions should continue to educate a significant portion of DoD's workforce—both military and civilian —in order to foster an intellectual environment driven by a diversity of experience and perspectives. This argues for the virtue and value of an overall graduate education strategy that leverages complementary elements of AFIT, NPS, and civilian institution education programs.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

The report's principal findings and recommendations align with six major themes. The themes, in priority order are as follows:

1. Strengthen the STEM+M competencies of DoD's total workforce by placing greater emphasis on graduate STEM+M education.
2. Maintain a balanced portfolio of STEM+M graduate education sources consisting of DoD and civilian institutions.
3. Expand and adequately resource civilian workforce STEM+M graduate education initiatives.
4. Recognize and support the importance of STEM+M research at AFIT and NPS.
5. Enhance AFIT and NPS graduate education outcomes by increasing institutional collaboration through partnerships and effective distance learning methods.
6. Elevate AFIT's strategic priority.

All report findings and recommendations, along with the supporting evidence for each finding and recommendation, can be found in Chapters 1 through 4. This chapter summarizes the contents of the report and consolidates principal recommendations associated with the above themes. Each theme is explained below.

1. Strengthen the STEM+M competencies of DoD's total workforce by placing greater emphasis on graduate STEM+M education.

The world's technical knowledge base and the technical complexity of modern warfare are rapidly increasing. By increasing its investments in graduate STEM+M education, even as the total workforce decreases in an increasingly constrained budget environment, DoD can continue developing and exploiting advanced technologies as key force multipliers. DoD leaders, regardless of background, will increasingly confront technical and technical management issues as the already rapid pace of technology change increases. DoD leadership should therefore encourage all graduate education programs to include technical and technical management-oriented components in order to send a strong signal of STEM+M's importance to the workforce and increase the STEM+M literacy of DoD decision makers.

Finding 1-1. Looking forward to the next 50 years of greater leveling among the global economies and uncertainty about DoD budgets, the elements of superiority must be achieved in other ways. First among them is the need for a more, not the same or less, capable DoD workforce. This is likely to rest on individuals with greater knowledge, experience, and insight in STEM+M areas. This will be true for both military and civilian elements of DoD's workforce, as well as its industrial base. Relevant graduate education and a culture of lifelong learning are means to those ends.

Recommendation 1-1. The Department of Defense should increase its investments in graduate STEM+M education, even as the total workforce decreases in an increasingly constrained budget environment.

Finding 1-2. The use of innovative technology solutions to address enduring DoD problems will not come simply by increasing the number of graduate degrees in STEM+M fields. Rather, it will require greater STEM+M "literacy" by all elements of the DoD workforce.

Recommendation 1-2. The Department of Defense should encourage greater inclusion of science, technology, engineering, and mathematics (STEM) and technically oriented management elements in all education programs in order to deepen the overall STEM literacy of the workforce.

Finding 1-3. The Air Force recently added STEM-related skills as an institutional competency for all military members and civilian employees.[3]

Recommendation 1-3. The Air Force's policy of instilling science, technology, engineering, and mathematics-related skills is one model the Department of Defense should emulate to further institutional competency for all military members and civilian employees.

2. Maintain a balanced portfolio of STEM+M graduate education sources consisting of DoD and civilian institutions.

AFIT and NPS each have important value propositions that yield significant return on DoD investments. Value-added elements include graduate programs built around defense-based curricula and supported by military-relevant graduate research, the formation of multiservice and multinational intellectual networks that aid students throughout their military careers, and infrastructure and policies that facilitate sensitive and classified research. With recognition and full support of DoD, AFIT and NPS can contribute to a balanced STEM+M portfolio. Faculty members also form a body of technical and management experts that DoD acquisition and logistics professionals use to obtain independent opinions on challenging issues.

A significant portion of DoD's STEM+M graduate education needs could be met through civilian institutions. This is particularly important for degree programs in mission-critical areas, such as law, medicine, and life and social sciences, which are not offered at DoD-funded education institutions in sufficient quantity to meet DoD needs.

Finding 2-1. AFIT and NPS are primarily master's degree-granting institutions because the number of Ph.D. degrees they confer is less than 3 percent of the number of master's degrees.

[3] *Air Force institutional competencies* are defined as the basic and essential knowledge, skills, and attitudes needed throughout one's career to operate successfully in a constantly changing environment. These education, training, and experiences provide the foundation upon which the Air Force's lifelong continuum of learning is built. The major categories are "Organizational" (employing military capabilities, enterprise leadership, managing organizations and resources, and strategic thinking), "People/Team" (leading people and fostering collaborative relationships), and "Personal" (embodies airman culture and communicating). Within the "employing military capabilities," competency is the "leverage technology" sub-competency that addresses STEM related behaviors. Institutional competencies apply to all members of the Air Force, military and civilian, and at all grades by proficiency levels. See U.S. Air Force, *Air Force Doctrine Document 1-1: Leadership and Force Development,* AFDD1-1, November 8, 2011, http://www.e-publishing.af.mil/.

Finding 2-3. AFIT and NPS do not have complete control over their admission process and are asked to take students assigned to them by other elements of DoD. For this reason, the range of preparation of their students is wider than many civilian universities, particularly at NPS. Both schools provide remediation help to incoming students who have been away from school for an extended time period due to operational demands.

Finding 2-5. NPS appears to place an emphasis on admitting personnel with non-STEM undergraduate degrees. Via a sequence of intense noncredit remedial courses, these students are offered an opportunity to go on to pursue a STEM-related master's degree. On the other hand, AFIT normally requires an undergraduate degree in a STEM field for admission to their graduate programs.

Finding 3-1. NPS and AFIT have student-to-faculty ratios, respectively, of 4 and 8. Based on *U.S. News and World Report* rankings, top engineering schools such as MIT and Stanford maintain ratios between 5 and 8. Therefore, it appears both AFIT and NPS have sufficient faculty numbers to deliver accredited graduate master's degrees and certificates. Based on the committee's graduate STEM education expertise, to include leadership and evaluator roles with ABET accreditation bodies, NPS and AFIT teaching and research methods are pedagogically consistent with other leading universities.

Finding 3-4. AFIT and NPS foster teamwork and facilitate the formation of intellectual networks that follow students throughout and beyond their military experiences. Developing military-to-military, joint, and interagency relationships can play a critical role as students work in future multi-Service and multi-national operations.

Recommendation 3-2. The Air Force Institute of Technology's (AFIT's) chain of command should be changed, perhaps to resemble the Naval Postgraduate School, with its own board, budget, accreditation, and program authority, in order for AFIT to maximize its value to the Department of Defense and the nation.

Recommendations 3-3. A senior-level panel should be formed composed of former senior military and Department of Defense (DoD) civilians with leadership experience in civilian educational institutions to recommend specific means to (1) remove or reduce the impediments cited in Finding 3-8; (2) advance the value of DoD science, technology, engineering, mathematics, and management (STEM+M) education institutions; and (3) assess the mission impact these impediments, and others that may develop, have on the STEM+M workforce. Such a panel should examine how the whole STEM+M education enterprise aligns programmatically and by research competencies with key DoD science and technology thrusts, and make recommendations with regards to programs, people (faculty and students), and, especially, business processes.

Finding 4-1. Quality civilian universities are a valuable source of STEM+M graduate education for all civilian and military DoD employees. For officers, they provide education in disciplines not covered by AFIT and NPS, as well as education for prospective military faculty at AFIT, NPS, and the Service academies. Because few DoD civilians attend AFIT or NPS, civilian universities are essential for their graduate education. DoD would be well served to continue to rely heavily on civilian institutions for its graduate STEM+M education needs.

Recommendation 4-1. The Department of Defense should continue and expand support for science, technology, engineering, mathematics, and management graduate education of its officers and civilian employees at civilian universities.

3. Expand and adequately resource civilian workforce STEM+M graduate education initiatives

DoD does much better strategically supporting the graduate education needs of its uniformed members than it does the needs of its civilian STEM+M workforce. This is true in terms of process, structure, opportunities, and funding. This issue could be addressed in three ways: (1) increase funding for civilian tuition assistance programs, (2) expand support for DoD's SMART program, and (3) aggressively use Defense Acquisition Workforce Development Funds (DAWDF) or "DAWDF-like" funds for the entire STEM+M workforce, by obtaining authorization from Congress either to expand existing DAWDF to include all STEM+M workforce professionals or to establish similar funding to educate those not covered by DAWDF.

Finding 1-5. The Air Force, Navy, and Marines have a comprehensive and well-executed process for the career development of their military officers. Moreover, these Services track and support the graduate education of its officers quite well. The committee reviewed these processes and believes they provide a solid basis for tracking the evolution of the military workforce. The committee had inadequate information to reach a conclusion about the Army processes.

Finding 1-6. A strategic mechanism to track and manage the overall civilian workforce is emerging in the inaugural DoD *Fiscal Years 2013-2018 Strategic Workforce Plan Report.*[4] It appears to be a comprehensive effort to manage the civilian workforce.[5]

Recommendation 2-2. In an era of rapidly developing distance learning technology and opportunity, the Department of Defense should seriously explore the possibility of combining the networking and bonding benefits of military officers in residence at the Air Force Institute of Technology or the Naval Postgraduate School with the benefits of exposure to other institutions and learning opportunities at civilian universities by using distance learning.

Finding 2-6. There is no centralized source, within DoD, of clear and consistent data on how many STEM+M degrees are being obtained by military and civilian DoD personnel at civilian universities.

Finding 4-6. Military tuition assistance is a highly valuable military benefit. DoD spends some $560 million per year to support students under military tuition assistance, including nearly 5,800 master's degree students. Although data are not available on what percentage of these students are active-duty officers seeking STEM+M degrees, it seems likely that this percentage is small. Encouraging more of these officer students to seek STEM degrees could help significantly to reduce DoD's need for more STEM+M officers.

Recommendation 4-6. The Department of Defense (DoD) should create a new category of Priority Military Tuition Assistance for science, technology, engineering, mathematics, and management graduate education and do the following:

---

[4] DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report,* Fall 2013, http://dcips.dtic.mil/documents.html.

[5] From DoD, *Fiscal Years 2013-2018 Strategic Workforce Plan Report* (2013):

> The plan incorporates the requirements of section 115b of title 10, United States Code (U.S.C.) and builds on lessons learned from previous efforts, which provide a unified process for workforce planning across the Department. The workforce planning process is guided by DOD Instruction (DODI) 1400.25, Volume 250, DOD Civilian Personnel Management System: Volume 250, Civilian Strategic Human Capital Planning, November18, 2008. This DODI establishes DOD policy to create a structured, competency-based human capital planning approach to the civilian workforce's readiness (p. ii).
>
> [It responds to] Section 935 of the NDAA FY 2012 amended section 115b of title 10, U.S.C. as follows:
>
> - Biennial Plan Required: The Secretary of Defense shall submit to the congressional defense committees in every even-numbered year a strategic workforce plan to shape and improve the civilian employee workforce of the Department of Defense; and
> - An assessment of the critical skills and competencies of the existing civilian employee workforce of the Department and projected trends for five years out (vice seven years) in that workforce based on expected losses due to retirement and other attrition (p. 12).

- Significantly increase the maximum tuition payment per credit hour.
- Encourage, where possible, cohorts of students to take the same program together.
- Provide, as feasible, high-bandwidth connections to enable high-quality interaction for those courses.
- Encourage, where possible, release time for students to take courses synchronously or at a minimum to keep pace with their classmates weekly.
- Allow military tuition assistance funds to be used at the Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS), to allow access to those courses and to give AFIT and NPS an incentive to compete for those resources and students.
- Assess the achievements of the students during their study and their contributions to DoD over their careers (see Figure 3-2 and associated discussions in Chapter 3).

Finding 4-7. SMART is achieving the purpose outlined for it in USC Title 10 Section 2192a. It offers full scholarships and post-degree employment in DoD laboratories to well-qualified, competitively selected students pursuing undergraduate or graduate degrees in STEM disciplines. SMART graduation and retention rates are high compared to national averages.

Recommendation 4-7. The Department of Defense (DoD) should continue and expand support for the Science, Mathematics, and Research for Transformation (SMART) program and should provide a blanket exemption to current and future hiring freezes, as well as placement priority, to ensure SMART graduates are placed promptly and effectively employed. Furthermore, DoD should ensure the candidate selection process continues to be conducted on a competitive basis.

Finding 4-8. DoD does a much better job of supporting the graduate education needs of its uniformed members than it does the graduate education needs of its civilian STEM workforce. This is true in terms of process, structure, opportunities, and funding. AFIT, NPS and many civilian institutions have the capacity to better support civilians. DoD needs to find a sufficient and predictable funding source for all STEM professionals.

Recommendation 4-8. The Department of Defense (DoD) should aggressively use Defense Acquisition Workforce Development Funds (DAWDF) for the existing covered science, technology, engineering, and mathematics (STEM) workforce members for graduate-level education through current long-term, full-time education provisions. Further, DoD should obtain authorization from Congress either to expand existing DAWDF to include all STEM workforce professionals or to obtain "DAWDF-like" funding, backfilling positions behind students attending school and supporting their transitioning back to their former jobs after graduation.

Finding 4-9. Through the Civilian Institutions Program, NDSEG, SMART, and other graduate education programs, DoD provides both adequate stipends and full tuition for the graduate students it supports. In contrast, the National Science Foundation (NSF) and the National Institutes of Health (NIH) provide adequate stipends at uniformly reduced tuition rates, which universities usually accept, for the Ph.D. students they support. West Point, NSF, and NIH have negotiated reduced tuition rates for Ph.D. students sent to civilian institutions. Adopting these practices across DoD would help the department stretch limited graduate education funds to support more graduate students.

Recommendation 4-9. The Department of Defense should provide a flat rate cost-of-education allowance to universities in lieu of tuition for Ph.D. students it supports, similar to allowances provided by the National Science Foundation and the National Institutes of Health.[6]

4. Recognize and support the importance of STEM+M research at AFIT and NPS.

An active research program is essential to quality graduate education. Active, high-quality DoD research programs

- Provide critical elements of the student's graduate education,
- Identify future education needs before requirements are specified,
- Exposes students early on to emerging technologies and new scientific and engineering discoveries,
- Instill a culture of lifelong learning in the students,
- Attract and retain quality faculty for all DoD educational institutions,
- Enhance the national visibility of DOD institutions, and
- Often result in cost savings and new capabilities for DoD.

Ensuring that AFIT and NPS are allowed to maintain active research programs and encouraging them to achieve international recognition in selected, DoD-rele-

[6] NSF, for instance, currently pays $12,000 per year.

vant areas could lead to better education outcomes for students at and graduates of both institutions.

Finding 3-3. AFIT and NPS are often viewed solely as education enterprises by their constituents. These institutions, however, are coupled research/education enterprises with productive research programs that improve the quality of student education, play an essential role in attracting and retaining top faculty, and generate valuable weapon system insights and technologies.

Recommendation 3-1. The Department of Defense (DoD) should recognize and support the comprehensive value proposition offered by the Air Force Institute of Technology and the Naval Postgraduate School. Measures of convenience, cost, and quality are not sufficient to meet the demand for a technically superior workforce. When viewed from a total value perspective, as described in the benefits column of Table 3-9, DoD's graduate science, technology, engineering, mathematics, and management enterprise is a tremendous asset to the respective Services, DoD, and the nation.

5. Enhance AFIT and NPS graduate education outcomes by increasing institutional collaboration through partnerships and effective distance learning methods.

By jointly sponsoring research and teaching activities, and by continuing to maintain and broaden their partnerships with DoD laboratories and civilian research universities, AFIT and NPS can provide a wider range of degrees and problem-solving perspectives to their students and enhance the quality and relevancy of their research. Both AFIT and NPS understand the elements of effective, quality methods of distance learning (DL). For example, NPS has achieved a national reputation for its systems engineering programs via quality DL methods. In an era of rapidly developing DL technology and opportunities, DoD can actively leverage their proven DL approaches to connect students in residence at AFIT, NPS, and civilian institutions; broaden AFIT and NPS student bodies with more civilian DoD personnel; and expand the size of AFIT and NPS Ph.D. programs by offering a wider range of courses and research experiences.

Recommendation 2-1. The Air Force Institute of Technology and the Naval Postgraduate School should proactively seek to expand the December 4, 2002, memorandum of agreement between the Navy and the Air Force so as to increase collaboration with each other, as well as to partner with other selected universities to create a critical mass of Ph.D. students. This will enable a deeper and wider range of courses and research experiences, particularly for some of the smaller Ph.D. programs.

Finding 2-2. At both AFIT and NPS, STEM+M master's and Ph.D. students pursuing degrees on campus at AFIT or NPS, not explicitly in distance-learning programs, generally do not take for-credit courses via distance learning from either their sister institution or at civilian institutions.

Finding 2-3. AFIT and NPS do not have complete control over their admission process and are asked to take students assigned to them by other elements of DoD. For this reason, the range of preparation of their students is wider than many civilian universities, particularly at NPS. Both schools provide remediation help to incoming students who have been away from school for an extended time period due to operational demands.

Finding 3-1. NPS and AFIT have student-to-faculty ratios, respectively, of 4 and 8. Based on *U.S. News and World Report* rankings, top engineering schools such as MIT and Stanford maintain ratios between 5 and 8. Therefore, it appears both AFIT and NPS have sufficient faculty numbers to deliver accredited graduate master's degrees and certificates. Based on the committee's graduate STEM education expertise, to include leadership and evaluator roles with ABET accreditation bodies, NPS and AFIT teaching and research methods are pedagogically consistent with other leading universities.

Finding 4-2. The effectiveness and efficiency of AFIT and NPS can be increased by significantly enhanced collaboration and building on the strengths of the two organizations. This was recognized by the Air Force and Navy in the December 4, 2002, memorandum of agreement "Forming an Educational Alliance between the Department of the Navy and the Department of the Air Force" and also by the findings and recommendation of the 2005 BRAC Commission, which called for establishing a "permanent oversight board responsible for curriculum review and approval, and program development for the resident and non-resident degree-granting programs at both schools,"[7] which would be chartered by the Office of the Secretary of Defense and have substantial authority.

Recommendation 4-2. The Department of Defense should implement the recommendation of the 2005 Defense Base Closure and Realignment Commission (Appendix Q, Section 197) to establish an empowered oversight board

[7] Ibid.

for the Air Force Institute of Technology and the Naval Postgraduate School, reporting to the Office of the Secretary of Defense.

Finding 4-3. AFIT effectively uses its partnership with universities in Dayton, Ohio, to enhance its capacity and capabilities. Both AFIT and NPS have partnerships with other universities, but little evidence has been offered that they are used extensively.

Recommendation 4-3. The Air Force Institute of Technology and the Naval Postgraduate School should establish and use a limited number of partnerships with quality universities located near Department of Defense (DoD) installations or that otherwise possess unique partnering benefits. They should leverage distance learning tools and methods to exploit these partnerships, and in conjunction with DoD laboratories, provide a wider range of quality degrees that are available at remote locations (i.e., not Dayton or Monterey) and accessible to additional military personnel.

Finding 4-4. AFIT effectively uses the Wright-Patterson AFB component of AFRL to strengthen its graduate education program, employing its experimental facilities for thesis research and its technical staff as adjunct professors. AFIT's collaborations with other components of AFRL, however, are not as robust. Finally, it appears that NPS does not significantly collaborate with DoD laboratories.

Recommendation 4-4. The Air Force Institute of Technology (AFIT) and the Naval Postgraduate School (NPS) should permit their graduate students to conduct thesis research at Department of Defense laboratories and other suitable locations when doing so provides a quality education. AFIT and NPS should also involve adjunct professors drawn from those organizations to help guide and supervise graduate students. Effective distance learning tools and methods should be leveraged to reduce costs and enhance the education experience.

Finding 4-5. Distance education is rapidly expanding in the number of courses offered and in the quality of education provided. NPS has successfully taught many of its degree programs by distance education; AFIT has offered more certificate programs and fewer degree programs. Increased use of distance courses will offer much more flexibility to DoD personnel to attain advanced degrees, especially for those unable to relocate to AFIT or NPS.

Recommendation 4-5. The Department of Defense (DoD) should increase the use of distance education for science, technology, engineering, mathematics, and management degrees. Specifically, the Air Force should invest in converting some Air Force Institute of Technology (AFIT) M.S. degrees to be offered by distance learning, face-to-face, or any of the varieties of blended and hybrid delivery. In addition, AFIT and the Naval Postgraduate School (NPS) should consider offering joint degrees, or joint courses, taught in person on one campus and by distance learning on the other. Finally, NPS and AFIT should use distance offerings to enable their students to be in residence at one of the DoD laboratories for their research while taking courses from their home universities.

6. Elevate AFIT's strategic priority.

Many DoD organizations recognize the strategic importance of their educational institutions by having them report at the highest levels in the Services or Joint Staff. These institutions include the Service academies, the Uniformed Services University of Health Sciences, and NPS. AFIT currently reports to Air University, which reports to the Air Education and Training Command (AETC), where AFIT's graduate STEM+M education and research activities do not align well with AETC's Professional Military Education and training missions. By aligning AFIT with leadership that prioritizes its education and research mission, DoD can increase AFIT's strategic value and give it the authority and autonomy it requires to effectively interact with institutional peers, such as NPS. In accordance with the examples cited above, the best way to achieve this result is to have AFIT report directly to the Chief of Staff of the Air Force.

Finding 3-5. From an organizational structure and chain of command perspective, AFIT is at a disadvantage in comparison to the other graduate-degree-granting DoD organizations. This disadvantage was highlighted in the organization of the alliance between AFIT and NPS. While the alliance was purported to be between AFIT and NPS, responsibility for oversight of the alliance was given to the NPS Board of Advisors and the AU Board of Visitors. To ensure a connection between those boards, the NPS superintendent was appointed to the AU Board of Visitors and the AU commander, not the AFIT commandant, was appointed to the NPS board.

Finding 3-7. AFIT's current command structure requires it to advocate for initiatives to maintain and strengthen its research-based graduate education programs via a lengthy chain of command that has limited graduate education expertise, virtually no technical research expertise, and a focus on immediate training and professional military education requirements.

Recommendation 3-2. The Air Force Institute of Technology's (AFIT's) chain of command should be changed, perhaps to resemble the Naval Postgraduate School, with its own board, budget, accreditation, and program authority, in order for AFIT to maximize its value to the Department of Defense and the nation.

Finding 3-8. Sequestration, furlough, pay freezes, and limitations on travel, among other factors, have hampered the ability of AFIT and NPS to provide the required educational experience needed by its students, particularly its uniformed students. Further, it is vitally important for faculty and students at these institutions to be able to attend scientific conferences to present research to their peers, network, receive feedback, and remain current. To this end, the Services would be well served to implement DoD Conference Guidance Version 2.0, dated November 6, 2013, from the Office of the Deputy Chief Management Office that states that for most conferences that "approval authority at their discretion to General Officers/Flag Officers/Senior Executive Service members in their organization."[8]

Finding 4-4. AFIT effectively uses the Wright-Patterson AFB component of AFRL to strengthen its graduate education program, employing its experimental facilities for thesis research and its technical staff as adjunct professors. AFIT's collaborations with other components of AFRL, however, are not as robust. Finally, it appears that NPS does not significantly collaborate with DoD laboratories.

[8] DoD. 2013. Memorandum: Implementation of Updated Conference Oversight Requirements. November 6. For additional information, see http://dcmo.defense.gov/products-and-services/conference-policies-controls/DoD%20Conference%20Guidance%20-%206%20November%202013.pdf. Accessed May 25, 2014.

Appendixes

A

Terms of Reference

A National Research Council (NRC) study committee will conduct a review of specialized degree-granting graduate programs of the Department of Defense in science, technology, engineering, mathematics (STEM) and management. Per the Defense Authorization Act for FY 2013, HR4310 Sec. 245, the review will address the following issues:

1. The need by the Department of Defense and the military departments for military and civilian personnel with advanced degrees in science, technology, engineering, mathematics, and management, including a list of the numbers of such personnel needed by discipline.
2. An analysis of the sources by which the Department of Defense and the military departments obtain military and civilian personnel with such advanced degrees.
3. The need for educational institutions under the Department of Defense to meet the needs identified.
4. The costs and benefits of maintaining such educational institutions, including costs relating to in-house research.
5. The ability of private non-Department of Defense institutions (public and private) or distance-learning programs to meet the needs identified.
6. Existing organizational structures, including reporting chains, within the military departments to manage the graduate education needs of the Department of Defense and the military departments in the fields of science, technology, engineering, mathematics (STEM) and management.

7. Recommendations for improving the ability of the Department of Defense to identify, manage, and source the graduate education needs of the Department in such fields.

The committee will prepare a report that documents its analysis, findings, and recommendations.

B

Biographical Sketches of Committee Members

JACQUES S. GANSLER, *Chair,* is the Roger C. Lipitz Chair in Public Policy and Private Enterprise in the University of Maryland's School of Public Affairs. He teaches graduate school courses and leads the School's new Center for Public Policy and Private Enterprise, which fosters collaboration among the public, private and nonprofit sectors in order to promote mutually beneficial public and private interests. Previously, Dr. Gansler served as the under secretary of defense for acquisition, technology and logistics from November 1997 until January 2001. In this position, he was responsible for all matters relating to Department of Defense (DoD) acquisition, research and development (R&D), logistics, acquisition reform, advanced technology, international programs, environmental security, nuclear, chemical, and biological programs, and the defense technology and industrial base. Prior to this appointment, Dr. Gansler was executive vice president and corporate director for TASC, Inc., an applied information technology company Virginia (from 1977 to 1997) during which time he played a major role in building the company from a small operation into a large, widely recognized and greatly respected corporation, serving both the government and the private sector. From 1972 to 1977, he served in the government as deputy assistant secretary of defense (materiel acquisition), responsible for all defense procurements and the defense industry, and as assistant director of defense research and engineering (electronics) responsible for all defense electronics R&D. Dr. Gansler has served on numerous corporation boards of directors, and governmental special committees and advisory boards, including as vice chairman, Defense Science Board; chairman, board of visitors, Defense Acquisition University; director, Procurement Round Table; chairman, Industry Advisory

Board, University of Virginia, School of Engineering; chairman, board of visitors, University of Maryland, School of Public Affairs; member of the FAA Blue Ribbon Panel on Acquisition Reform; and senior consultant to the "Packard Commission" on Defense Acquisition Reform. Dr. Gansler is a member of the National Academy of Engineering. He holds a Ph.D. in economics from American University, an M.S. in electrical engineering from Yale University, and an M.E. in electrical engineering from Northeastern University.

THOMAS J. BURNS, *Vice Chair,* joined ENSCO, Inc., as president and CEO in June 2014. Dr. Burns recently served as senior vice president and manager for Science Applications International Corporation (SAIC) Sensors and Phenomenology Operation where he was responsible for more than 900 employees and more than $300 million in R&D, system solutions, and products business. Prior to joining SAIC, Dr. Burns co-founded and served as CEO and chairman of SET Corporation, a small high-tech business specializing in the creation and commercialization of smart sensing technologies. Acquired in 2010, SET operates as a wholly owned subsidiary of SAIC. Prior to founding SET, Dr. Burns co-founded and served as chief operating officer of ObjectVideo, Inc., a leader in smart video solutions for commercial and military security applications. He joined ObjectVideo from the Defense Advanced Research Projects Agency where he pioneered the development of model-based signal and image exploitation technologies, building on his experiences directing computer vision research as a U.S. Air Force officer at Air Force Research Laboratory (AFRL). While assigned to AFRL, he led AFRL's premiere Automatic Target Recognition program, receiving AFRL's prestigious Peter R. Murray Program Manager of the Year award. Dr. Burns is co-inventor of patents on video and radar technology and has published numerous refereed papers in areas as diverse as electro-optics and wavelet mathematics. He is currently a member the National Research Council's (NRC's) Air Force Studies Board and the United States Air Force Museum board of managers. Dr. Burns also serves as a board director of Yakabod, Inc., an innovative knowledge-management product company. He received a Ph.D. in electrical engineering from the Air Force Institute of Technology (AFIT).

ROBERT A. CALICO, JR., is an independent consultant. He retired as the director of academic affairs for AFIT at Wright-Patterson Air Force Base (AFB), Ohio, in 2006. The school's mission is to provide master of science and doctor of philosophy degree programs for Air Force officers in the areas of engineering, science, and management that are critical to maintaining the Air Force's technological superiority. Dr. Calico attended the University of Cincinnati where he earned bachelor of science, master of science, and doctor of philosophy degrees in aerospace engineering. He authored numerous publications in the areas of flexible spacecraft dynamics and control, aircraft spin prediction, and control of time periodic systems. Dr. Calico joined the faculty of the Graduate School of Engineering and Management in 1972, where he held the positions of assistant professor, associate professor, and professor of aerospace engineering. He was appointed interim dean of the Graduate School of Engineering and Management in October of 1989 and dean in July 1990. Upon his retirement, Dr. Calico was appointed dean emeritus and has served as an independent consultant. In April 2007, he became a member of the board of trustees for Riverside Research where he continues to serve.

RITA COLWELL is a Distinguished University Professor both at the University of Maryland, College Park, and at Johns Hopkins University Bloomberg School of Public Health, chairman emeritus and senior advisor of Canon U.S. Life Sciences, Inc., and president, CosmosID, Inc. Her interests are focused on global infectious diseases, water, and health, and she has developed an international network to address emerging infectious diseases and water issues, including safe drinking water for both the developed and developing world. Dr. Colwell has held many advisory positions in the U.S. government, nonprofit science policy organizations, and private foundations, as well as in the international scientific research community. Dr. Colwell is a member of the National Academy of Sciences, the Royal Swedish Academy of Sciences, Stockholm, the American Academy of Arts and Sciences, the Royal Irish Academy of Science, and the American Philosophical Society. She is the recipient of the national Medal of Science awarded by the President of the United States, the Order of the Rising Sun awarded by the Emperor of Japan, and the Stockholm Water Prize, awarded by the King of Sweden. Dr. Colwell holds a Ph.D. in oceanography from the University of Washington.

EARL H. DOWELL is the William Holland Hall Professor and Chair for Mechanical Engineering and Material Sciences at Duke University. Dr. Dowell is a fellow of the American Academy of Mechanics, the American Institute of Aeronautics and Astronautics (AIAA), and the American Society of Mechanical Engineers. He has also served as vice president for publications and member of the executive committee of the board of directors of AIAA, as a member of the U.S. Air Force Scientific Advisory Board, the NRC's Air Force Studies Board, the AGARD (NATO) advisory panel for aerospace engineering, as president of the American Academy of Mechanics, chair of the U.S. National Committee on Theoretical and Applied Mechanics, and as chairman of the National Council of Deans of Engineering. Currently he serves on the boards of visitors of the Carnegie Mellon University (CMU), Princeton University, the University of Illinois, and the University of Rochester. He is an occasional consultant to government, industry and universities in science and technology policy and engineering education as well as on topics of his research. Before coming to Duke as dean of the School of Engineering serving from 1983-1999, he taught at the Massachusetts Institute of Technology (MIT) and Princeton. He has also worked with the Boeing Company. Dr. Dowell received his Sc.D. from MIT.

JOHN V. FARR is a professor of engineering management and director of the Center for Nation Reconstruction and Capacity Development at the United States Military Academy at West Point. Prior to returning to West Point in 2010, he was a professor of systems engineering and engineering management in the School of Systems and Enterprises at Stevens Institute of Technology. He was the founding director of the Department of Systems Engineering and Engineering Management at Stevens, which he led from 2000 to 2007. He served as associate dean for academics from 2007 to 2010. He taught at West Point from 1992 to 2000, and achieved the rank of professor of engineering management. Dr. Farr was also the first permanent civilian professor in engineering at the Academy. He is a past president and fellow of the American Society for Engineering Management, a fellow of the American Society of Civil Engineers, former member of the Army Science Board and the Air Force Studies Board of the NRC, a Fulbright Scholar, and currently serves as a commissioner for the Engineering Accreditation Commission of the Accreditation Board of Engineering and Technology. He is a former editor of the *Journal of Management in Engineering* and the founder of the *Engineering Management Practice Periodical*. He has authored more than 150 technical publications, including three textbooks. He is a registered civil engineer in New York and Mississippi and holds an undergraduate degree from Mississippi State University, a master's from Purdue University, and a Ph.D. in civil engineering from the University of Michigan.

BRENDAN GODFREY is a visiting senior research scientist at the University of Maryland, where he conducts studies on numerical simulation of plasmas, participates in committees of the NRC, and served as advisor to the U.S. Deputy Assistant Secretary of Defense for Research. Previously, he was director of the Air Force Office of Scientific Research (AFOSR), responsible for its nearly half-billion-dollar basic research program. He was an Air Force officer at Kirtland AFB from 1970 to 1972, performing plasma research. He began his civilian career at Los Alamos National Laboratory, establishing its intense particle beam research program. He then managed and conducted intense microwave and particle beam research at Mission Research Corp., becoming vice president and regional manager. In 1989, he returned to the Air Force as civilian chief scientist of the Weapons Laboratory. Later responsibilities included director of Phillips Laboratory high power microwave research; director of the 1,500-person Armstrong Laboratory; director of plans at AFRL, and deputy director of Brooks City-Base. Known for his contributions to computational plasma theory and applications, he is author of more than 200 publications and reports. He also has served on numerous professional and civic committees. He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and of the American Physical Society. Dr. Godfrey received his Ph.D. from Princeton University.

WESLEY L. HARRIS is the Charles Stark Draper Professor of Aeronautics and Astronautics and director of the Lean Sustainment Initiative at MIT. He was elected to the NAE for contributions to understanding of helicopter rotor noise, for encouragement of minorities in engineering, and for service to the aeronautical industry. He has performed research and published in refereed journals in the following areas: fluid mechanics; aerodynamics; unsteady, non-linear aerodynamics; acoustics; lean manufacturing processes; military logistics and sustainment; and chaos in sickle cell blood flow. Dr. Harris has substantial experience as a leader in higher education administration and management. He also has demonstrated outstanding leadership in managing major national and international aeronautical and aviation programs and personnel in the executive branch of the federal government. He is an elected fellow of the AIAA, AHS, and of the NTA for personal engineering achievements, engineering education, management, and advancing cultural diversity. Dr. Harris graduated from Princeton University with a Ph.D. in aerospace and mechanical sciences.

MICHAEL L. HEIL is president and CEO of the Ohio Aerospace Institute (OAI). Previous to OAI, Dr. Heil had a long and distinguished military career and previously served as director, Center for Space Studies and Research at AFIT. His experiences include serving as director of AFRL's Propulsion Directorate with responsibilities for propulsion and power research facilities both at Wright-Patterson and Edwards AFBs. He oversaw facilities valued at more than $2.1 billion, while leading the efforts of more than 1,000 scientists, engineers, and staff. His responsibilities included ensuring the directorate's $300 million annual budget produced cutting-edge technology results for the Air Force and the nation. A distinguished engineering graduate from the U.S. Air Force Academy, class of 1975, Dr. Heil was commissioned and immediately pursued his master's degree in flight structures at Columbia University on a Guggenheim fellowship. He received a doctorate in aerospace engineering from AFIT in 1986. His service to the nation includes engineering duties on the F-15 and program management on the C-17 and Advanced Cruise Missile. He held the positions of deputy director of the Astronautics Laboratory, commander of the Phillips Laboratory and Arnold Engineering Development Center, commandant of AFIT, and special assistant to the commander of AFRL. He has served in two Air Force acquisition centers, four defense laboratories, a test center, a major command staff, the Office of the Secretary of Defense, and the faculties of the Air Force Academy and AFIT.

ROBERT J. HERMANN is a private consultant. Previously he served as a senior partner at Global Technology Partners, LLC. He retired as senior vice president for science and technology of the United Technologies Corporation (UTC) in 1998. He is a former director of DoD's National Reconnaissance Office and a former senior official at the National Security Agency (NSA). Dr. Hermann served as a member of the President's Foreign Intelligence Advisory Board during the Clinton Administration (1993-2001). As senior vice president of science and technology at UTC, Dr. Hermann was responsible for assuring the development of technical resources and the full exploitation of science and technology by the corporation. He was also responsible for the United Technologies Research Center. Dr. Hermann joined UTC in 1982 as vice president of systems technology in the electronics sector and later served in a series of assignments in the defense and space systems groups. Dr. Hermann concluded his tenure as immediate past chairman of the American National Standards Institute (ANSI) board of directors at the end of 2002 following a 2-year term; he had served as chairman of the ANSI board of directors during 1999 and 2000 and as a member of the ANSI board since 1993. Prior to joining UTC, Dr. Hermann served 20 years with the NSA with assignments in research and development, operations, and NATO. In 1977, he was appointed principal deputy assistant secretary of defense for communications, command, control and intelligence. In 1979, he was named assistant secretary of the Air Force for research, development, and logistics and in parallel was director of the National Reconnaissance Office. He received B.S., M.S., and Ph.D. degrees in electrical engineering from Iowa State University. Dr. Hermann's expertise is in defense technology and system R&D, defense systems acquisition and management, and defense strategic planning.

WALTER F. JONES is the executive director of the Office of Naval Research (ONR) where he is the senior civilian manager and provides executive, technical, and scientific direction in the performance of ONR's mission of planning and managing science and technology research for the Department of the Navy. He works closely with ONR's directorate leads in the identification, prioritization, and support of specific areas of science and technology development. Dr. Jones most recently was director, Plans and Programs, AFRL, Wright-Patterson AFB. He was responsible for developing and managing the processes that defined AFRL's $3 billion annual investment in technologies for future Air Force systems. These systems include space, weapons, aeronautics, and command, control, communications, computers, intelligence, surveillance and reconnaissance. Dr. Jones has held a wide variety of positions in government and academia. He has served as director, Aerospace and Materials Sciences, AFOSR. In this capacity, he planned, coordinated, and executed a $55 million basic research program, including solid mechanics, fluid mechanics, materials science, and propulsion. He has also served as a senior program analyst with the Office of the Deputy Director of Central Intelligence for Community

Management. He has held several positions with the Air Force, including deputy for research sciences with the Office of the Assistant Secretary of the Air Force (Acquisition), and deputy for science and technology with the Office of the National Security Space Architect. In addition, Dr. Jones has held faculty positions at the University of Florida, University of Tennessee, and Clemson University. Dr. Jones received his Ph.D. and M.S. in engineering mechanics and a B.S. in mechanical engineering from Clemson University.

KATHRYN NEWCOMER is the director of the Trachtenberg School of Public Policy and Public Administration at the George Washington University. She teaches public and nonprofit, program evaluation, research design, and applied statistics. She routinely conducts program evaluations and training for federal government agencies and nonprofit organizations. Dr. Newcomer has published five books: *Improving Government Performance* (1989), *The Handbook of Practical Program Evaluation* (1994, 2004, 2010), *Meeting the Challenges of Performance-Oriented Government* (2002), *Getting Results: A Guide for Federal Leaders and Managers* (2005), and *Transforming Public and Nonprofit Organizations: Stewardship for Leading Change* (2008), and a volume of *New Directions for Public Program Evaluation, Using Performance Measurement to Improve Public and Nonprofit Programs* (1997), and numerous articles in journals including the *American Journal of Evaluation* and *Public Administration Review*. She received the Elmer B. Staats Award for her work on accountability in government, presented by the National Capital Area Chapter of the American Society for Public Administration in 2008. She is an elected fellow of the National Academy of Public Administration and currently serves on the Comptroller General's Educators' Advisory Panel. Currently she is an elected member of the board of the American Evaluation Association (2012-2015). She served as president of the National Association of Schools of Public Affairs and Administration for 2006-2007. She has received two Fulbright awards, one for Taiwan (1993) and one for Egypt (2001-2004). She has lectured on performance measurement and public program evaluation in Ukraine, Israel, the UAE, Nicaragua, Brazil, Egypt, Taiwan, and the United Kingdom. She received her B.S. and M.A. at the University of Kansas and her Ph.D. in political science at the University of Iowa.

LEIF E. PETERSON is managing partner for Advanced Human Resource Concepts and Solutions. Before retiring in 2007, Mr. Peterson was a member of the Senior Executive Service and the director of Manpower, Personnel and Services for the Air Force Materiel Command (AFMC) at Wright-Patterson AFB. He provided executive management of the command's nearly 80,000 military and civilian professionals throughout the United States and overseas in research facilities, test sites, universities, and at product development, logistics and specialized centers. The function of the directorate was to shape the AFMC workforce to deliver warwinning expeditionary capabilities and provide oversight, direction, and control for all personnel activities within AFMC. Mr. Peterson entered federal service in 1971 as a labor relations specialist at the U.S. Air Force Headquarters. He held numerous positions as a civilian personnel officer, serving two tours at Eglin AFB, Florida, and 6 years overseas. In 1983, Mr. Peterson became deputy director of civilian personnel for Air Force Systems Command at Andrews AFB, Maryland. He later returned to U.S. Air Force Headquarters as chief of staffing of development and equal employment opportunity. For 8 years he was director of civilian personnel at Tactical Air Command and Air Combat Command at Langley AFB, Virginia. He was then assigned as director of civilian personnel and programs at AFMC. He was appointed to the Senior Executive Service in May 2004 assuming his previous position as deputy director of personnel.

STEPHEN M. POLLOCK is a Professor Emeritus of Industrial and Operations Engineering (IOE) at the University of Michigan. He has been involved in applying operations research and decision analysis methods to understand and influence a variety of operational phenomena. Dr. Pollock was a member of the technical staff at Arthur D. Little, Inc., before joining the faculty at the U.S. Naval Postgraduate School in 1965. In 1969 he became a faculty member at the University of Michigan, where he was chair of the IOE Department from 1981 through 1990. He also chaired the university's Research Policies Committee and served on the College of Engineering's Executive Committee. In 1992 he received the Stephen S. Attwood Award, the highest honor given to a faculty member by the College of Engineering. He has authored more than 60 technical papers, co-edited two books, and has served as a consultant to more than 30 industrial, governmental, and service organizations. Dr. Pollock was associate editor and area editor of *Operations Research*, senior editor of *IIE Transactions*, associate editor of *Management Science*, on the editorial boards of other journals as well as on various advisory boards for the National Science Foundation. He was on the NRC's Army Science Board from 1994 through 1999. He was elected president of the Operations Research Society of America in 1986 and awarded the 2001 INFORMS Kimball Medal for contributions to operations research and the management sciences. He a fellow of INFORMS and of the AAAS and is a member of the National Academy of Engineering. Dr. Pollock received a bachelor of science in engineering physics from Cornell University and a Ph.D. in physics and operations research from MIT.

STEVEN E. RAMBERG is a distinguished research fellow at the Center for Technology and National Security Policy at the National Defense University (NDU) on assignment from the Applied Research Laboratory of Pennsylvania State University. At NDU he occupies the Chief of Naval Research Chair where he provides analysis and advice on science and technology topics and policies, primarily in areas of naval relevance. He also regularly participates in studies, panels, and lectures for NDU, the National Academy of Sciences, the National Ocean Council via the Ocean Research and Resources Advisory Panel, and others. During his career, he served as a fellow and as vice president for Arete Associates during 2007 to 2010; as the director of the NATO Undersea Research Centre (NURC) in LaSpezia, Italy, from 2003 to 2007; and as director and chief scientist for ONR from 2001 to 2003 after joining ONR in 1988. His career at ONR also involved oversight of ocean, atmosphere, and space programs in basic research through applied programs, including the Navy-owned research vessels in the academic fleet, as well as inaugurating the National Ocean Partnership Program across 12 federal agencies. At the NURC, he focused on maritime, mostly undersea, research programs while advising NATO in a number of informal and formal settings including research and technology strategies, coordination of programs among the 26 NATO nations, and transformation of NATO capabilities. In this capacity he was frequently called upon to give keynote addresses at international gatherings on topics ranging from status and trends in undersea research to issues of marine mammal risk reduction together with opportunities for port and harbor security research and maritime archaeology. Earlier, he worked at the Naval Research Laboratory where he published more than 60 unclassified papers in the archival literature on fluid dynamics of bluff bodies, nonlinear ocean waves, stratified wakes, turbulence near a free surface, and related remote-sensing topics.

CHUCK THORPE is senior vice president and provost at Clarkson University, since July 2012. Dr. Thorpe received his B.A. in natural science from North Park University in 1979. He was with CMU from 1979 to 2012 as a Ph.D. student (computer science, 1984); post-doctoral researcher (1984-1985); and faculty in the Robotics Institute (1985 to present). From 2000 to 2004 he was head of the Robotics Institute, supervising 40 faculty with a combined research budget of $40 million per year. His research group builds robot cars, capable of either driving themselves or watching a human driver and warning in case of impending collisions. From 2004 to 2010, Dr. Thorpe was founding dean and CEO of Carnegie Mellon Qatar, a branch campus of the university offering degrees in computer science, business, and information systems in Doha, Qatar. Dr. Thorpe and his team set up operations, recruited faculty and students, outfitted a temporary building and helped design their permanent home, and created the full CMU experience, 7,000 miles away from the main campus. In the 2011-2012 academic year, Dr. Thorpe was on assignment to the White House, serving as assistant director for advanced manufacturing and robotics in the Office of Science and Technology Policy of the Executive Office of the President. He was partially supported by an ASME Swanson Foundation fellowship. In that role he helped shape the President's National Robotics Initiative and Advanced Manufacturing Partnership. As senior vice president and provost at Clarkson, Dr. Thorpe oversees the four colleges (School of Business, Coulter School of Engineering, School of Arts and Sciences, and Institute for a Sustainable Environment), the research centers, IT, Government Affairs, Library, and the division of University Outreach and Student Affairs. Dr. Thorpe has produced more than 120 refereed publications and graduated 20 Ph.D. students. He is a fellow of IEEE and AAAI.

C

Meetings and Speakers

MEETING 1
SEPTEMBER 10-11 2013
NATIONAL ACADEMY OF SCIENCES BUILDING
WASHINGTON, D.C.

Congressional Perspectives and Origin of Study
Mr. Kevin Gates, Professional Staff Member, House Armed Services Committee

HAF/A1 Perspectives
Mr. Bill Hampton, Force Development Integration Division

Air Force Education Requirements Board
Col Jeffrey White, Chief, Air Force Learning Division (A1DL)

Science, Technology, Engineering, Mathematics (STEM) and Management Navy's Specialized Degree Granting Graduate Programs
CAPT Michael Davis, N15, Director, Information, Analysis and Development Division
CDR Paul Acquavella, Education Branch Head, OPNAV N153

Air Force Institute of Technology
Dr. Todd Stewart, Director and Chancellor, Air Force Institute of Technology

NPS Overview for National Academies
RADM Jan Tighe, Interim President, Naval Postgraduate School

Financial Perspectives
Mr. Blaise Durante, Former Deputy Assistant Secretary for Acquisition Integration, Office of the Assistant Secretary of the Air Force for Acquisition

Advanced Academic Degrees for Military Scientists and Engineers
Mr. Pat Hogan, Chief, Acquisition Career Management and Resources Division, Office of the Assistant Secretary of the Air Force for Acquisition

MEETING 2
OCTOBER 16-17, 2013
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Uniformed Services University of the Health Sciences
Dr. Charles Rice, President, Uniformed Services University of the Health Sciences

Air University
Maj Gen Walter Givhan, Vice Commander, Air University

Financial Management Discussion
Ms. Ann Marburger, Comptroller, Air Force Institute of Technology

AFRL Overview and AFIT Synergy
Mr. Ricky Peters, SES, Executive Director, Air Force Research Laboratory

National Air and Space Intelligence Center
Mr. Gary O'Connell, Chief Scientist, National Air and Space Intelligence Center

Former AFRL/CC Perspectives
Maj Gen Richard Paul (USAF, Ret.)

Graduate School of Engineering and Management
Dr. Heidi R. Ries, Dean of Research, Air Force Institute of Technology

School of Systems and Logistics
Mr. Richard Wojick, Air Force Institute of Technology

The Civil Engineer School
Col Paul Cotellesso, Air Force Institute of Technology

Air Force Life Cycle Management Center
Lt Gen CD Moore II, Commander, Air Force Life Cycle Management Center

Wright State University Perspectives
Dr. Fred Garber and Dr. Brian Rigling, Professors, Department of Electrical Engineering, Wright State University

Defense Civilian Personnel Advisory Service
Mr. John Shearer, Director for Strategic Human Capital Planning

Value of AFIT to the Operations Research Analysis Career Field
Dr. Mark Gallagher, SES, Technical Director, Office of Studies and Analyses, Assessments and Lessons Learned

MEETING 3
NOVEMBER 6-7, 2013
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

President's Review
VADM Ron Route (USN, Ret.), President, Naval Postgraduate School

Graduate School of Engineering and Applied Sciences
Dr. Philip Durkee, Dean, GSEAS, Naval Postgraduate School

Graduate School of Operational and Information Sciences Overview
Dr. Dean McCormick, Dean, Graduate School of Operational and Information Sciences (GSOIS)

Naval Post Graduate School
Dr. John Arquilla, Chair, Defense Analysis, Naval Postgraduate School
Dr. Robert Dell, Chair, Operations Research, Naval Postgraduate School

School of International Graduate Studies Overview Brief for the National Research Council
Dr. James Wirtz, Dean, School of International Graduate Studies (SIGS), Naval Post Graduate School

Financial Perspectives
Mr. Kevin Little, Comptroller, Naval Postgraduate School

NPS Distance Learning Education Programs
Dr. Doug Moses, Vice Provost, Academic Affairs, Naval Postgraduate School

School of Business and Public Policy
Dr. Bill Gates, Dean, Graduate School of Business and Public Policy (GSBPP), Naval Postgraduate School

Science, Mathematics, and Research for Transformation 101 Brief for the National Research Council
Dr. Laura Stubbs, SES, Office of the Assistant Secretary of Defense (Research and Engineering)

MEETING 4
DECEMBER 5-6, 2013
KECK CENTER OF THE NATIONAL ACADEMIES
WASHINGTON, D.C.

Perspectives on DoD and Civilian Graduate Education Institutions
Dr. Marlin Thomas, Research Professor, University of Michigan

AFIT PhD Programs
Dr. Todd I. Stewart, Director and Chancellor, AFIT
Dr. Adedeji B. Badiru, Dean, Graduate School of Engineering and Management
Col Matthew D. Sambora, Senior Military Professor
Dr. Bradley S. Liebst, Head, Department of, Aeronautics and Astronautics (via VTC)
Dr. Nathaniel J. Davis IV, Head, Department of Electrical, and Computer Engineering (via VTC)
Dr. Nancy C. Giles, Head, Department of Engineering Physics (via VTC)
Dr. Joseph J. Pignatiello, Jr., Head, Department of Operational Sciences (via VTC)

Dr. Mark N. Goltz, Interim Head, Department of Systems Engineering and Management (via VTC)
Dr. Alan V. Lair, Head, Department of Mathematics and Statistics (via VTC)

National Defense University
Dr. Mary McCully, Acting Chancellor, Information Resources Management College, National Defense University

GTRI Approaches to Applied and Classified Research for the Department of Defense
Dr. Lon Pringle, Deputy Director, Georgia Institute of Technology Research Institute

United Technologies' Approach to Graduate Education Needs (VTC)
Dr. Michael Winter, Chief Engineer for Technology, Pratt & Whitney, United Technologies Corporation

Georgia Institute of Technology's Approach to Distance Learning
Dr. Nelson C. Baker, Dean, Professional Education, Georgia Institute of Technology

MEETING 5
JANUARY 8-10, 2014
KECK CENTER OF THE NATIONAL ACADEMIES
WASHINGTON, D.C.

Briefing: The Future Department of Defense Science and Engineering Workforce
Dr. Tim Coffey, Independent Consultant, National Defense University (emeritus)

STEM and Army S&T Enterprise
Ms. Nancy J. Harned, Executive Director for Strategic and Program Planning, Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology

MEETING 6
FEBRUARY 19-21, 2014
KECK CENTER OF THE NATIONAL ACADEMIES
WASHINGTON, D.C.

Writing Meeting

D

Select Findings and Recommendations from *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics (STEM) Workforce*

Listed below are select findings and recommendations for special emphasis.

Finding 6. Managing the STEM Workforce
The career development support for the DOD uniformed STEM workforce is excellent while the career development support for the DOD civilian STEM workforce is far less developed. The defense-related Industry lies somewhere between them. (See Finding 6-4.)

Recommendation 5. Upgrade Education and Training for the DOD Civilian STEM Workforce
The DOD should ensure that the education and training, and the re-education and re-training opportunities for its civilian STEM workforce are both commensurate with similar opportunities afforded career military personnel and tailored to the needs of the civilian workforce. (See Box S6.) (See Recommendation 5-2 and Finding 6-4.)

Other emphasized findings and recommendations in the report:

Recommendation 3-2a. The Department of Defense needs officially to define a STEM taxonomy that spans the military and civilian workforce in a manner that meets its requirements and accommodates the mission-driven needs of the services within the department. When determining whether to define STEM narrowly or more broadly, DOD needs to take into consideration the purposes for which this definition will be used and the funding issues addressed in Finding 4-1, giving due consideration to non-traditional STEM fields such as social sciences. Within the current budget environment the committee advises using a more narrowly defined STEM taxonomy for making training and education investment decisions for critical STEM skills.

Recommendation 4.1. The DOD should fund STEM recruitment and development in a manner that facilitates stability, such as multi-year programming, "one color" of money for STEM related costs, or funding based on a percent of total obligational authority. This would facilitate stability for long-term STEM investments and greater consistency across and within the services. In addition, DOD should require all services to justify, as part of the approval process, STEM-related manpower reductions in terms of impact on technology-based capabilities and, where appropriate, whether there has been sufficient return on investment from those who have recently completed postsecondary education paid for by the government.

Recommendation 4.3. The DOD should strengthen its ability to recruit, educate, and retain top STEM talent by offering competitive salaries and a constructive work environment, providing challenging and interesting problems in the workplace, enabling existing talent to keep up with the newly emerging scientific trends, and providing opportunities for the retraining of its STEM workforce to meet changing scientific and technological needs.

Recommendation 4.6. The DOD should consider changes in personnel policy that would enable it to move more nimbly to make competitive hiring offers in DOD-critical scientific and engineering fields. Some of these changes can be made internally within DOD. Where this is not currently, DOD should seek legislative and/or regulatory relief. The following changes warrant consideration by DOD:

- More active outreach and recruitment efforts, aimed at civilian hires, of needed scientists and engineers that emphasize the many exciting technologies that are being developed by DOD and their potential contribution to the nation;
- New measures to expedite recruitment offers for occupations in which DOD determines that it must compete with more nimble corporate recruiters;
- Additional authority to expedite security clearances needed for such positions, including permission for temporary hiring into non-sensitive roles pending confirmation of security clearance;
- Actions to protect or "ring-fence" science and engineering positions determined by DOD to be critical capabilities, thereby protecting the loss of such capabilities due to future RIFs and hiring freezes; and
- Further provisions to incentivize DOD scientists and engineers to seek additional continuing education and training in rapidly developing areas of science and technology.

Recommendation 5-2. Because DOD's STEM needs evolve, a strategic assessment of DOD's own STEM training/ education capacities should be undertaken periodically to ensure that its capabilities to prepare its existing workforce to serve DOD needs is sufficient. As a follow up to this assessment, DOD should create/adapt programs in support of its STEM professionals to maximize their currency in this rapidly changing science, technology, and DOD program/project management environment. The DOD effort could also include creating certificate and professional master's degree programs developed in partnership with universities and possibly industry, whose content specifically targets the educational and skills needs identified by DOD.

Finding 5-4. Integration of postdoctoral fellows into the DOD STEM mission is the fastest, most cost efficient way to recruit and screen PhDs for future career employment while making them aware of exciting DOD opportunities. Postdoctoral fellowships have been largely ignored in favor of higher-cost support of graduate students whose expertise (selected 6 years in advance) may not align with the rapidly changing needs of DOD. Although DOD has contracts to pay postdoctoral fellows through the National Research Council and the American Society for Engineering Education, among others, the funds come directly from laboratory operating budgets and compete in many cases with funds for staff salaries. A DOD-wide postdoctoral fellowship program that covers all costs of the fellow to the laboratories would be most cost-effective.

Recommendation 5-4. The DOD should initiate a postdoctoral fellowship program for recruitment of the highest quality STEM graduates into the DOD laboratories that covers all costs of the fellowships. The applications should include inputs from both the postdoctoral candidate and the doctoral research mentor.

Finding 6.4. The career development support for the DOD uniformed STEM workforce is excellent, whereas the career development support for the DOD civilian STEM workforce is far less developed. The defense-related industry lies somewhere between them.