SCIENCE & TECHNOLOGY POLICY INSTITUTE

Department of Defense Utilization of Military Scientists and Engineers

March 2014

Approved for public release;
distribution is unlimited.

IDA Paper P-5082
Log: H 13-001450

IDA SCIENCE & TECHNOLOGY
POLICY INSTITUTE
1899 Pennsylvania Ave., Suite 520
Washington, DC 20006-3602

IDA

The Institute for Defense Analyses is a non-profit corporation that operates three federally funded research and development centers to provide objective analyses of national security issues, particularly those requiring scientific and technical expertise, and conduct related research on other national challenges.

About This Publication

This work was conducted by the IDA Science and Technology Policy Institute under contract NSFOIA0408601, Task TP-20-1000.AH, "DoD Utilization of Uniformed Scientists and Engineers," for the Office of Science and Technology Policy. The views, opinions, and findings should not be construed as representing the official position of the National Science Foundation or the Office of Science and Technology Policy in the Executive Office of the President.

Acknowledgments

This publication is the result of a collaborative effort by members of the IDA Science and Technology Policy Institute and the IDA Systems and Analyses Center. IDA acknowledges and appreciates the contributions of the following staff members: Jocelyn M. Seng, Steven D. Kramer, George C. Tolis, Brian J. Sergi, Susannah V. Howieson, Rebecca A. Grier, Kaitlin E. Kleiber, and Maggie X. Li. IDA also appreciates the contributions of Pamela E. Flattau, Dennis O. Madl, Michael A. Rigdon, and Michael L. Dominguez who served as technical reviewers for this project.

Copyright Notice

© 2014 Institute for Defense Analyses
4850 Mark Center Drive, Alexandria, Virginia 22311-1882 • (703) 845-2000.

This material may be reproduced by or for the U.S. Government pursuant to the copyright license under the clause at FAR 52.227-14 (December 2007).

SCIENCE & TECHNOLOGY POLICY INSTITUTE

IDA Paper P-5082

Department of Defense Utilization of Military Scientists and Engineers

Executive Summary

Background

The Office of Science and Technology Policy (OSTP) asked the IDA Science and Technology Policy Institute (STPI) to characterize the demographics of military scientists and engineers within the Department of Defense (DOD) as part of a larger effort to evaluate the overall health and sufficiency of the U.S. science and engineering (S&E) workforce. The research team used quantitative and qualitative methods to bring greater clarity to how military scientists and engineers are used in DOD. The methodology included a literature survey, demographic analysis of DOD personnel databases, and several structured focus groups.

DOD meets its needs for advanced military technologies through its access to skilled scientists and engineers working in a variety of settings inside government and in the private sector. The uniformed military S&E officers employed by DOD that are the subject of this report totaled approximately 28,000 in 2011. These military scientists and engineers contribute to national security through: (1) their role as "translators" within DOD between the technical world and the operational world, (2) their ability to enhance the acquisition of complex technical systems, (3) their ability to act as liaisons between the private-sector civilian technology establishment and the military, (4) their flexibility to sometimes be more easily deployed to combat areas than civilians, and (5) their often relatively short terms in positions intended to help bring in new ideas. In some situations this last reason was considered to be a negative.

Findings

The major findings from this project follow.

- *Numbers of military scientists and engineers*. Over the past several decades, the number of military scientists and engineers has decreased from 61,000 (21% of all officers) in 1986 to 28,000 (13% of all officers) in 2011.
- *Differences across military departments in uses of military scientists and engineers*. The three military departments use military scientists and engineers to different extents, particularly in their in-house laboratories. Less than 2% of Army and Navy laboratory research staff members are military scientists and

engineers, compared to more than 14% of Air Force laboratory research staff. The implications of this difference were outside the scope of this project.

- *Comparability of military officer grade structure*. For fiscal year (FY) 2011, the grade structure of military S&E officers is at least comparable to that of all military officers up to the level of O–5. That is, the promotion opportunities for military S&E officers up to O-5 are similar to promotion opportunities for other officers within each Service. At the O–6 level and above, the grade structure is less comparable, with proportionately fewer military S&E officers being promoted into senior ranks.
- *S&E officer promotions*. Focus groups expressed concerns that S&E officers need to stretch beyond technical achievements and technical proficiency when looking for promotions. One way to do this would be to alternate assignments between S&E career fields and other military roles. Another way, particularly later in a career, would be to take up only nontechnical positions. These pathways were used by focus group members with varying success.
- *Defining the S&E career path.* Focus group members believed that the military S&E career path was not well defined. Careers were sometimes considered to be determined more by luck than by directed purpose. It was felt that there were insufficient higher level S&E billets in which to place military scientists and engineers. At some of the laboratories, the number of management positions filled by military scientists and engineers has decreased. In some instances, such as writing performance reviews, focus group members thought that civilian scientists and engineers in DOD did not understand the special needs of military scientists and engineers.
- *Effectiveness of scientists and engineers*. Based on the information collected, an assessment of how effectively military scientists and engineers are being utilized can only be provided anecdotally. One measure of effectiveness is how well DOD is utilizing scientists and engineers while on active duty, that is, whether they are using their technical expertise within their assignments. There appeared to be a tendency for the direct use of technical backgrounds early in a career with perhaps only indirect use or no use later in a career. Another measure of effectiveness is how well the member is serving DOD, particularly whether the military scientists and engineers are of appropriate quality (in comparison with their civilian counterparts in government) and performing well in their positions. As expressed in the focus group meetings, supervisors and colleagues are generally satisfied with the job performance and competence of the military scientists and engineers. A third measure is how well DOD uses the expertise of retired military scientists and engineers. Many of the focus group members

thought this could be improved, particularly since military retirees may consider civilian DOD and defense-related contractor employment as a post-retirement career track.

- *Civilian vs. military scientists and engineers*. Some friction and competition is apparent between military and civilian scientists and engineers at some of the DOD laboratories. This may be due to limited positions, differences in recognition, differences in opportunities, and differing career goals of the two groups. This may be similar to a situation at the military schools between civilian and military faculty (including scientists and engineers).
- *Data on military scientists and engineers*. Important and militarily useful information about the backgrounds of military scientists and engineers is lacking in the DOD Defense Manpower Data Center (DMDC) database. Specifically, the education-discipline-degree data field is often not populated for military scientists and engineers, while it is for civilian positions. In addition, each department has its own codes for Military Occupational Specialty in comparison to civilians, who have a common occupational code structure, defined by the Office of Personnel Management.

Possible Ways to Improve the Use of Uniformed S&E Officers

OSTP asked for suggestions for ways to improve the use of uniformed S&E officers. Given the limitations of the data, these potential steps are based largely on the views and opinions conveyed in the focus groups. The members of the focus groups perceived an underutilization of S&E that is resulting from challenges in the career path and retention of S&E officers. In particular, the discussants believed that existing promotion structures discouraged S&E officers from pursuing technical work or research, and that career paths for uniformed S&E personnel were less accessible and less well defined than those pursuing administrative or program manager tracks. These concerns were thought to be related to the small number of billets available for S&E positions, the valuation of technical expertise in the promotion process, and shortcomings in the S&E placement processes.

The suggestions of focus group members have potential advantages and disadvantages with respect to how uniformed scientists and engineers are used. Accordingly, these suggestions may have unknown consequences for the overall health of the military S&E community or for the careers of participating officers. Thus, if pursued, the suggestions should be implemented first as experimental programs, with appropriate data collection and analysis. The size and nature of the experiments should be chosen to produce small perturbations on current activities since it may not be possible to predict all of their direct outcomes and indirect ramifications.

The research team did not attempt to rank these suggestions or determine the implementation challenges they might face. The ideas are described in the main body of the paper and summarized briefly below:

- Increase the number of higher ranked S&E billets.
- Reserve promotion slots for outstanding officers making substantial use of their S&E knowledge.
- Pair junior military scientists and engineers as "technical deputies" with more experienced counterparts when new applied research projects that are anticipated to last only a few years are starting.
- Increase the recognition of military scientists and engineers by developing department-specific or joint awards.
- Track the transition from military to civilian positions (particularly DOD civilian positions) by S&E officers after they leave the military.
- Provide a mechanism for direct conversion to civil service S&E research and management careers.
- More adequately match technical backgrounds to assigned positions for newly graduated incoming military scientists and engineers.
- Establish an experimental program to assess if military scientists and engineers are more effective acquisition program managers than non-S&E military staff when managing highly technical programs.

In databases maintained by the DMDC, the research team found that the education discipline field is largely unpopulated for military S&E personnel, while it contains extensive data for civilian positions. The research team thus recommends that DOD better track the educational degrees of military personnel so as to help DOD monitor the utilization of its scientists and engineers in the future.

Contents

1. Introduction

A. Objective and Tasks

The Office of Science and Technology Policy (OSTP) tasked the IDA Science and Technology Policy Institute (STPI) to investigate and assess the effective utilization of military commissioned officer scientists and engineers. (Although enlisted and noncommissioned officers are also an important component of the technical military force, they are not the subject of this report.) The objective of the task was to characterize the demographics of military scientists and engineers within the Department of Defense (DOD) and to determine how they were being utilized to meet national security needs.

The course of the research for the task was guided by four key questions:

- How are assignments of military scientists and engineers determined?
- What is the career path progression of military scientists and engineers?
- What are anticipated future military scientific and engineering (S&E) personnel requirements?
- How effectively are military S&E officers currently being utilized?

As discussed later in this report, not all these questions could be answered definitively.

Concern over the health and sufficiency of the S&E workforce is part of a larger effort to understand the overall Federal national security science and technology (S&T) enterprise. OSTP asked the research team to assess recent trends and the current status of the military S&E workforce, and the analysis that follows sheds new light on the question of how well DOD is utilizing its military S&E talent to ensure that it will keep pace with its own needs and technology developments across the globe.

B. Information Sources and Methods

The STPI research team's approach to this project was to perform the following tasks.

- Conduct a literature review to explore the utilization of military scientists and engineers, concentrating on the coverage of the U.S. military from U.S. sources.
- Characterize the utilization of military scientists and engineers quantitatively by using DOD human capital databases to determine ranks, degrees, utilization,

affiliation, promotion rates, and other demographics of military scientists and engineers.

- Use focus groups and discussion to collect qualitative information not available from the quantitative data, including perceptions about promotion possibilities and the appropriate use of military scientists and engineers.

Industrial analogs were considered but not found to be useful for the purposes of this project since they did not adequately represent the military S&E and nonmilitary S&E components simultaneously present in many DOD organizations.

For the quantitative data review, the research team analyzed the following data sources:

- Defense Manpower Data Center (DMDC) records
  - DOD Standard Address Database
  - DMDC fiscal year (FY) 2011 military personnel records extract
  - Historical DMDC information
- DOD Instruction 1312.1-I, "Department of Defense Occupational Information Collection and Reporting" (DOD 2013)
- Department of Education, Classification of Instructional Programs, 2000 Edition

The principal source of workforce data used in this project was the personnel database the staff of the DMDC maintains. For this project, the DMDC staff provided the research team with files that reflect the personnel data from the entire DOD military officer workforce at 5-year intervals from 1986 through 2011, without individual identifying information.

The methodology for a given year was to first extract military officer records with relevant data elements as defined in DOD Instruction 1312.01, "Department of Defense Occupational Information Collection and Reporting" (DOD 2013).The next step was to select the military S&E personnel records by using a task-defined definition for them. Steps were then taken to aggregate, categorize, and analyze data by key parameters (occupational category, age, grade/rank, and educational level). The data elements were interpreted using relevant taxonomies and dictionaries. Finally, workforce demographic characteristics were tabulated and graphed.

For the interviews and discussions, potential candidates were identified and an attempt was made to include the following areas and organizations:

- Workforce Policy
  - Office of the Secretary of Defense for Personnel and Readiness

- Select S&E senior officers
- In the S&T community
- In acquisition community
- In test and evaluation community

- Assignments Personnel
  - Army Personnel Center
  - Navy Personnel Center
  - Air Force Personnel Center

In addition, after this task began, the research team was asked by the OSTP sponsor to utilize structured focus groups along with conducting individual interviews. The 2- to 3-hour focus group discussions normally consisted of about a dozen people and were led by a trained and experienced IDA facilitator who has a doctorate in human factors and experimental psychology. Typically, two members of the research team as well as representatives from OSTP were observers.

The next three chapters provide an overview of the information gathered through the three approaches explored by the research team: Chapter 2 describes the results of the literature review; Chapter 3 provides quantitative, demographic data obtained through analysis of the DMDC records; and Chapter 4 outlines the results of the focus group discussions and interviews. In conclusion, Chapter 5 summaries the findings from these methods and explores possible options for improving the utilization and effectiveness of military officers who are scientists and engineers. Given the limitations to the data provided by the DMDC (discussed in Chapter 3), these options are based largely on the views and suggestions conveyed in focus group discussions.

The research team also performed additional research activities to complement the above methods. A brief exploration of the history of military scientists and engineers was performed and is provided in Appendix A. An attempt was also made to include information on how the Office of the Secretary of Defense (OSD) and the leadership of the military departments view this part of the military workforce. A search of statements by senior DOD leaders on the topic can be found in Appendix B. Furthermore, information from the National Science Foundation's Science and Engineering Indicators was used and can be found in Appendix C.

Regarding the quantitative data, Appendix D gives a table listing the specific DMDC data elements (variables) received for the data analysis, while Appendix E provides additional demographic data not detailed in Chapter 3 (including information from official biographies of general and flag officers). Additional information and background on the focus group meetings and interviews can be found in Appendix F, which is followed by a list of references and abbreviations.

2. Background and Literature Review

The use of military officers with advanced technical expertise dates back at least to the days of the early Roman Empire. As the professional training of scientists and engineers became more formalized in universities during the nineteenth century, this tradition continued. Under the leadership of Sylvanus Thayer, in 1817 West Point began emphasizing science and engineering in its cadet curriculum. Albert Michelson, the first American to win a science Nobel Prize, served as a naval officer shortly after the Civil War and again during World War I. By World War II, the importance of science and technology (S&T) in warfare was increasingly emphasized, and several studies expressed concern about the effective use of military scientists during World War II (U.S. Army 1948). That concern has continued to the present day (Nichols 2002).[1]

Many of the concerns that prompted this task have surfaced in previous studies.[2] In spite of the advances in technology over time, many of the personnel issues that influence effectiveness are unchanged. These include promotion and leadership opportunities, how to incorporate them into the rest of the force, the balance between officer leadership and technical requirements, their value and effectiveness, and their appropriate numbers and educational backgrounds. The Army, Navy, Air Force, and the Department of Defense have all conducted studies examining the health and sufficiency of U.S. military scientists and engineers and exploring related personnel issues, and this section provides an overview from these studies.

A. Army

From 1981 to 2001 the Army conducted four major studies that examined its requirements for military scientists and engineers and what would be desirable working conditions for them. The conclusion of all of them was that a contingent of technically competent officers was a necessity. The following brief descriptions are taken from Nichols (2002).

---

[1] A more detailed look at the history of military scientists and engineers is provided in Appendix A and illustrates that the role and effective use of military scientists and engineers has been a topic for many years.

[2] See, for example, Nichols (2001), U.S. Army (1948), Thane (2007), NRAC (2010), Hallion (2010), and DePalma and Brobst (2008).

The 1982 Army Science Board Summer Study concentrated on personnel in the research, development, and acquisition area. It concluded that (1) technically trained officers are needed in the research, development, and acquisition (RD&A) field and in the requirement-generation process, (2) S&E officers do not have suitable career opportunities, (3) there should be a new career RD&A career path where the S&E officer can serve primarily in RD&A positions with occasional operational assignments, and (4) their promotion opportunities should be similar to those of combat officers.

A 1988 Leader Development Action Plan and a 1989 Uniformed Army Scientist Working Group came to similar conclusions. They reiterated the need for officers with technical doctorates to work in RD&A and the laboratories. A 1991 briefing based on these analyses determined a requirement for 250 RD&A S&E officers.

A 1990 Army Laboratory Command review was begun because of a concern about low retention of military scientists and engineers in the Army laboratory system, at least partly due to poor promotion possibilities. This review advocated a quality uniformed Army scientist program with a formalized career field and appropriate promotion opportunities. Some benefits of this type of program were thought to be increased soldier/civilian S&E linkages, closer connections between technology and the battlefield, acquisition process improvements, and higher retention of scientists and engineers.

The Army Science Board issued a study in 1996 that considered the use of military scientists and engineers. It felt that S&E officers were important to the Army. Some of its conclusions were controversial in that it said that there was low technical proficiency among line officers and in the Combat Development organizations. The study said that the Army did not value technical knowledge as a required line-officer attribute and that the Army as a whole did not value S&E officers for their S&E knowledge. Recommendations from the study included the following:

- Establishing a separate career path for S&E officers with a clear promotion progression.
- Identifying and filling uniformed technologist positions in the support and operational Army.
- Having more S&E officers on senior general staffs.
- Raising the S&E standards.

Implicit in these recommendations is that the Army cannot depend solely on contractors and civilians to transition technology from basic concepts into actual military capability. In 2001, the Army had approximately 53 billets specifically for technical doctorate holders and a total of about 121 non-medical officers on active duty with technical doctorates (Nichols 2002).

In 2003, the Army started the Uniformed Army Scientist and Engineer (UAS&E) program (Thane 2007). Before this, in the mid-1980s, the Army had initiated the Technology Enhancement Program, which sent entry-level second lieutenants and mid-career majors to earn technical master's degrees and PhDs, respectively (Shoop and Alford 2002). As originally conceived the UAS&E program had about 100 trained officers from major to colonel with advanced technical degrees who would serve in defense laboratories, at U.S. Army Research, Development and Engineering Command (RDECOM), on Army and joint staffs, and in key advisory positions. An individual would typically study for advanced degrees in 2- to 4-year blocks of time interspersed with more traditional military activities. As the program was actually implemented, the UAS&E officers were primarily drawn from RDECOM acquisition officers who already had an advanced technical degree. In 2006, four officers started PhD programs and two started master's programs. By 2007, there were 127 members. In the late 2000s, however, there were funding issues associated with these degree programs (Brown 2007), and the program was officially ended in January 2010. Anecdotally, this was due to competition for personnel and funding from other Army priorities. There have recently been calls for its reinstatement.

A 2013 Army Science Board study also examined Army military scientists and engineers (Army Science Board 2013). It concluded that on the military side, there is no well-defined S&E career path in the Army; thus, rebuilding a uniformed S&T core of technically competent officers should be an Army priority. It felt that senior DOD and Army leadership should support actions to increase the number and quality of military scientists, engineers, and technical leaders by, among other activities:

- Reestablishing the UAS&E program.
- Increasing graduate-level science, technology, engineering, and mathematics (STEM) education opportunities that support the critical must-do-in-house technologies.
- Establishing UAS&E billets as rotational assignments throughout the Army S&T enterprise.
- Increasing S&E summer intern opportunities for Reserve Officer Training Corps and U.S. Military Academy cadets to encourage future technical career field choices.

B. Navy

The major research laboratory of the Navy is the Naval Research Laboratory (NRL). Currently, less than about 0.5% of its staff are military officers. This is consistent with its historical background. When it was first conceived about a century ago, Thomas Edison and some others involved in its founding wanted it to be essentially a civilian organization. Edison wanted it to have "nothing to do with the Navy except that if any naval officer has an idea, he can go there and have it made."

The head of the Naval Consulting Board in 1921 felt that civilian technologists not under the influence of Navy culture should be in charge of the experimental work. In 1941, only about 5% of laboratory personnel were military officers, although this ratio increased to almost 50% by 1945. This large and temporary wartime percentage was due at least in part to an agreement with the local draft board where drafted civilian scientists already working at the laboratory were inducted into the Navy and then assigned to positions at the laboratory.

The Navy has long used uniformed scientists and engineers in positions outside of NRL (Weir 2001). Don Walsh, the Navy lieutenant who participated in the 1960 Trieste dive effort to the Challenger Deep, had an engineering degree from the Naval Academy. In 2010 the Assistant Secretary of the Navy (Research, Development, and Acquisition) sponsored a study by the Naval Research Advisory Committee. Among other topics this study briefly examined the role of military scientists and engineers in the Naval Forces (NRAC 2010). The Marines do not operate any dedicated research and development laboratories and tend to act as a "customer" for Navy laboratories. Although specific Naval Force requirements can be quite different from that of other services, the study's conclusions had much in common with the Army analyses:

- The Department of the Navy faces the future with a seriously weakened technical workforce.
- The Department must rebuild technical leadership in the uniformed Navy.
- The Department should provide greater incentives for military personnel to achieve technical expertise and not just to receive graduate education.
- The Department should increase the number of military billets in the Naval Forces Research and Development enterprise. For example, the Naval Undersea Warfare Center located in Newport, RI, had about 2,100 scientists and engineers but only 31 active duty technical and nontechnical military personnel. The SPAWAR (Space and Naval Warfare Systems Command) Systems Center–Atlantic had 1,247 scientists and engineers but a total of only 22 technical and nontechnical officers. Among other benefits this will help to provide the civilian workforce with an essential understanding of operational needs by working side-by-side with experienced military personnel.
- Military personnel who have an expanded understanding of research and development capabilities may find this knowledge can enhance their decision-making abilities when they assume key leadership roles later in their careers.
- There is a perception among some military scientists and engineers that promotion opportunities are greater in the program manager career track than in the technical track.

- There are too few military S&E assigned to technical billets in warfare centers and systems commands.
- Closer coordination between the operational and technical communities is essential.
- Military test pilots, who typically have technical degrees, are now all assigned to test squadrons and no longer work alongside scientists and engineers at the Naval Air Warfare Center Weapons Division at China Lake, CA, as was done in the past.

C. Air Force

Like the other military departments, the Air Force and its predecessors have used military S&E almost from the birth of aviation (Hallion 2010). In 1914, the U.S. Army Signal Corps sent technical officers to the Massachusetts Institute of Technology to study aeronautics, and in 1938–1939 Wright Field sent seven officers to study at major engineering universities. From 1955 to 2005 the percentage of Air Force officers who were categorized as being in scientific research and development engineering varied from about 3% to 7%. In 2008, there were a total of 4,722 61S/62E S&E officers in a total Air Force officer corps of 64,512.

Shortly after the end of World War II in December 1945, the Director of the Army Air Forces Scientific Advisory Group, T. von Karman (1945), wrote in a report to Gen. H. Arnold about the effective use of technical officers:

> It is believed that many shortcomings of research and development in the Air Forces originate from a lack of appreciation, at higher levels, of the qualifications necessary for successful direction of a laboratory or a proving ground. The theory that an intelligent officer is able to direct any organization, military, technical or scientific, is certainly obsolete. An officer in charge of a laboratory or proving ground can be really useful only if he holds the position for a sufficient time to become thoroughly acquainted with the subject matter and personnel. Officers with engineering training on engineering duty must not be handicapped, as regards promotion, because of long tenure of the same assignment or time spent in acquiring advance education.
>
> The position and rank of officers responsible for research and development must be made commensurate with the importance of their work and achievement and must not depend on the size of the organizations under their command.
>
> Scientific results cannot be used efficiently by soldiers who have no understanding of them, and scientists cannot produce results useful for warfare without an understanding of operations.

A recent 2010 report by the National Research Council (NRC) commissioned by the Air Force examined the Air Force technical workforce, including the uniformed component (NRC 2010). It confirmed the importance of technically competent officers to the Air Force mission. This study emphasized the distinction between what it called STEM-degreed (having at least an undergraduate degree in a technical field), STEM-cognizant (lacking a specific technical degree but by reason of training or experience having some knowledge of a technical subject), and STEM-assigned (being assigned to a position that required a STEM degree). Some of its findings and recommendations are:

- Only five military officer career fields have stated requirements for STEM education.
- The Air Force does not have a consistent definition of its STEM workforce.
- About 40% of the officers in the acquisition management career field have technical degrees.
- The Air Force should revise as appropriate its current requirements for STEM capabilities.
- Multiple reductions in STEM-degreed officer authorizations and STEM-degreed personnel have had a negative impact on manning levels and morale and may be affecting the ability to recruit.
- The U.S. Air Force Academy (USAFA) is a major source of new officers that are either STEM-degreed or STEM-cognizant. About 41% graduate with a STEM degree, and this number has been declining. The USAFA should periodically review the core curriculum to ensure that graduates with non-STEM majors nonetheless are STEM-cognizant.
- It is important to realize the importance of STEM-degreed *and operationally experienced* officers in the statement of operational requirements. Without the ability of operational users to translate operational needs into technical terms, the acquisition community is at a serious disadvantage.
- Putting officers who are neither STEM-degreed nor STEM-cognizant in the highest management positions can also result in shortfalls in the oversight of important defense acquisition programs.
- There are captain and field-grade manning issues in the career fields that require a STEM degree. One of these is the demand on field-grade officers to deploy.
- Retention rather than recruitment is one of the primary challenges confronting managers of STEM-degreed officers.
- Within the acquisition community, STEM-degreed personnel compete well for promotions at the lower ranks, but they do not compete as well for promotions to higher ranks. Thus, the acquisition workforce is rich in STEM-degreed lieutenants and undermanned in STEM-degreed officers at every higher grade.

- The Air Force does not currently have a process in place to systematically review its allocation and utilization of STEM-degreed officers in light of changing requirements and priorities. The Air Force should establish a process to review systematically and (at least) annually the utilization of all of its STEM-degreed officers.
- The Air Force Institute of Technology resident school offers graduate STEM education programs that address problems of unique importance to the Air Force; comparable programs are not available at civilian institutions.

Partly in response to the types of concerns in the National Research Council report, in 2011 the Air Force developed and instituted a strategic roadmap called Bright Horizons to develop and manage the S&E workforce of the future (U.S. Air Force 2011). This includes the approximately 10,000 core STEM officers. With regard to military officers, one goal is to establish adequate and predictable funding levels for military billets. Another priority is to assess whether the Air Force should establish a goal for the minimum percentage of U.S. Air Force Academy and other commissioning source graduates with a STEM major. It also has an initiative to review on a scheduled basis the curricula at the Air Force Institute of Technology and USAFA to ensure that STEM curricula are consistent with the mission need of the Air Force. There is also a goal for each STEM career field to identify and baseline for officers required skills training, professional continuing education, and career-broadening opportunities. Since this is a rather new program, it is too early to assess its success.

D. Department of Defense

The Director, Defense Research and Engineering, in 2009 commissioned from the MITRE Corporation's JASON Program Office a report to examine some national security aspects of S&T. The report recommended that DOD (MITRE 2009):

> Establish a Research Corps within each service to address the chronic S&T personnel issues within the services. DOD should develop an S&T Corps to bring in military people outside of the normal line promotion process. Routine rotations across service boundaries should become normal career progress. Promotions should be based on the value of research contributions to national security, beyond service needs. This would more properly value both personnel and research programs. Civilians should also be assigned to the S&T corps and be allowed to compete for opportunities across service lines. The goal should be to foster the growth of a dynamic research pool across DOD that is protected from advancement pressures of the operational and acquisition communities. These steps would be analogous to the service medical corps or acquisition corps and so fit the model for joint service that DOD has adopted. The increased professionalism, training, career paths, Defense-

> wide mobility, visibility, and esprit would all help address the problems of research personnel within DOD.

The concept of a separate promotion track for military scientists and engineers was also a common theme for the focus groups convened for the present task because of the belief that a separate track would enable military scientists and engineers to compete for promotions among themselves rather than against all officers in the military department.

Three years later, a report by the Defense Science Board (DSB 2012) specifically examined basic research conducted by DOD, concluding:

> Maintaining a constant influx of new ideas and fresh perspectives is important to the vitality of the DOD laboratories. … Further, the rotation of military officers between operations and research can bring a fresh understanding of operations to the laboratories and a higher level of technical literacy to the operational military.

It recommended that (DSB 2012):

> DOD laboratory directors work with the military services to create additional billets at DOD laboratories for qualified military officers with the eventual goal to make S&T a valued military career path, on a par with pilots or intelligence experts.

The implication of this statement is that science and technology is not now considered a valued component of a military career path, a sentiment echoed by many of the participants in the focus groups for the present task.

3. Demographic Analysis

A. Definition of Military Scientists and Engineers Population

There is no standard procedure for clearly identifying the military S&E population. While the scope of the project includes research scientists (typically with advanced technical degrees), it also includes commissioned military officers with at least a technical baccalaureate degree serving in other capacities (e.g., acquisition and deployed units). At the request of the sponsor, officers with medical degrees (i.e., doctors, dentists, and veterinarians) were not included.

The research team's intention was to identify those officers with science and engineering degree disciplines referenced by the Department of Education taxonomy Classification of Instructional Programs (see Appendix D for quick reference to the classification). Information on S&E degrees was thought to be available in the Defense Manpower Data Center (DMDC), a personnel database maintained by DOD that includes data on all military and civilian personnel. The data set generated by the DMDC included all military officers for the years 1986 through 2011.

This method worked well in a previous IDA study of the DOD civilian workforce since the data field for degree discipline, which was part of the DOD record, contained information on the type of degree.

However, unlike for the civilian records, the data field for degree discipline, which is a part of the DMDC record for the military (i.e., Educational Discipline Code; see Table D-1 in Appendix D) was sparsely populated with data. Data for naval officers was the most complete, with about 40% of the personnel having degree discipline information. Since it was not clear if this amount of data represented an appropriate cross-section of personnel, the degree discipline data field was not used.

This lack of information available for understanding the military scientists and engineers in the military database was also noted in a recent National Academies report (NRC 2014):

> After examining the data, the committee decided it did not have confidence in the usefulness of the DOD classification system to identify military STEM occupations. Thus the committee did not feel justified in drawing any conclusions about the military STEM workforce from the data provided by the DMDC.

The report also observed (NRC 2014, 3–17):

> Due to difficulties associated with defining military STEM occupations, the committee was not able to assess the military STEM workforce using the data provided by DMDC.

While acknowledging this data deficiency, the team attempted to use the DMDC data to understand the military S&E workforce. Lacking the educational degree discipline information, the team attempted to identify the military S&E officer population by DOD Occupational Code in the process described below.

The first step was to determine the total population of military officers. Based on the FY 2011 DOD personnel data received from DMDC, the military comprises 1.4 million members, of which 218,552 are officers. Figure 1 shows the distribution of military officers among the Air Force, Army, Navy, and Marine Corps.

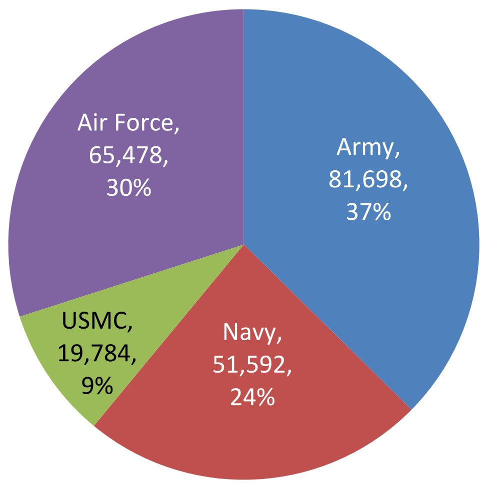


Figure 1. DOD Officer Census: Total 218,552 Officers (FY 2011)

Table 1 and Figure 2 show military officer populations by grade and by service in FY 2011. The general grade structure peaking at the O-3 level is similar for all four services.

Table 1. DOD Officer Census (does not include 976 general and flag officers)

Grade	Army	Navy	USMC	Air Force
O-1	10,167	6,558	2,788	6,728
O-2	9,384	6,531	3,840	7,219
O-3	30,064	16,868	6,518	23,222
O-4	17,231	10,712	3,924	14,521
O-5	10,022	7,131	1,929	9,916
O-6	4,508	3,542	697	3,555

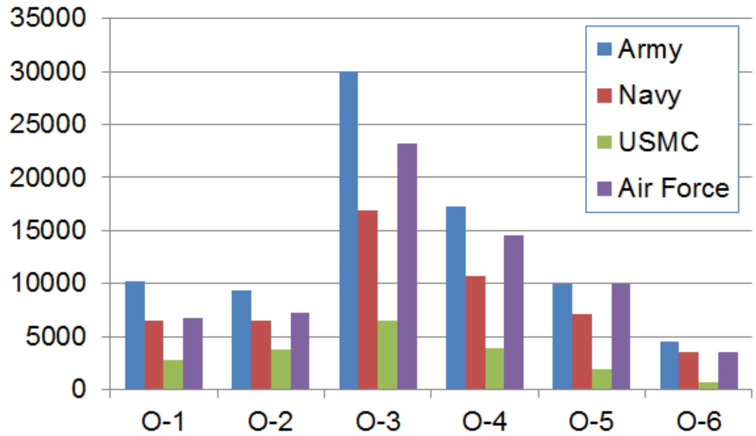


Figure 2. Grade Structure of DOD Military Officers (FY 2011) by Department

The next step required using the DMDC to determine the occupational codes of these officers. Figure 3 shows the distribution of military officers within the DOD Occupational Codes, defined by DOD I 1312.1-I. Figure 3 shows that the largest population is composed of tactical operations officers, who can have direct responsibility for conducting combat operations. The second largest population is the one made up of health-care officers. Each DOD occupational category has subcategories, and three categories—Administrators, Scientists and Professionals, and Engineering and Maintenance—are thought to have many scientists and engineers. As a result, the research team examined these three high-level DOD Occupational Codes of S&E interest. Unfortunately, the results did not have sufficient definition. That is, the resulting S&E officer population totaled 54,000, which was deemed too large a population given some informal service estimates.

Because of lack of access to the educational degree data and the deficiency of the high-level occupational codes, the most specific occupation information available for all officers was examined. Four occupation data fields are included in the personnel records: duty occupation, secondary duty occupation, primary service occupation, and secondary service occupation. The duty occupation codes identify the areas in which the officer is currently working. It is possible, and in some cases perhaps likely, for an S&E trained officer to be working in a non-S&E position and for the converse to occur. In contrast, the primary service occupation code is associated with the area in which the officer was primarily trained. As a result, it was determined that of the data available, the primary service occupation represented the closest (although not perfect) proxy for identifying scientists and engineers.

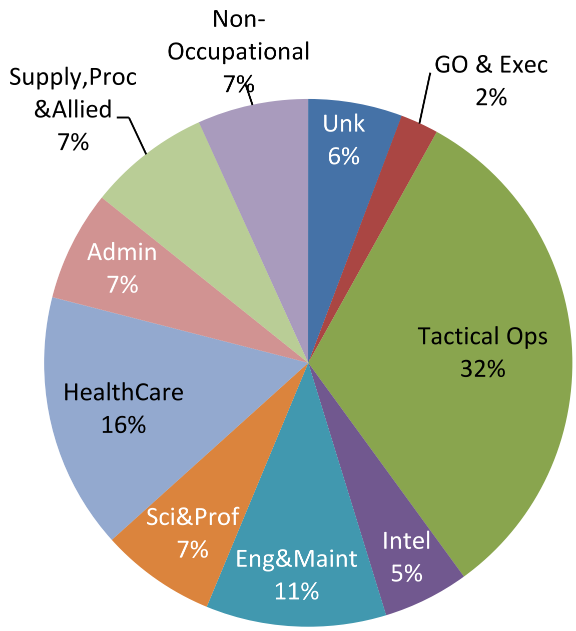


Figure 3. Total Officer Population Distribution within DOD Occupational Categories (FY 2011)

The military S&E population of interest was then defined based on key words within the officer's Primary Service Occupation Code titles. The result was a total population size reduction from 54,000 (defined by the three originally chosen DOD Occupational Categories) to about 28,000. The following major key words were used to define the S&E population:

Acquisition	Mathematics
Biology	Meteorology
Chemistry	Physics
Communications	Psychology
Computer	Research
Electronic	Scientist
Engineer	Tech
Information	Test

Most of these key words, such as *biology, scientist, research, engineer,* and *physics,* seem to indicate an S&E background, although this may not be true in all instances. Also, key words such as *information* and *acquisition,* which were included in an attempt to capture as many S&E officers as possible, may include non-S&E officers as well.

Figure 4 shows the distribution of military scientists and engineers by the key word in the title corresponding to their Primary Service Occupation Code. Note that there may have been some double counting if multiple key words are in the title.

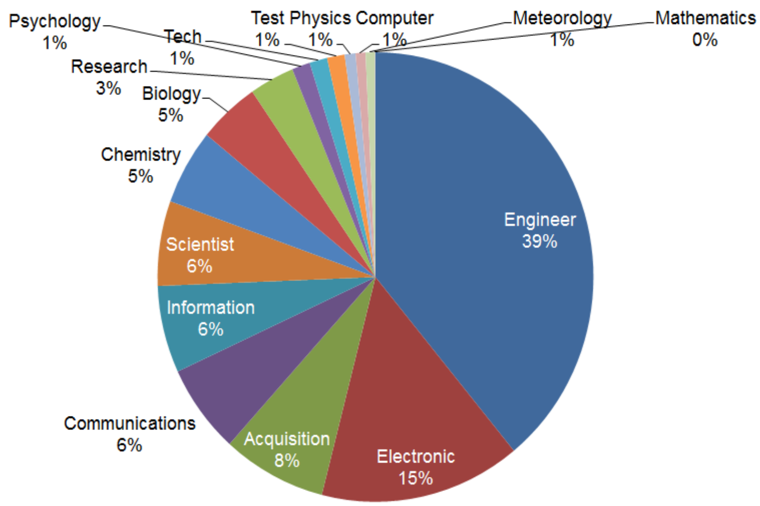


Figure 4. Distribution of Military S&E, defined by Key Word in their Primary Service Occupation Duty Title (FY 2011)

Based on these key words, the research team defined scientists by the terms *scientist, chemistry, biology, research, psychology, physics,* and *mathematics.* In aggregate, the military scientists and engineers can be characterized as approximately 20% scientists and 80% engineers.

With this definition, the current 28,000 DOD S&E military officer population corresponds to the distribution indicated in Figure 5. The first two numbers correspond to the two-digit DOD occupational categories which follow that number. After the category description is the number of officer scientists and engineers identified to be in that category, followed by the percentage. Additional characterization of the current demographic information can also be found in Appendix E.

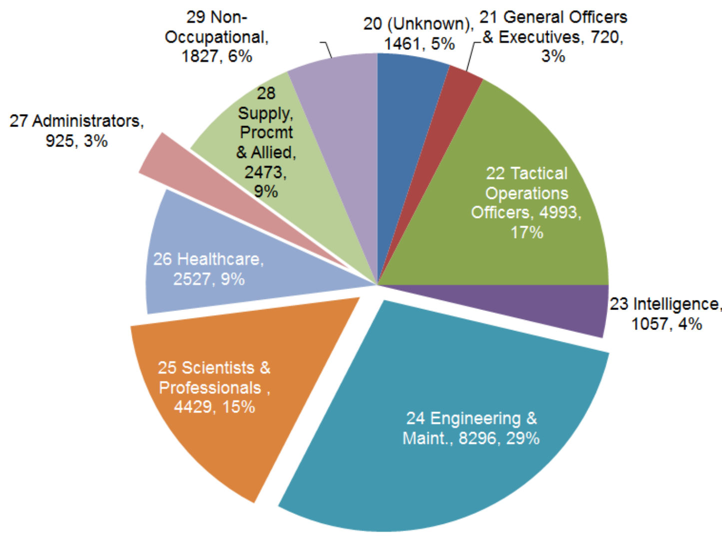


Figure 5. S&E Population Distribution within DOD Occupational Categories (FY 2011)

B. Historical Trends

After the end of the cold war in 1991, the total number of military officers progressively declined until FY 2001, after which the total number began increasing slightly. Figure 6 shows this trend.

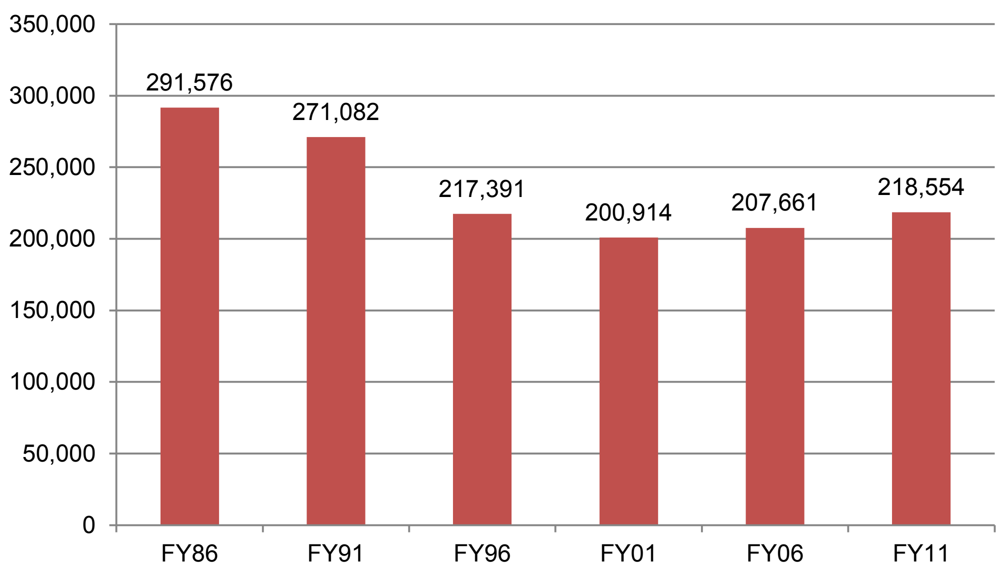


Figure 6. Historical Data of All Officers (FY 1986–FY 2011)

Correspondingly, over the past several decades, the number of military scientists and engineers has declined. From 1986 through 2011, the total number of military officers in the active U.S. Army, Navy, Marine Corps (USMC), and Air Force has decreased from about 291,000 to 218,000 with a steeper decline in the relative number of military scientists and engineers from 61,000 to 28,000, or from about 21% to 13% of the total officer force.

Figure 7 shows the total number of S&E officers by military department and the historical trend of military S&E officers within each department. With the exception of the USMC, which has relatively low number of military scientists and engineers, there is a decrease in military S&E population in all the departments. In absolute and relative terms, however, the decrease was different for the different services. About 67% of the decrease in scientists and engineers between FY 1986 and FY 2011 was due to a reduction in the Air Force S&E officer population by 20,000. The Air Force had only one-third the number of scientists and engineers in FY 2011 as it did in FY 1986. Put another way, in FY 1986 the Air Force had half the total S&E officers in the military but only about one-third the total by FY 2011. In FY 2011, the percentage of officers who were scientists and engineers was about 20% in the Navy, 13% in the Army, and 11% in the Air Force.

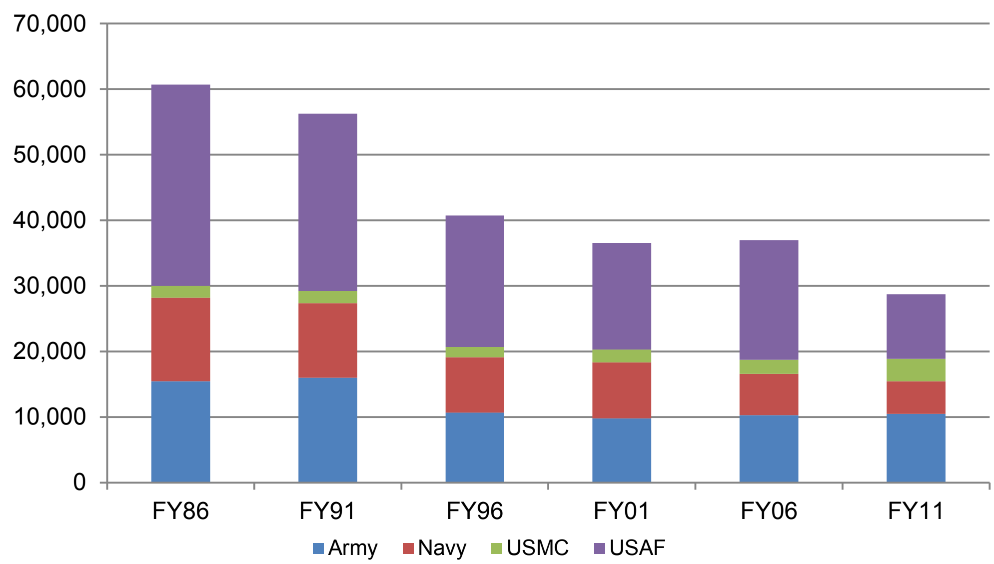


Figure 7. Historical View of S&E Officers

C. Characterization of the Military S&E Population

Table 2 shows the 25 most prominent occupations within the military officer S&E population. The word "engineer" appears explicitly in 10 of them, and together they comprise about one-half of all military officer scientists and engineers. In total, the 25 occupation categories shown in Table 2 contain about 75% of the total population of S&E officers.

Table 2. S&E Population in the Top Primary Service Occupation Codes

Primary Service Occupation Code Title	Count
Engineer	2,904
Acquisition Manager	2,149
Combat Engineer Officer	1,677
Chemical, Biological, Radiological, and Nuclear (CBRN)	1,398
Developmental Engineer, Electrical/Electronic	1,130
Communications Officer	1,047
Combat Engineer	991
Communications-Electronics Engineer	925
Developmental Engineer, Project	840
Civil Engineer, General Engineer	772
Signal Intelligence/Electronic Warfare	641
RL - Special Duty Officer Billet - Information Professional Officer	559
Operations Research Analyst	520
Preventive Medicine Sciences	463
Developmental Engineer, Aeronautical	452
Behavioral Sciences	448
Laboratory Sciences	447
Information Systems Management	422
Tactical Signal Intelligence-Electronic Warfare	414
Operations Research/Systems Analysis	367
Developmental Engineer, Mechanical	324
Reconnaissance/Surveillance/Electronic Warfare Combat Sys Officer, RC-135 EWO	308
Bioenvironmental Engineer, General	286
LDO - Engineering/Repair, Surface	273
LDO - Electronics, Surface	269

Figures 8–10 show the wide organizational distribution of military scientists and engineers in FY 2011 for the Army, Navy (including USMC), and Air Force, respectively.

These pie charts illustrate several key points. The first is that most uniformed scientists and engineers are not in organizational components where they might be expected. This occurs partly because the number of positions at laboratories and military academies and colleges is relatively small but also because civilians may be used in their stead in organizations that require scientists and engineers. For example, just by its name the Army Corps of Engineers would be expected to be heavily populated by uniformed scientists and engineers. As Figure 8 shows, however, this organization has the lowest representation of any shown.

There are also some significant differences between services. Figures 8 and 9 show that the Army and Navy have the largest cohorts of scientists and engineers in the Army Forces Command and the Commander—U.S. Atlantic Fleet, respectively. A primary mission of both of these commands is to provide existing combat-ready forces to Combatant Commanders. In contrast, as shown in Figure 10, the largest Air Force S&E component is in the Air Force Materiel Command, whose main mission is to conduct research, development, test, and evaluation and to provide acquisition management services and logistics support to the combat forces.

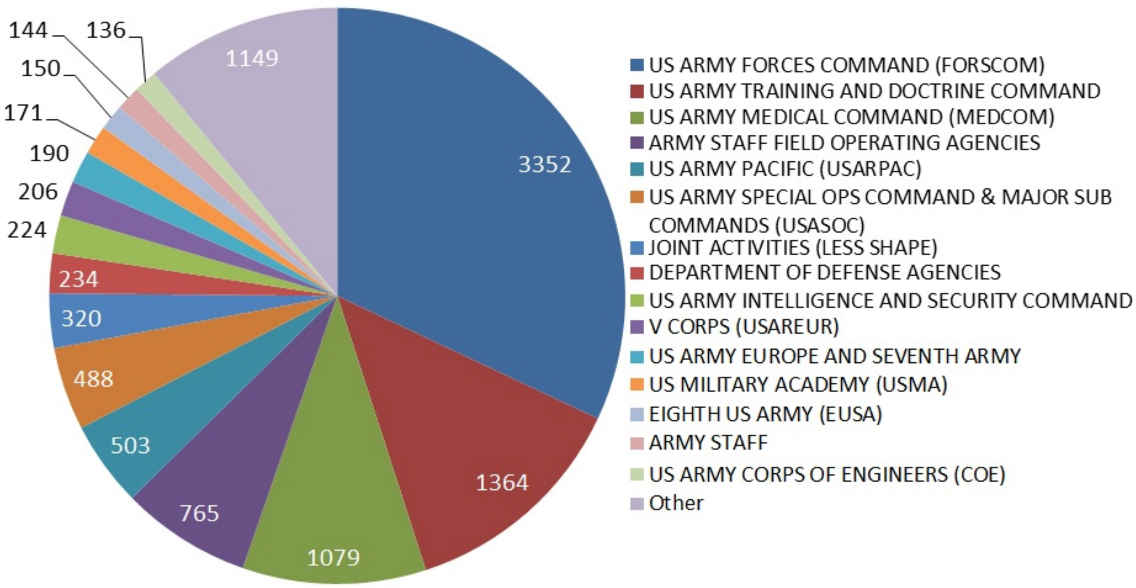


Figure 8. Army S&E Population Distribution within Major Commands and OSD Organizations

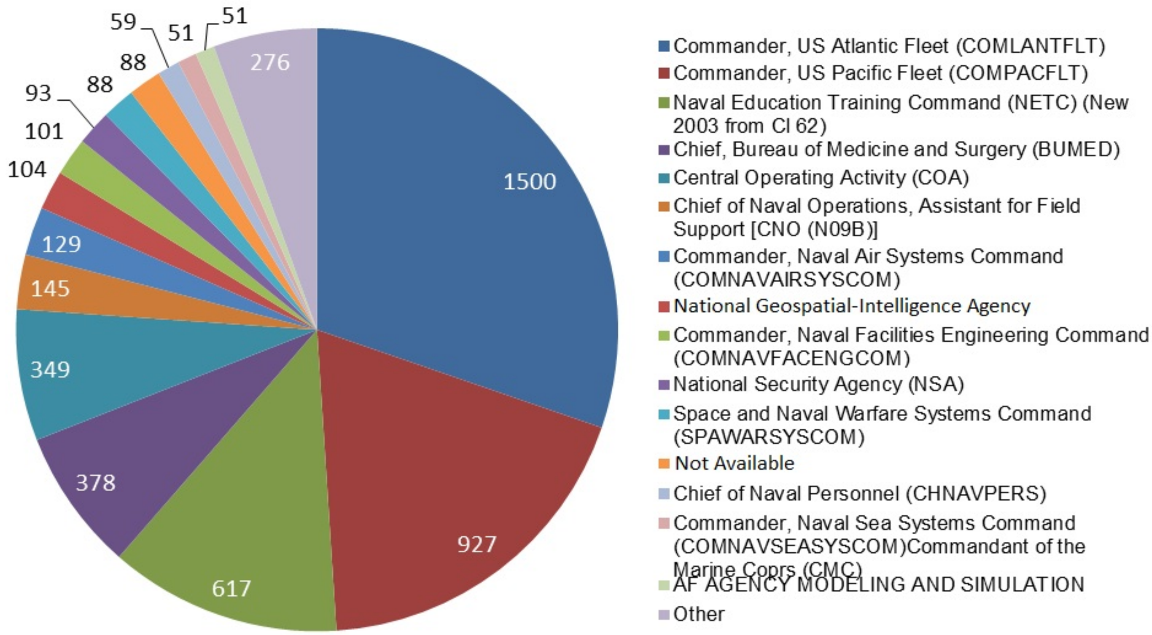


Figure 9. Navy S&E Population Distribution within Navy Major Commands and OSD Organizations

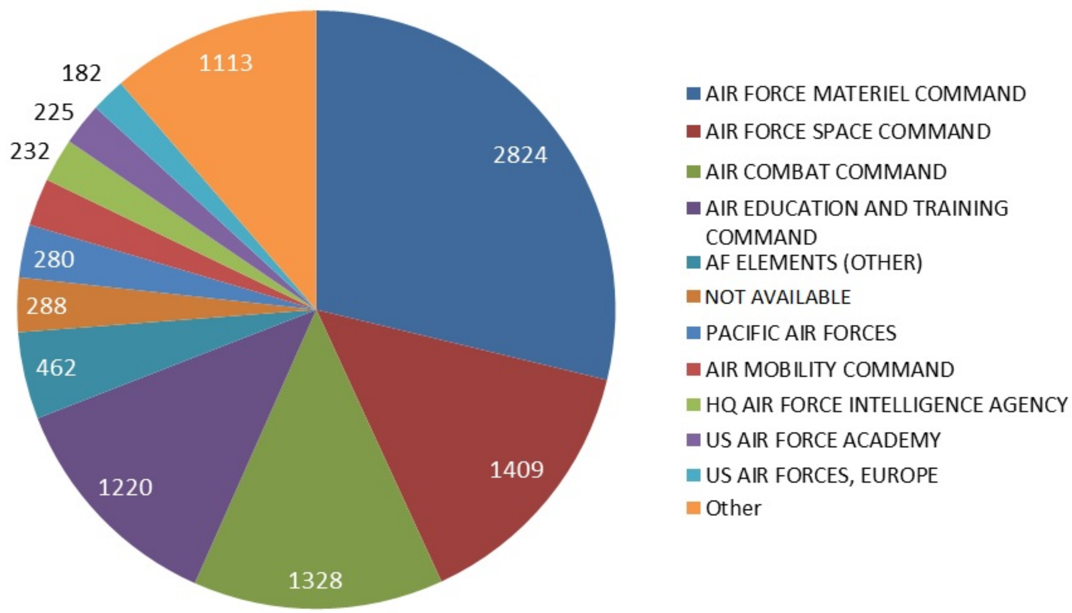
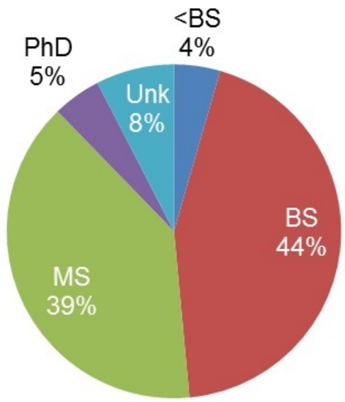


Figure 10. Air Force S&E Population Distribution within Air Force Major Commands and OSD Organizations

Figure 11 shows the highest educational degree level of the military S&E population in FY 2011. These include all degrees, not just S&E degrees. The highest degree is not necessarily in an S&E field. For example, an officer with a bachelor's degree in a technical field may go on to a master's degree in business administration. Information from the focus group discussions suggests that this happens frequently and is sometimes encouraged, since the perception is that it can enhance promotion possibilities, particularly to the O-6 grade.



Degree Level	Count	% of Total
No college degree	1,279	4%
Bachelors degree	12,651	44%
Masters degree	11,263	39%
Doctorate degree	1344	5%
Unknown	2,171	8%
TOTAL	28,708	

Figure 11. Educational Level of the Military S&E Population in FY 2011

D. Grade Structure Comparisons

Table 3 and Figure 12 show the grade structures of the military S&E population and the non-S&E military officer population for FY 2011. The proportions appear similar except for perhaps O-6. A more detailed analysis of grade structure is given in Appendix E. As will be shown in the next section, results for the previous years examined showed a similar structure for S&E and non-S&E officers.

Table 3. S&E versus Non-S&E Military Officers by Grade for FY 2011

FY 2011	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	Total
Scientists and engineers	4,105	3,816	10,078	5,938	3,639	1,111	14	4	3	0	28,708
Non-scientists and non-engineers	22,136	23,158	66,594	40,450	25,359	11,191	445	317	151	2	189,843

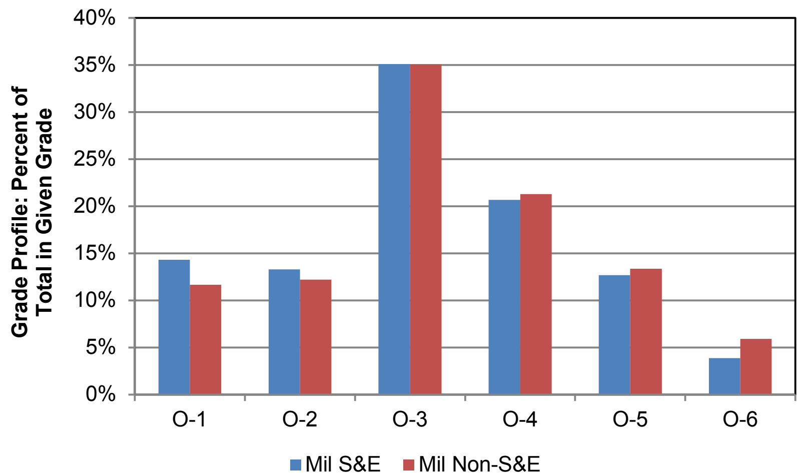


Figure 12. Grade Structure of All Non-S&E Officers Compared to S&E Officers in Their Respective Populations (FY 2011)

Figure 13 shows the distribution of all officers by grade. The chart on the left shows data from O-1 through O-6, and the chart on the right shows data for O-7 to O-10 at an expanded scale.

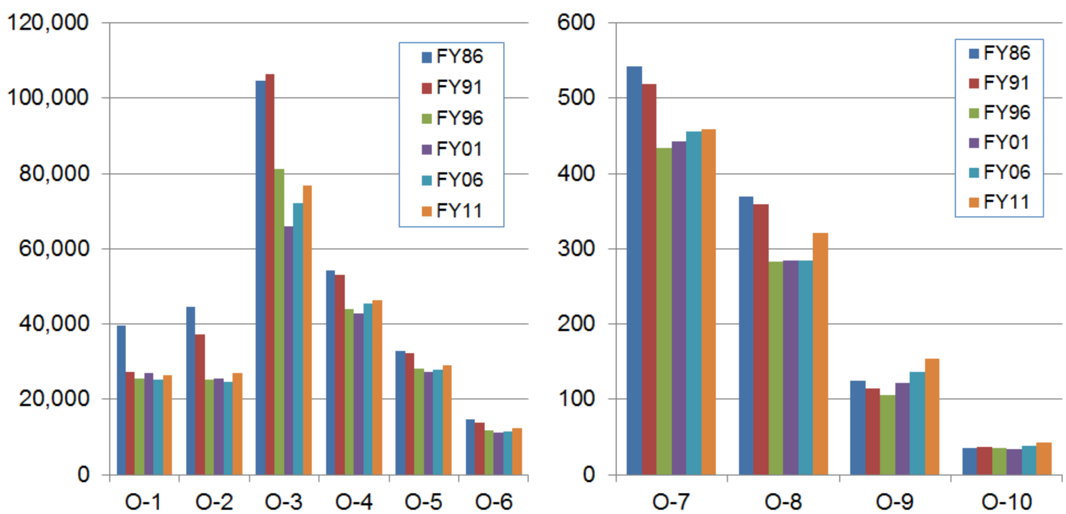


Figure 13. Historical Grade Structure of All Officers (FY 1986–FY 2011)

E. Service Laboratories

Publicly available literature revealed a notable difference in recent military S&E numbers at the major DOD laboratories. In the Naval Research Laboratory (NRL), there are about 8 military members (including both scientists and engineers and non-scientists and non-engineers) in research components and 1,500 S&E civilians, which gives a military S&E component of less than 0.5% of the S&E workforce (NRL 2010). In the Army Research Laboratory, there are about 25 military personnel (including both scientists and engineers and non-scientists and engineers) and 1,256 Federal civilian scientists and engineers in six S&E directorates, which gives a military S&E component of less than 2% of the workforce (NRC 2011). In the Air Force Research Laboratory, there are about 850 military scientists and engineers working with 2,800 Federal S&E civilians, which gives a military S&E component of about 23% of the total Federal S&E workforce (NRC 2010). If the 2,250 S&E contractors in the Air Force Research Laboratory are included, the military scientists and engineers would constitute about 14% of the total 5,900 S&E workforce there.

In summary, although the definitions are not totally consistent and there is no publicly available information on the officer/enlisted composition of laboratories, the Air Force uses military S&E in its laboratories much differently than the Army and Navy. For example, in the Army and Navy, less than 2% of the laboratory research staff is made up of military S&E, compared to about 14% in the Air Force. The Marines do not have any conventional technical research laboratories and depend on Navy resources. The implications of this difference cannot be easily evaluated and depend on many factors. The actual S&E needs of the different services, which may be quite different, were not examined. Also, with this exception concerning laboratories, other differences of this quantitative magnitude between the services were not found in the areas examined.

F. Defense Manpower Requirements

An annual Defense Manpower Requirements Report is prepared by the Office of the Under Secretary of Defense for Personnel and Readiness. Within the FY 2012 report, tables by service indicate the military and civilian manpower totals by force and infrastructure category, giving FY 2010 actuals and FY 2011 and FY 2012 estimates. Among other infrastructure categories, one is designated the "Science and Technology Program," the only one that is specifically science and engineering related. The number of military billets in this category total 1,500. Virtually all these billets are positions in the Army and Air Force. For comparison, the civilian total is 17,300.

Billets requiring an S&E background could be required in the other categories as well; however, it is impossible to discern any further detail.

4. Results of the Focus Groups

The research team conducted a number of interviews and organized focus groups to assess qualitatively the effectiveness and utilization of the military officer scientist and engineer workforce. To this end, the following topics and questions were addressed in each discussion:

- What is the role of military scientists and engineers? What value do military S&E officers provide?
- Are S&T officers and billets being used “effectively”?
  - Is their assignment broadly consistent with their educational specialty?
  - Does their assignment provide opportunities to enhance their academic specialty to become more of an expert?
- What is the strategic plan for STEM officers regarding requirements, recruitment, retention, retraining, and retirement?
  - What key factors or strategy determines assignments for S&E personnel?
  - What metrics are used in the assignment process?

This section summarizes the information gleaned from the focus group discussions on these three major themes regarding scientists and engineers as military officers. More information on the organization and the details of focus group and other meetings can be found in Appendix F.

A. Focus Group Findings on Utilization

Two prominent utilization questions were discussed at the focus group meetings: What is the role of military S&E and why are they important? What do the services gain from having military S&E? The focus group members reached consensus on the following answers:

- What is the role of military S&E and why are they important?
  - In a liaison role to operational commands, they serve as people who understand technical programs and as intermediaries between operational commands and the more technically oriented portions of DOD.
  - Because they wear uniforms, they have more credibility with the military commander in the field.

- They can provide a different perspective, including more operational understanding than civilians on how to evaluate technology for military applications.
  - They serve as a feeder pool for future service acquisition corps personnel. Being technically astute, the military scientists and engineers serve credibly as acquisition program managers when interfacing with industry.
  - They are useful for building bridges to other agencies due to the unique military career networks of which they may be members.
- What do the services gain from having military S&E?
  - Deployments can use their technical capability.
  - With both a technical and military background, they may serve more effectively than civilians as leaders of scientific groups at DOD laboratories, since they may better understand the military importance of a particular technology.
  - Having strong military S&E talent makes it easier to attract and retain more military technical talent, give credibility to military S&E, and attract collaboration opportunities with industry and academia.
  - When interacting with foreign military technologists, an advantage to being a U.S. military scientist or engineer may be shared military experiences.
  - Military scientists and engineers are usually easier to assign and reassign to different positions than civilian scientists and engineers.
  - There was general satisfaction with the quality and performance of military scientists and engineers.

There was little discussion of the relative monetary cost between military and civilian scientists and engineers determining placement in a particular activity.

B. Focus Group Findings on Effectiveness

Focus group members discussed at length how to best assess the effective use of military scientists and engineers. One measure of effectiveness is how well DOD is utilizing the S&E officers' technical expertise within their assignments. Those assigned to laboratories typically said they make direct use of their degrees, as did those assigned to acquisition positions for programs with a high technical component In other cases, the use was indirect, although often considered no less important. Some felt that their technical expertise, combined with their uniform and its implication of operational experience, along with their actual direct knowledge of military needs, gave them credibility and trust with both operators and technical developers. Consequently, they believe they were more effective in a primary role as liaisons between these two groups. This effectiveness was considered particularly helpful when technology was being transferred from research and development to the battlefield.

Regarding the challenges facing military S&E effectiveness, the focus group members reached consensus on the following answers:

- Promotion opportunities are often considered to be more limited than those available to non-S&T officers, particularly in the O-4 to O-6 positions. This limitation can affect effectiveness.
  - The time commitment to get an advanced degree often costs an operational opportunity that is hard to overcome. Alternatively, an opportunity to obtain an advanced degree may not be used so that an operational position, which may be felt to enhance promotion opportunities, can be taken.
  - Military officers are looked at first as leaders and only secondarily as technical people. It was considered virtually impossible to have a successful career strictly as a technologist because promotions were based on leadership potential rather than technical competence.
  - Many if not most of the military S&E organizations tend to be dominated by civilians, and the civilians sometimes do not know the special requirements of military scientists and engineers such as how to fill out military performance reports in a way most likely to enhance promotion possibilities.
  - It was often felt that individuals had to carefully plan their careers on their own and that promotions to O-4 and above were often due more to “luck” than through any real service help. In some cases, individuals felt they had to “hide” their interests in science and engineering to progress. In other cases, individuals felt they had to completely abandon science and engineering and, for example, obtain a master’s degree in business administration to progress. A promotion beyond O-5 was usually not considered realistically possible for a person who wanted to concentrate on science and engineering.
  - In some instances, there seemed to be some friction and competition between military and civilian scientists and engineers. This friction and competition may be due to real or perceived availability of limited positions, differences in recognition, and differing career goals of the two groups. This may be similar to a possibly related situation at the service schools between civilian faculty (including S&E) and military faculty (including S&E) (HASC 2010).

- Some success was reported with alternating assignments in and out of S&T career fields. There was no consensus as to whether the first assignment of a new junior S&E officer should be in a technical or operational position. An advantage of a technical assignment first was to better use the technical background of the officer. An advantage of an operational assignment first was to give the officer a better appreciation of how technology was actually used in the military.
- In some areas, such as higher laboratory management, fewer positions formally required the S&E skill set, which was felt to hinder advancement on a technical track. There was a feeling that in recent decades, laboratory management had often moved from being more military oriented to being more civilian oriented, which among other things reduced the available military S&T billets.
- There were reported instances where military scientists and engineers were not using their technical skills. For most careers, the majority of assignments did not directly use science and engineering, although there were some which did. Since military tours of 2 to 4 years were typically much shorter than civilian assignments, military S&E were sometimes not used to head long-term projects. It was reported that often by the time a military S&E really learned a position or was able to contribute to research, it was time to leave.
- There were reported challenges in keeping up technically, among them new travel restrictions on attending conferences. In some cases individuals financed their continuing education on their own time, with their own funds.
- The lack of flexibility in position placement rules was mentioned as causing ineffective use of technical knowledge. S&E officers such as psychologists or electrical engineers usually have scientific specialties beyond general categories and are not strictly interchangeable, even within occupational specialties. In one focus-group real example, two officers were each assigned in the same geographical area and time to positions that were a better fit to the specialty of the other one. Despite several attempts, they were unable to exchange positions.

There is virtually no information on the relative combat performance of military scientists and engineers and military non-scientists and non-engineers. A study of tactical combat performance in Afghanistan and Iraq found no evidence that a technical education influenced tactical combat performance DePalma and Brobst (2008).

C. Focus Group Findings on Strategies for Military S&E Officers

The focus group members also discussed at length the question of possible changes that could improve the effectiveness of military scientists and engineers. A summary of these discussions follows.

- Increasing military tour lengths, or at least having the ability to stay longer within the same organization, would make it more likely for military scientists and engineers to have significant impact on the longer time scales often characteristic of science and technology.
- Recognizing the value of a critical mass of military scientists and engineers in an organization and sustaining a minimum number of assigned military scientists and engineers would improve job performance and morale. The National Geospatial-Intelligence Agency has about 0.25% military S&E officers. The U.S. Army Research, Development and Engineering Command has about 60 military S&E officers out of 20,000 employees. These numbers were thought to be too small, but appropriate numbers to represent a critical mass were not estimated.
- Technical effectiveness should be made an important part of a promotion review.
- Despite being told that the military weighs leadership ability over technical expertise, a number of entering military scientists and engineers believe that they can have a successful career by concentrating only on a technical field. This may be because they do not understand what they are told or because they think they can be an exception. Since this belief wastes resources on people who leave the military at an early career stage or who stay as very dissatisfied individuals, the actual limited S&E career progression should be made very clear and emphasized to prospective entering scientists and engineers.
- Military scientists and engineers often transition into civilian or contractor roles, and their expertise and experience are retained in the DOD environment. This could be made easier. For example, military scientists and engineers currently need to work in the private sector for a few years before entering civil service to significantly increase their salaries.

D. Discussion

The focus groups convened for this research suggested that the fall in the relative share of S&E officers may reflect an underutilization of S&E that is resulting from challenges in the career path and retention of S&E officers. In particular, the members of the focus groups believed that existing promotion structures discouraged S&E officers from pursuing technical work or research, and that career paths for uniformed S&E personnel were less accessible and less well defined than those pursuing administrative or program manager tracks. The focus group members perceived these concerns to originate from several sources, explored in detail below.

First, a number of focus group members felt that at present there is an insufficient number of higher ranked S&E military positions (billets) in which to place uniformed S&E officers. S&E officers were cited as having relevant skills for a number of DOD positions, whether at a DOD laboratory, in an acquisition program, or in a position that does not directly require technical expertise. Despite this, participants noted that many higher level positions at the laboratories are reserved for civilians, limiting the number of military billets available for S&E officers. Similar findings on the insufficient number of billets were made in the 2010 Naval Research Advisory Committee (NRAC) report on the Naval Research and Development Enterprise and the 2013 Army Science Board (ASB) study on the Army's military S&E. Relatedly, focus group participants reported that while it might be valuable for retiring S&E officers to assume civilian posts at DOD programs or laboratories, the lack of accessible conversion pathways to do so presented potentially limited the extent to which this way possible.

Second, both the literature and interviews suggested that S&E skills were not sufficiently incentivized or valued by existing military promotion structures. The 2010 NRAC study noted a perception among military S&E officers that promotion opportunities were perceived to be greater as a program manager than as a practicing S&E officer. A recent National Research Council (NRC) study on the Air Force found that S&E officers did not compete well for promotions to higher ranks. Similarly, data collected by the research team on grade structure indicated that while the relative percentage of military scientists and engineers matched well to non-scientists at lower grade levels, this percentage declined at higher grade levels (see Figure 12 in Chapter 3).

In addition, the focus group members observed that promotion opportunities for S&E officers were limited by a number of factors, including the cost and time required to earn advanced degrees and the fact that technical skill is not typically used as a metric for promotion. Discussants also argued that because officers are largely promoted for leadership ability and operational experience instead of technical expertise, scientists and engineers wishing to advance in rank are largely dissuaded from continuing their technical work. Accordingly, participants noted that officers with S&E backgrounds often pursued degrees in other fields in order to advance. In addition, interviewees argued that civilians in the DOD laboratories often do not understand the military promotion structure but are charged with evaluating S&E officers in laboratory billets; this dynamic was thought to hurt inadvertently the S&E officer's opportunity to advance.

Third, focus group members argued that a lack of flexibility in position placement rules served to create an underutilization of S&E officers by ineffectively using their skill sets. Interviewees noted examples where S&E officers have specific scientific specialties were placed in positions that did not require these skills. As an illustrative example, one focus group cited a case where two S&E officers were each assigned to a position that more appropriately suited the technical skill set of the other officer. Both of these positions were in the same geographical location, yet the officers were not permitted to exchange positions with each other despite several requests to do so. S&E officers in positions ill-suited to their specialties might find it challenging to keep up their technical competency and may be dissuaded from continuing to pursue technical work. In addition, some participants cited that the short length of military placements made it challenging for S&E officers to have a significant impact before they were rotated.

Finally, focus group members noted that many military S&E officers found challenges in staying technically competent. One challenge is the cost and time to earn advanced degrees; participants noted that some military officers were obliged to finance their own degrees and pursue them on their time if they want to increase their knowledge. In addition, existing DOD travel restrictions which are impeding the ability of military S&E personnel to attend scientific conferences, which are crucial to staying current and maintaining contacts in many S&E disciplines.

Throughout the conversations on the perceived challenges to the career paths of S&E officers, discussants suggested a number of policy options. These policy options represent possible ways of addressing the existing barriers to S&E career advancement as well as better monitoring the utilization and sufficiency of military S&E officers, and could be considered by the DOD Office of the Undersecretary for Personnel and Readiness (OSD/P&R). The focus group discussions suggested these options in light of their findings and discussions, and accordingly they are presented here simply as perceptions of the interviewees. It was beyond the scope of this project to conduct a detailed analysis of the costs, benefits, and feasibility of the approaches suggested by the focus group members.

1. Increase S&E officer billets

The primary suggestion for addressing the insufficient number of billets for military S&E officers was to work with DOD and the services to increase the number of available billets. This recommendation echoes the previous one made by the 2012 Defense Science Board report, which advised that "DOD laboratory directors work with the military services to create additional billets at DOD laboratories for qualified military officers with the eventual goal to make S&T a valued military career path." Interestingly, the research team discovered that the availability of billets varies across the services; whereas only two percent of Army and Navy laboratory research staff are military S&Es, they comprise 14% of Air Force laboratory staff. While it is unclear whether this difference is the result of a specific policy action, this variation reflects an opportunity for OSD/P&R to explore ways to encourage the services to host more military officer billets at the labs.

In addition to creating billets directly, another recommendation provided by the ASB report was to re-establish the Uniformed Army Scientist and Engineer (UAS&E) program. The UAS&E program was originally developed in 2003 as a program for placing S&E officers in relevant billets and for supporting officers seeking higher education in technical fields. According to some interviewees the program was discontinued in 2010 because of a lack of funding. In addition to working with the services to create more S&E billets, another policy option is to pursue re-organizing a similar program either within or across the services so as to help place S&E officers in relevant positions.

Furthermore, focus group members identified the lack of conversion pathways for retiring military S&Es to move to civilian positions as a challenge to maximizing the utilization of military S&Es. For example, certain civilian positions in DOD —including those at DOD laboratories, for example—may base their salary offerings on previous salary levels. Since S&E positions in the private sector often have greater pay that those in the military, retiring officers with S&E backgrounds may feel compelled to first work in the private sector to "re-baseline" their salary before accepting a civilian DOD position. This may serve to limit the ability or willingness of military S&E officers to transition to civilian positions. Creating mechanisms to address these salary discrepancies and to help transition military personnel into civilian DOD positions, such as laboratory branch and division chiefs, program managers, DARPA program managers, and requirements advisors, might help to retain S&E officer talent in civilian positions.

2. Value S&E contributions in promotion

To address some of these systemic problems facing challenges to career advancement and promotion for S&E officers, the focus group members proposed a number of suggestions to increase recognition of S&E contributions and integrate technical skills into the promotion process for S&E officers. One suggestion is to provide awards or insignia to incentivize and honor scientific or technical achievements such as achieving an advanced degree, publishing in a scientific journal, or developing a patent. Another suggestion entails reserving a select number of officer positions to promote personnel with S&E backgrounds, or ensuring that the strength of S&E relevant skills and achievements (e.g. research contributions, publications, patents, discoveries, or other metrics) factor into promotion criteria for S&E officers. These efforts could replicate similar mechanisms that are already employed by the services in the promotion and evaluation of medical officers.

Finally, steps should be taken to ensure that military officers working under and supervised by civilians are not disadvantaged for promotion. Policy actions to this effect might include providing greater guidance to civilian employees at the labs or in DOD programs on how to fill out military performance reports in a way that enhances promotion possibilities, or arranging for performance reviews to be completing by other military leaders.

3. Improve S&E officer placement

In order to increase the effective use of military S&E officers, focus group members suggested that DOD might consider basing placement decisions in part on the officer's technical skill sets. Ensuring that S&E officers are placed in positions where they can leverage their knowledge is important not only to ensure their proper utilization, but also to encourage potential officers to continue to pursue S&E education. One suggestion for improving the placement process was to develop and information technology based system that would help match available billets to S&E officers. This functionality is applied in the medical field through the National Resident Matching Program, which places graduating medical school students in hospitals based on available positions and the skill set of the student. In addition, increasing flexibility in placement regulations (e.g. allowing requests to change positions when reasonable) or increasing placement duration for S&E officers might increase the effective use of S&E personnel.

4. Collect data on S&E officers

In databases maintained by the Defense Manpower Data Center (DMDC), the research team found that the education discipline field is largely unpopulated for military S&E personnel, while it contains extensive data for civilian positions. This disparity has been previously identified; in a 2012 study, the National Research Council noted that "[d]ue to difficulties associated with defining military STEM occupations, the committee was not able to assess the military STEM workforce using the data provided by DMDC." By better tracking the educational degrees of military personnel, DOD may be better able to monitor the utilization of its scientists and engineers in the future. Accordingly one policy action to consider is ensuring that these data are collected.

In particular, the research team identified the need to establish a consistent S&E MOS description, which could be in addition to the service-specific MOS, and which is compatible with the Office of Personnel Management (OPM) civilian code structure. This information could be useful for assessing the utilization effectiveness and quality of military and civilian scientists and engineers. It could also provide useful information in determining personnel postings.

5. Conclusion

A. Overview

This chapter summarizes the research team's findings and suggested improvements as derived from the literature review, exploration of DMDC data, and focus group results. The absence of data in the educational degree discipline data field of the DMDC database significantly impacted this project. The fact that the comparable civilian data field is more frequently populated could indicate a difference in how important military and civilian S&E competencies are considered, one consistent with the military culture of an officer being a leader first, with technical expertise a secondary characteristic. Since the database did not necessarily contain degree information, the team had difficulty in determining both the number of military S&E officers and how they were utilized. Another difference that influenced the analysis was that each service has its own codes for each Military Occupational Specialty (MOS), in contrast to civilians, who have a common occupational code structure defined by the Office of Personnel Management.

Despite the data limitations, the occupational code analysis described in Chapter 3 estimated that in 2011, military S&E officers totaled approximately 28,000. While the data methods employed by the team provide some interesting findings—including a historical decline of the size of the military S&E population, a comparison of S&E and non-S&E officers at various pay grades, and differences in utilization of S&E among the service laboratories—the research team found that further data on S&E degrees of officers would be required in order to better assess the health and sufficiency of the military S&E population. (This is explored in the discussion section in Chapter 4.) In addition to the data provided In Chapter 3, further demographic analysis possible with the data available is provided in Appendix E.

Given the quantitative data limitations, the findings and options for improvement presented are in large part derived from information gathered in the literature review and from the focus group discussions. The outcome of the focus groups in particular indicated that DOD meets its needs for advanced military technologies through access to skilled scientists and engineers working in a variety of defense settings. These military scientists and engineers contribute to national security through: (1) their role as "translators" within DOD between the technical world and the operational world, (2) their ability to enhance the acquisition of complex technical systems, (3) their ability to act as liaisons between the private-sector civilian technology establishment and the military, (4) their flexibility to sometimes be more easily deployed to combat areas than civilians, and (5) their often relatively short terms in positions to help bring in new ideas.

This last point was somewhat controversial in the focus groups. It was felt that in some cases the short tours could be detrimental. The point was made that there should be appropriate flexibility in the length of a tour. The focus groups also found that there is a difference in how the technical backgrounds of military and civilian personnel are characterized.

Based on individual observations, several consistent themes emerged between and within the groups. The section below discusses these general themes although it should be stated that their inclusion does not signify unanimous agreement. The project did not attempt to verify independently any of the focus group observations. In order to preserve confidentiality for these small groups, these results are presented without reference to the specific organizations or individuals represented.

B. Summary of Findings

The following list of findings summarizes the results of the research team's literature review, quantitative analysis, and focus group studies.

- *Numbers of military scientists and engineers*. Over the past several decades, the number of military scientists and engineers has decreased from 61,000 (21% of all officers) in 1986 to 28,000 (13% of all officers) in 2011.
- *Differences across military departments in uses of military scientists and engineers*. The three military departments use military scientists and engineers to different extents, particularly in their in-house laboratories Less than 2% of Army and Navy laboratory research staff members are military scientists and engineers, compared to more than 14% of Air Force laboratory research staff. The implications of this difference are outside the scope of this project.
- *Comparability of military officer grade structure*. For FY 2011, the grade structure of military S&E officers is at least comparable to that of all military officers up to the level of O–5. That is, the promotion opportunities for military S&E officers up to O-5 are similar to promotion opportunities for other officers within each Service. At the O–6 level and above, the grade structure is less comparable, with proportionately fewer military S&E officers being promoted into senior ranks.
- *S&E officer promotions*. Focus groups expressed concerns that S&E officers need to stretch beyond technical achievements and technical proficiency when looking for promotions. One way to do this would be to alternate assignments between S&E career fields and other military roles. Another way, particularly later in a career, would be to take up only nontechnical positions. These pathways were used by focus group members with varying success.

- *Defining the S&E career path*. Focus group members believed that the military S&E career path was not well defined. Careers were sometimes considered to be determined more by luck than by directed purpose. It was felt that there were insufficient higher level S&E billets in which to place military scientists and engineers. At some of the laboratories, the number of management positions filled by military scientists and engineers has decreased. In some instances, such as writing performance reviews, focus group members thought that civilian scientists and engineers in DOD did not understand the special needs of military scientists and engineers.
- *Effectiveness of scientists and engineers*. Based on the information collected, an assessment of how effectively military scientists and engineers are being utilized can only be provided anecdotally. One measure of effectiveness is how well DOD is utilizing scientists and engineers while on active duty, that is, whether they are using their technical expertise within their assignments. There appeared to be a tendency for the direct use of technical backgrounds early in a career with perhaps only indirect use or no use later in a career. Another measure of effectiveness is how well the member is serving DOD, particularly whether the military scientists and engineers are of appropriate quality (in comparison with their civilian counterparts in government) and performing well in their positions. As expressed in the focus group discussions, there generally is satisfaction by their supervisors and colleagues with the job performance and competence of the military scientists and engineers. A third measure is how well DOD uses the expertise of retired military scientists and engineers. Many of the focus group members thought this could be improved, particularly since military retirees may consider civilian DOD and defense-related contractor employment as a post-retirement career track.
- *Civilian versus military scientists and engineers*. Some friction and competition is apparent between military and civilian scientists and engineers at some of the DOD laboratories. This may be due to limited positions, differences in recognition, differences in opportunities, and differing career goals of the two groups. This may be similar to a situation at the military schools between civilian and military faculty (including scientists and engineers).
- *Data on military scientists and engineers*. Important and militarily useful information about the backgrounds of military scientists and engineers is lacking in the DOD DMDC database. Specifically, the education-discipline-degree data field is often not populated for military scientists and engineers, while it is for civilian positions. In addition, each department has its own codes for MOS in comparison to civilians, who have a common occupational code structure, defined by OPM.

C. Possible Ways to Improve the Use of Uniformed S&E Officers

OSTP asked for suggestions for improving the use of uniformed S&E officers. Given the limitations of the data, these potential steps are based largely on the views and opinions conveyed in the focus groups. The members of the focus groups perceived an underutilization of S&E that is resulting from challenges in the career path and retention of S&E officers. In particular, the discussants believed that existing promotion structures discouraged S&E officers from pursuing technical work or research, and that career paths for uniformed S&E personnel were less accessible and less well defined than those pursuing administrative or program manager tracks. These concerns were thought to be related to the small number of billets available for S&E positions, the valuation of technical expertise in the promotion process, and the shortcomings in the S&E placement processes.

The suggestions of focus group members have potential advantages and disadvantages with respect to how uniformed scientists and engineers are used. Accordingly, these suggestions may have unknown consequences for the overall health of the military S&E community or for the careers of participating officers. Thus, if pursued, the suggestions should be implemented first as experimental programs, with appropriate data collection and analysis. The size and nature of the experiments should be chosen to produce small perturbations on current activities since it may not be possible to predict all of their direct outcomes and indirect ramifications.

The research team did not attempt to rank these suggestions or determine the implementation challenges they might face.

- Increase the number of specific higher ranked S&E billets such as laboratory branch and division chiefs and acquisition program managers. This could make the S&E career track more attractive to officers.
- Reserve a set of promotion slots each year in each military department for outstanding performance by officers making substantial actual use of their S&E knowledge. The contribution of outstanding officers selected and not selected for the program could be compared. This special promotion track for military scientists and engineers could help DOD retain exceptional individuals.
- Pair junior military scientists and engineers as "technical deputies" with more experienced counterparts when new applied research projects that are anticipated to last only a few years are starting. The officers would remain deputies until the projects were successfully developed or terminated. Based on job performance, which is not synonymous with program outcome, the officer would have opportunities for promotion. This could provide a more structured career path for military scientists and engineers while also providing technical continuity in converting applied research to acquisition.

- Increase the recognition of military scientists and engineers by developing department-specific or joint awards such as citations for technical accomplishments or by adopting additional insignia indicating an S&E achievement similar, for example, to awards for marksmanship.
- Track the transition from military to civilian positions (particularly DOD civilian positions) by S&E officers after they leave the military. This could be useful in determining how effectively their technical and military expertise is being used by DOD after they leave military service.
- Provide a mechanism for direct conversion to civil service S&E research and management careers—such as laboratory branch and division chiefs and program managers—for exceptionally talented, uniformed scientists and engineers leaving military service.
- More adequately match technical backgrounds to assigned positions for newly graduated incoming military scientists and engineers by establishing for each military department a program similar to the National Resident Matching Program used in graduate medical education, which matches student prioritized desires with prioritized available institutions and positions.
- Establish an experimental program that would randomly assign competent S&E and non-S&E staff to small but highly technical acquisition programs and examine the results based on suitable metrics. This program would assess if military scientists and engineers are more effective acquisition program managers than non-S&E military staff when managing highly technical programs.

Appendix A.
History of Military Scientists and Engineers

The use of military officers with advanced technical expertise dates back at least to the days of the early Roman Empire. As the professional training of scientists and engineers became more formalized in universities during the nineteenth century, this tradition continued. Beginning in 1817, West Point, under the leadership of Sylvanus Thayer, placed an increased emphasis on science and engineering in its cadet curriculum. The first American to win a science Nobel Prize (1907), Albert Michelson, served as a naval officer shortly after the Civil War and again during World War I. Perhaps one of the most publicly well-known S&E officers between the two world wars was the Army test pilot and air racer Jimmy Doolittle. According to his Air Force biography, he earned a doctorate in aeronautics from MIT in 1925 while in the Army Air Corps, and he played a significant role in the development of early instrument flying (Conway 2006).[1]

World War II gave added emphasis to the importance of science and technology (S&T) in warfare. Under Major General Leslie Groves, who himself had an engineering background, the Manhattan Project successfully produced the first nuclear weapons. Although the leading scientists in the Project were civilians, there were also a number of technical military personal primarily from the Army although with some Navy personal also. The Army personnel were concentrated at Los Alamos and Oak Ridge in the Special Engineer Detachment (SED), which was organized in 1943 (Jones 1985). At its peak in Oak Ridge, the SED consisted of approximately 1,300 enlisted men, about 800 of whom had S&E college degrees (Oak Ridge SED 1945). Those with college degrees tended to be noncommissioned officers. The SED was led at the end of the war by an Army captain who had a degree in mechanical engineering. During the summer of 1945 at Los Alamos, the military SED consisted of about 1,400 enlisted personnel, while the civilian scientists and technicians totaled about 1,300 people.

The Manhattan project made use of military scientists and engineers in a number of ways. The first atomic intelligence Alsos mission to Italy in December 1943 included two military scientists (one Army and one Navy) and two civilian scientists. It was an Army major with a degree in chemical engineering whom Groves directed to brief General

---

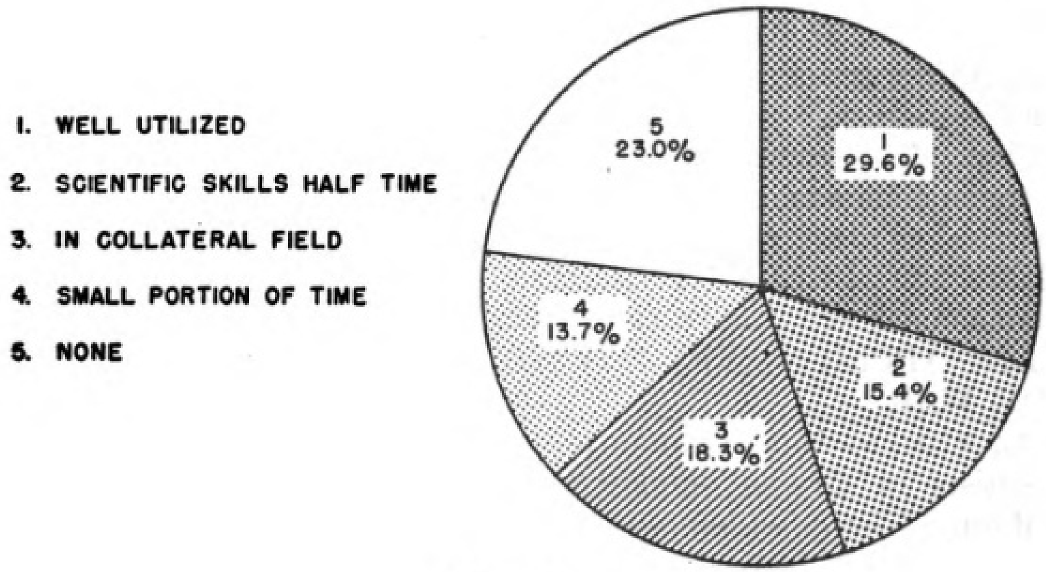
[1] See U.S. Air Force website, General James Harold Doolittle, http://www.af.mil/AboutUs/Biographies/Display/tabid/225/Article/107225/general-james-harold-doolittle.aspx.

Eisenhower in 1944 before the Normandy invasion about possible German use of radioactive materials to contaminate a battlefield. William Parsons, a naval officer who had studied ordnance engineering, was the weapons officer on board the Enola Gay (U.S. Navy n.d.).

S&E personnel were used in other work besides that supporting the Manhattan project, but in most of these efforts, the majority of scientists and engineers were civilians. The Office of Scientific Research and Development helped its contractors to obtain deferments for 9600 of their key technical employees (Stewart 1948, 276). One exception was Navy reserve Commander Howard Aikins group, which worked on an early general-purpose mechanical computer located at Harvard University. In 1945 all eight scientists on his staff, including Lieutenant junior grade Grace Hopper, were temporary naval reserve officers (Williams 1999).

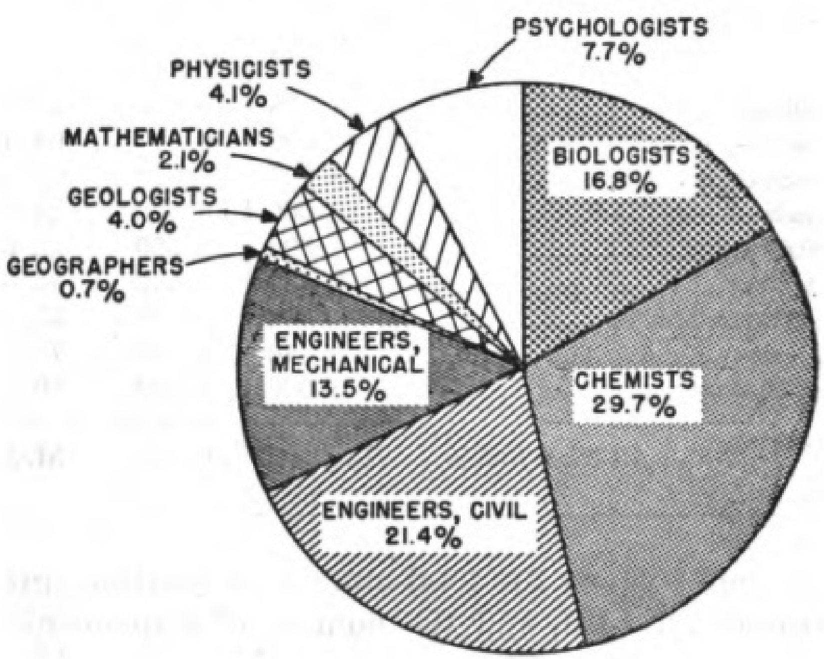
Both during and after World War II, there was concern about the effective use of uniformed military scientists in that conflict. In 1947, one survey actually examined this issue, studying about 15,000 self-selected S&E respondents who had served in World War II (U.S. Army 1948). Almost all the respondents (about 93%) had a least a 4-year college degree with about 25% having a doctorate. This study estimated that the total number of scientists and engineers in uniform was less than 50,000, while the largest number of military personnel at any one time was about 8,000,000. Although the results varied by field, the study estimated that about 15% of U.S. S&E personnel saw military service in World War II. As Figure A-1 shows, approximately 45% felt that their technical utilization was either good (expertise used appropriately about half the time in service) or excellent (expertise used appropriately almost all the time), and 36% felt it was poor (expertise used appropriately for only a short time) or nonexistent (expertise not used). The rest felt that it was "reasonably satisfactory." Those scientists and engineers with higher degrees tended to indicate better utilization.

Figure A-2 from the same study shows the scientific fields of the military respondents. Note that this breakdown and other results from the report may be skewed by the scientific societies chosen for analysis and the self-selection of the participants. The authors of the report felt that on the whole there were an insufficient number of available specialized positions in the services to utilize all S&E personnel effectively.



Source: U.S. Army, *Scientists in Uniform, World War II* (Washington, D.C.: 1948), http://babel.hathitrust.org/cgi/pt?id=mdp.39015076679169;view=1up;seq=5.

Figure A-1. Degree of Utilization of Military Scientists



Source: U.S. Army, *Scientists in Uniform, World War II* (Washington, D.C.: 1948), http://babel.hathitrust.org/cgi/pt?id=mdp.39015076679169;view=1up;seq=5.

Figure A-2. Scientific Fields of Military Respondents

The study was concerned about the inability of scientists to carry projects through to active military application:

> The absence of close liaison between the services and the world of science between the wars meant that many key military positions of a technical nature reportedly became filled by men without appropriate scientific background. It was not surprising, therefore, that the services tended to utilize procedures and methods which they knew were fairly effective and were loath to use new and untried technical procedures proposed by scientists who lacked military experience. There was also a tendency to place the research-minded man at a fairly low echelon where his influence was not great. In order to secure technical action, he was required to convince his superiors of the need for new procedures. Often his technical arguments could not be understood by the supervisor who lacked comparable technical training. Hence, much technical work was carried on but never applied effectively to military activities.

The study's authors expressed concerns about how assignments were allocated to military scientists, in particular:

> Another factor [in ineffective utilization] was the concept that an officer could be rotated from job to job and be uniformly effective in all of them. Although necessary for officers expected to occupy a variety of administrative or command positions, this practice is indefensible when applied to positions which require a professional technical background.

The study's authors also felt that in many cases scientists and engineers serving as officers were much better utilized and in a better position to effect change than S&E enlisted personnel, but they also acknowledged that effective utilization of S&E personnel was affected by advancement policies. For example:

> In the small pre-World War II services, advancement was based on competence in various aspects of the service and an officer was rotated from job to job to give him broad experience. It is a sound concept in positions primarily administrative in nature, or of the type involving command functions. This procedure not only is unwise but wasteful and inhibitory of efficiency when applied to positions which are primarily technical in nature, where efficient performance depends on a specific technical background.

Concern about the utilization of military scientists and engineers continued after the Vietnam War and through the cold war (Nichols 2002).

Some analyses looked at services as a whole, others looked at specific organizations such as service research laboratories, and some looked at specific S&E fields. An example of this last type was a report that examined the use of uniformed behavioral scientists in the Air Force (Ruck and Mitchell 1993). This study, which surveyed all uniformed behavioral scientists, selected scientific managers, and selected civilian supervisors, found:

> [G]eneral agreement on the need for uniformed behavioral scientists but little consensus on what their role should be in contingency operations or in wartime. Respondents recommended gaining requisite experience through increased participation in exercises and assignment of operational duties.

Appendix B. Senior Leader Viewpoints

The STPI research team conducted a small effort to determine what senior DOD leaders have said publicly about military scientists and engineers and found few such statements. Of the four given here, one only deals with science and engineering tangentially, but the other three address the topic directly.

In a speech at West Point on February 25, 2011, Secretary of Defense Robert Gates did not specifically mention military science and engineering, but his suggestions apply to it as well (Gates 2011):

> In addition to the essential troop command and staff assignments, you should look for opportunities that in the past were off the beaten path, if not a career dead end—and the institutional Army should not only tolerate, but encourage you in the effort. Such opportunities might include further study at grad school, teaching at this or another first-rate university, spending time at a think tank, being a congressional fellow, working in a different government agency or becoming a foreign area specialist.

General Paul Kern (commanding general of the Army Materiel Command, 2001–2004), when inaugurating a new—since ended—Army S&E program, noted how scientists and engineers could help the Army adapt new technologies for its use (Drewen 2003):

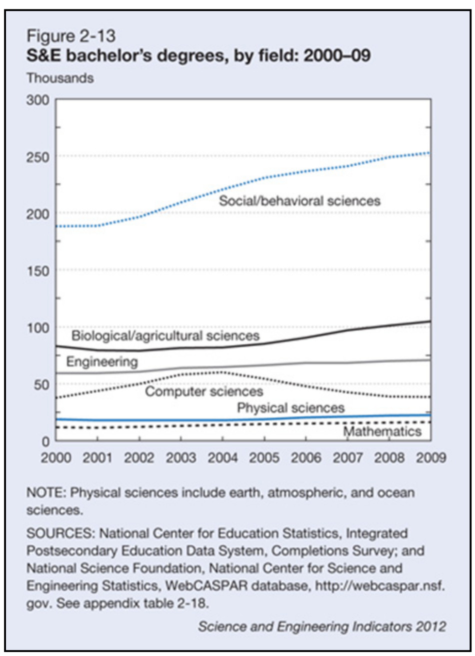
> The uniformed Army scientist and engineering officer, equipped with field experience and an advanced engineering or hard-science degree, provides the Army with specialized technical skills and understanding. These officers enable our Army to make informed decisions on new and emerging technology and then to rapidly transition that technology from the laboratory to warfighters on the battlefield.

In congressional testimony, R.Adm. Matthew Klunder, Chief of Naval Research, emphasized the role of S&T (HASC 2012): "Our ability to support the warfighter also depends on our ability to sustain a science and technology, engineering, and mathematics workforce in our Active and Reserve ranks and our research laboratories."

Introducing in 2011 the roadmap for the Air Force Bright Horizons program designed to increase STEM effectiveness, Michael B. Donley, the Secretary of the Air Force, (U.S. Air Force 2011), said, "Effective strategic management of our Airmen is the cornerstone of our future, and STEM Airmen will play an ever-increasing role in our success."

Appendix C.
Science and Engineering Indicators

To determine whether the supply of U.S. S&E officers is sufficient to meet military science and engineering (S&E) needs the STPI research team reviewed the National Science Foundation S&E Indicators (NSF 2012) summary of the civilian U.S. S&E workforce. Figure C-1 shows the bachelor's degrees recently awarded in the United States in the various S&E fields. The National Science Foundation numbers include a relatively small number of students in fields such as political science and sociology who are primarily U.S. citizens. In 2009, approximately 500,000 degrees were confirmed, of which about half were in the social and behavioral sciences. In the 2009/2010 academic year, about 90,000 foreign undergraduate students were enrolled in S&E fields, and approximately 17,000 were awarded bachelor's degrees in 2009. Foreign S&E bachelor's degrees make up about 4% of the total awarded in the years covered in the figure, although in certain engineering fields it is about twice that amount.

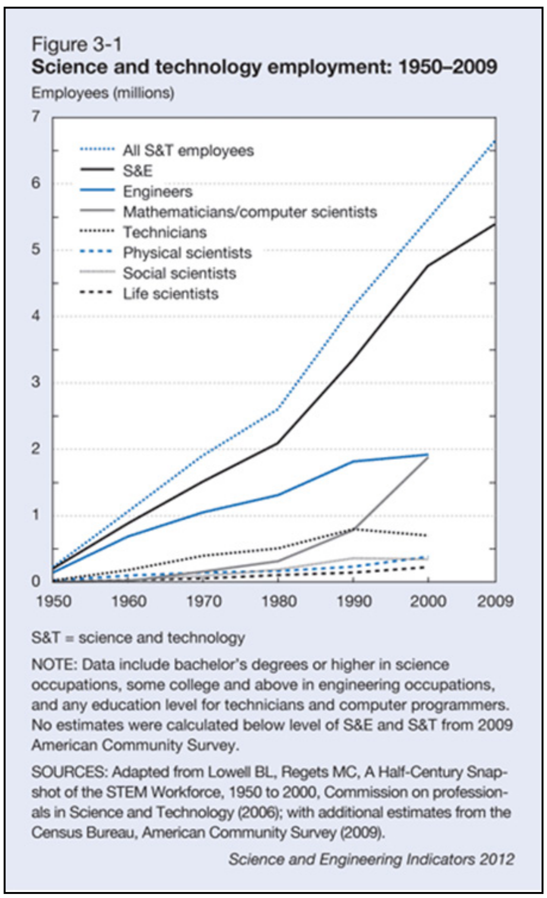


Source: NSF (2012).

Figure C-1. S&E Bachelor's Degrees, by Field

In 2009, graduate S&E enrollment in the United States totaled about 612,000, of which about 443,000 (72%) were U.S. citizens or permanent residents. In certain S&E graduate education fields this fraction is much less, however. For example, 49% of students in chemical engineering, 39% of students in electrical engineering, 51% of students in computer science, and 57% of students in physics were U.S. citizens or permanent residents. In 2009, approximately 41,000 S&E doctoral degrees were awarded in the United States. Of these, about 28,000 (68%) were awarded to U.S. citizens or permanent residents, although in certain fields this number was significantly lower. In 2009, 711 (34%) of doctorates in electrical engineering, 437 (49%) of doctorates in chemical engineering, 472 (40%) of the doctorates in mechanical engineering, 730 (46%) of doctorates in computer science, and 781 (49%) of the doctorates in physics went to U.S. citizens or permanent residents.

Figure C-2 shows the U.S. S&E employment numbers for about the last 50 years. In 2009 there were about 5.5 million people in the United States employed in what the National Science Foundation called S&E positions and 6.5 million people employed in the larger science and technology category.



Source: NSF (2012).

Figure C-2. Science and Technology Employment: 1950–2009

There are approximately 28,000 S&E officers in the U.S. military. Under the assumption that the average career is about 25 years, then about 1000 new S&E officers would be required each year to maintain the current status. This number is small compared to the over 500,000 S&E bachelor's degrees awarded annually and even compared to the 28,000 doctorate graduates each year who are U.S. citizens or permanent residents. In 2012 the Air Force had approximately 1100 officers (about 1.7% of the total) with doctorate degrees (field not specified).[1] Extrapolating this percentage to the other services suggests that the military needs at most a few hundred new officers with S&E doctorates each year to maintain its current number—or about 1% of the yearly production of S&E doctorates of U.S. citizens and permanent residents. Just considering just numbers, the military use of S&E officers is not constrained by supply; however, this conclusion may be different for certain specific fields within S&E.

---

1 Air Force Personnel Center, "Military Demographics," 2012, http://www.afpc.af.mil/library/airforcepersonneldemographics.asp.

Appendix D.
Data Parameters

Table D-1 is a list of the data elements (variables) received from the Defense Manpower Data Center (DMDC) for the analysis. Table D-2 shows the Department of Education taxonomy Classification of Instructional Programs (CIP).

Table D-1. Alphabetical Listing of Data Elements Provided by the DMDC

Variable Name	Field Number	Variable Name	Field Number
Accession AFQT Category Code	79	Military Aeronautical Rating Code	91
Accession Educational Designator Code	83	Pay Grade Months Quantity	57
Accession Program Source Code	41	Person Age Quantity	26
Active Federal Military Service Months Quantity	17	Person Birth Calendar Date	25
Assigned Unit Identification Code	7	Person Sex Code	27
Assigned Unit Major Command Code	62	Person Social Security Number Identifier	1
Authorized Access Security Clearance Code	48	Primary DOD Occupation Code	19
Command Status Code	72	Primary Service Occupation Code	20
Defense Program Planning Code	39	Professional Military Education Level Code	44
Duty Base Facility Identifier	13	Race Code	28
Duty DOD Occupation Code	21	Secondary DOD Occupation Code	23
Duty Service Occupation Code	22	Secondary Service Occupation Code	24
Duty Unit Location Country Code	8	Service Branch Classification Code	2
Duty Unit Location US Postal Region ZIP Identifier	10	Uniformed Service Initial Entry Calendar Date	14
Duty Unit Location US State Alpha Code	9	Uniformed Service Organization Component Code	3
Educational Discipline Code	92	Uniformed Service Pay Grade Code	4
Educational Level Code	43	Uniformed Service Rank Effective Calendar Date	6
Ethnic Group Code	29		

Source: DOD APF Civilian Personnel Edit Unpacked File (200803 and After), in progress.

Table D-2. Classification of Instructional Programs (CIP) Edition 2000, U.S. Department of Education, Institute of Educational Services

CIP Family	CIP Title	CIP Family	CIP Title
01	Agriculture, Agriculture Operations, and Related Sciences	32	Basic Skills
02	Agricultural Sciences	33	Citizenship Activities
03	Natural Resources and Conservation	34	Health-Related Knowledge and Skills
04	Architecture and Related Services	35	Interpersonal and Social Skills
05	Area, Ethnic, Cultural, and Gender Studies	36	Leisure and Recreational Activities
09	Communication, Journalism, and Related Programs	37	Personal Awareness and Self-Improvement
10	Communications Technologies/Technicians & Support Services	38	Philosophy and Religious Studies
11	Computer & Info Sciences & Support Services	39	Theology and Religious Vocations
12	Personal and Culinary Services	40	Physical Sciences
13	Education	41	Science Technologies/Technicians
14	Engineering	42	Psychology
15	Engineering Technologies/Technicians	43	Security and Protective Services
16	Foreign Languages, Literatures, and Linguistics	44	Public Administration and Social Service Professions.
19	Family and Consumer Sciences/Human Sciences	45	Social Sciences
21	Programs for Series 21	46	Construction Trades
21	Technology Education/Industrial Arts	47	Mechanic and Repair Technologies/Technicians
22	Legal Professions and Studies	48	Precision Production

Appendix E.
Additional Data from Demographic Analysis

Breakdown of the Military S&E Population by Occupational Code

Table E-1 details the distribution of military S&E officers, as defined for this project. It lists the five most prominent subcategories within each of the nine major DOD Occupational Categories. Note that because there are other subcategories that are not shown, the sum of the major subcategories within each category does not equal the total number of officer S&E shown for each category.

Table E-1. Top Primary Service Occupation Codes within Each DOD Occupational Category

Category & Code	Count	Category & Code	Count
21 General Officers & Executives	**720**	**26 Healthcare**	**2,527**
Information Warfare Officer (Staff)	164	Preventive Medicine Sciences	444
Information Warfare Officer (National)	87	Laboratory Sciences	434
Tactical Information Warfare Officer (Surface)	87	Behavioral Sciences	413
LDO - Information Warfare	60	Bioenvironmental Engineer, General	265
Biochemistry	60	Clinical Psychologist	207
22 Tactical Operations Officers	**4,993**	**27 Administrators**	**925**
Combat Engineer Officer	1,431	Information Systems Management	396
Engineer	1,016	RL - Special Duty Officer Billet - Information Professional Officer	122
Combat Engineer	574	Acquisition Manager	53
Reconnaissance/Surveillance/Electronic Warfare Combat Systems Officer, RC-135 EWO	293	Inspector, Technical	35
Naval Flight Officer (NFO), Qualified EA-6B Electronic Warfare Officer	161	LDO - Information Systems	29
23 Intelligence	**1,057**	**28 Supply, Procurement & Allied**	**2,473**
Signal Intelligence/Electronic Warfare	559	Acquisition Manager	1,696
Information Operations Officer	197	Acquisition	223
Signal Intelligence/Ground Electronic Warfare Officer	114	Developmental Engineer, Electrical/Electronic	80
Acquisition Manager	28	Aviation Acquisition Management Professional	80
LDO - Information Warfare	23	Technical Supply Officer (Aviation)	50
24 Engineering & Maint.	**8,296**	**29 Non-Occupational**	**1,827**
Engineer	1,416	Uniformed Services University of Health	205

Category & Code	Count	Category & Code	Count
		Sciences (USUHS) Student	
Chemical, Biological, Radiological, and Nuclear (CBRN)	1,038	Engineer	176
Communications Officer	904	Combat Engineer Officer	165
Developmental Engineer, Electrical/Electronic	679	Chemical, Biological, Radiological, and Nuclear (CBRN)	117
Civil Engineer, General Engineer	651	Communications Officer	101
25 Scientists & Professionals	**4,429**	**20 (Unknown)**	**1,461**
Communications-Electronics Engineer	847	Engineer	264
Developmental Engineer, Project	539	Combat Engineer	180
Operations Research Analyst	409	Chemical, Biological, Radiological, and Nuclear (CBRN)	104
Tactical Signal Intelligence-Electronic Warfare	386	Combat Engineer Officer	63
Operations Research/Systems Analysis	329	SC - Civil Engineer Corps	59

Distribution by Major Command of the Military S&E Population

Table E-2 shows the Major Command organizations employing the largest number of military scientists and engineers.

Table E-2. Distribution by Major Command of the Military S&E Population

Code	Major Command	Count
FC	92MSS Fairchild AFB WA (AMC)	3,352
1M	Air Force Materiel Command	2,824
60	Commander, US Atlantic Fleet (COMLANTFLT)	1,500
1S	Air Force Space Command	1,409
TC	US Army Training And Doctrine Command (TRADOC)	1,364
1C	Air Combat Command	1,328
0J	Air Education and Training Command	1,220
MC	US Army Medical Command (MEDCOM)	1,079
70	Commander, US Pacific Fleet (COMPACFLT)	999
SE	Army Staff Field Operating Agencies (Resourced By 0A-22)	765
76	Naval Education Training Command (NETC)	631
P1	US Army Pacific (USARPAC)	503
SP	20MSS Shaw AFB SC (ACC)	488
3V	AF Elements (Other)	462
18	Chief, Bureau of Medicine and Surgery (BUMED)	378
02	AF Inspection Agency	360
JA	Joint Activities (Less SHAPE)	320
13	Unassigned	295

Code	Major Command	Count
0R	Pacific Air Forces	280
1L	Air Mobility Command	252
DF	355MSS Davis-Monthan AFB AZ (ACC)	234
0U	HA Air Force Intelligence Agency	232
0B	US Air Force Academy	225
AS	US Army Intelligence And Security Command (INSCOM)	224
E5	1-2MSF Otis ANG/ANX MA	206
E1	US Army Europe And Seventh Army	190
--	(624 Other Major Commands)	7,588

Age Profile of Military S&E

Figure E-1 shows the age profile of the military S&E population for both male and female officers. The heavy bar at an age slightly above 40 represents the age when the officers complete their 20 years required for full retirement. The general structure of the age distributions is comparable for the military scientists and engineers and total military officer populations, although there is a slightly longer tail for the total officer population at the highest ages.

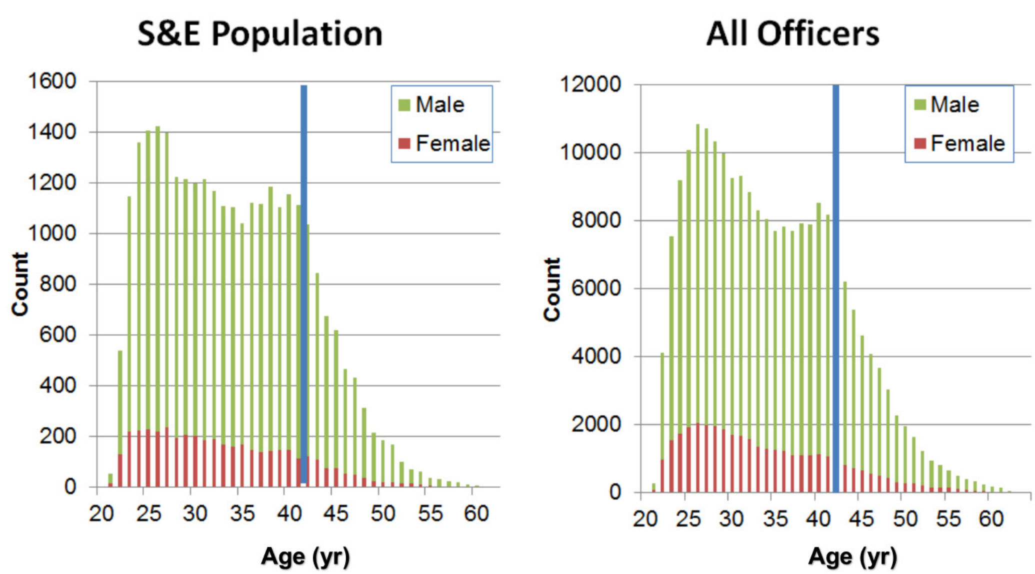


Figure E-1. Age Profile of Military S&E Population Compared to Age Profile of Total Military Officer Population

More Detail on Grade Structure

Figure E-2 is the ratio of the two bars in each grade level depicted in Figure 12 of the main text. It shows the fraction of the S&E officers in each grade (as compared to all S&E officers) to the fraction of the non-S&E officers in each grade (as compared to all non-S&E officers). The deviation from 1.0 is a measure of the difference in grade structure between S&E and non-S&E officers.

Although definitive information is lacking, the results of Figure E-2 can be explained by the following hypothesis. As a percentage, there were somewhat more S&E officers than non-S&E officers at the entering O-1 level in FY 2011. Using the Army as an example, many incoming officers who graduate from West Point and Reserve Officer Training Corps programs have active service obligations of 4–6 years. Typical time in service to reach O-3 in the Army is about 4–5 years (U.S. Army 2010). For the Marine Corps it is about 4 years and 7 months (Hoffman 2008). If one assumes that proportionally more S&E officers than non-S&E officers leave the military at this early stage, then the decrease shown in Figure E-2 for the low-ranking officers could be explained. That is, those inclined toward a solely technical career in the military may find that they are better suited to civilian life (Calandra 2003).

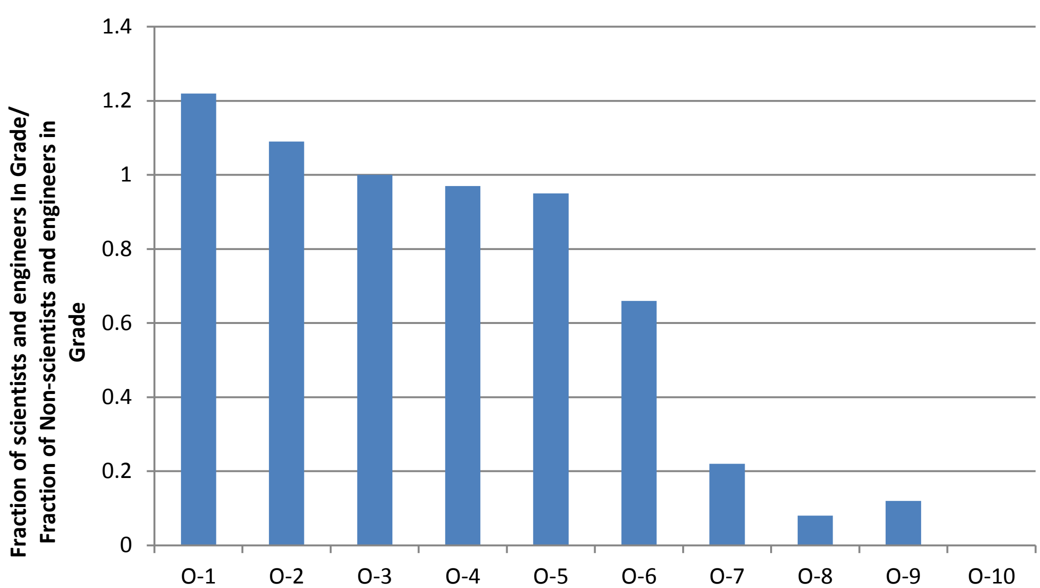


Figure E-2. Ratio of the Fraction of S&E Officers to the Fraction of Non-S&E Officers by Grade

In the past, leadership and management responsibilities for incoming S&E officers have sometimes been emphasized over the technical component of positions (Hoeber et al. 1985). Many other factors besides S&E background and desires can influence retention, however (Fricker 2002). In the recent past the promotion rate to captain has been high—98% for the Army in 2007 (U.S. Army 2007) and essentially 100% for the Air Force from 2002 to 2010 (Gosselin 2010)—so this decrease is probably not due to differential promotion rates. Those officers who stayed would then probably be committed to complete at least 20 years to qualify for retirement. As a result, it would be expected that the values in Figure E-2 would remain about the same from O-3 until the 20-year point (typically reached at the end of the O-5 grade if there was not any difference in promotion opportunities. As Figure E-2 shows, this is indeed the case. This type of reasoning in conjunction with the information in Figure E-2 would lead to the conclusion that at least to the level of O-5, S&E officers and non-S&E officers had comparable promotion rates.

Figure E-2 shows a relatively large drop in the relative proportion of S&E officers at the O-6 level. This could be caused, for example, by a lower promotion rate, a lower service retention rate, or some combination of the two. Several focus group participants mentioned that S&E officers found it easier to find jobs after retirement (as well as if they separated after their initial commitment was fulfilled) than non-S&E officers. This might make them more likely to voluntarily leave the military. In some cases, they would return to their old organizations, sometimes after spending a few years in private industry, to increase their salary. The Air Force Acquisition Career Field Management Office presented data that showed that the promotion rates for the two groups of officers in Air Force acquisition were essentially the same up to O-6.

Promotion Historical Trends

Figure E-3 shows the trend of total military officers. After the end of the cold war in 1989, the total number of military officers progressively declined until FY 2001, after which the total number began increasing slightly. The chart on the left shows data from O-1 through O-6, and the chart on the right shows the same data, at an expanded scale, for O-7 to O-10.

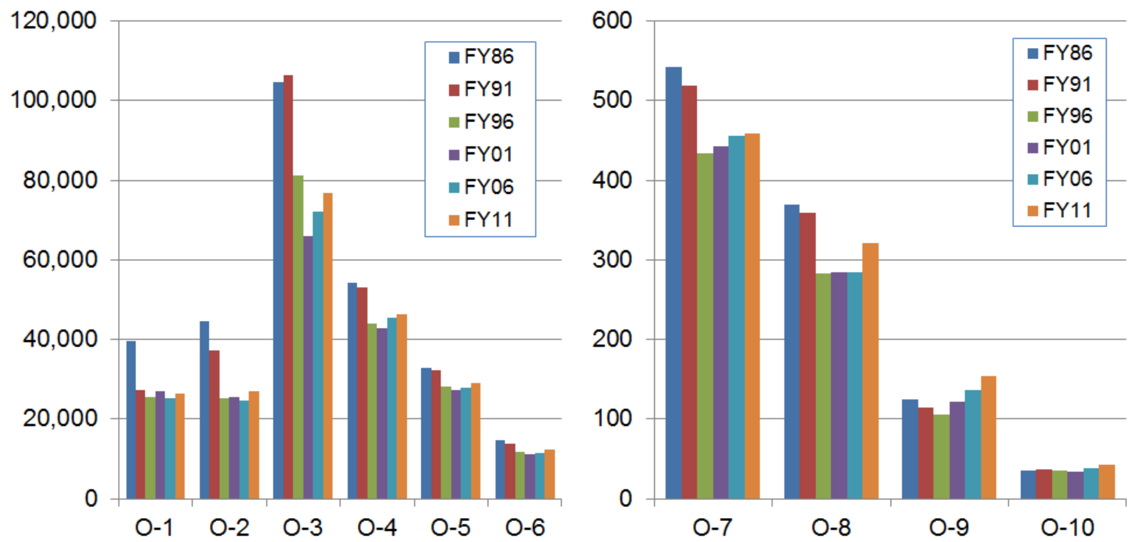


Figure E-3. Historical Grade Structure of All Officers (FY 1986–FY 2011)

Figures E-4 and E-5 show the total number of S&E officers within each service at 5-year intervals, beginning in FY 1986. The military S&E population has decreased from a relative high of 60,669 in FY 1986 to 28,708 in FY 2011. With the exception of the U.S. Marine Corps, which has relatively low number of military scientists and engineers, Figure E-5 shows a decrease in military S&E population in all the services. In absolute and relative terms, however, the decrease was different for the different services. For example, about 67% of the decrease in scientists and engineers between FY 1986 and FY 2011 was due to a reduction in the Air Force S&E officer population by 20,000; the Air Force had only one-third the number of scientists and engineers in FY 2011 as it did in FY 1986. Similarly, in FY 1986 the Air Force had about one-half the total number of scientists and engineers for all services combined; by FY 2011, it had only about one-third the total.

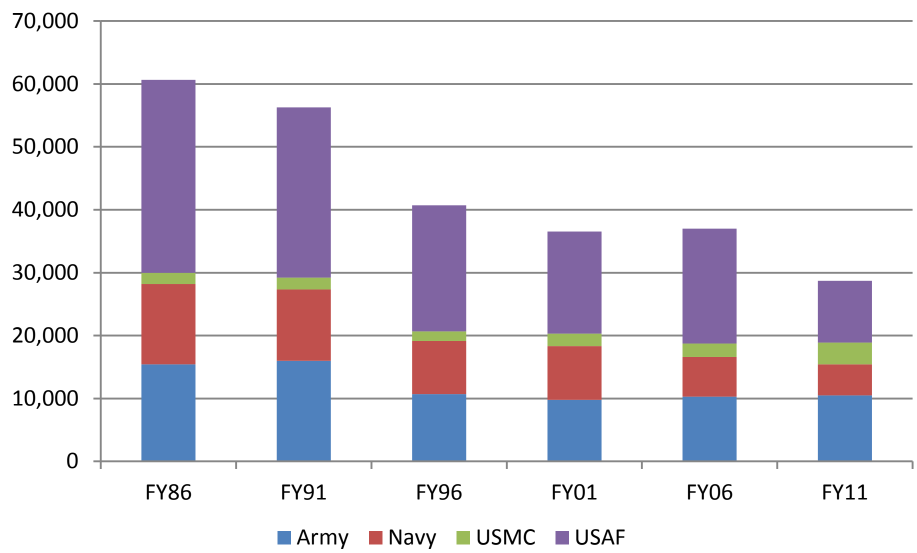


Figure E-4. Historical View of S&E Officers

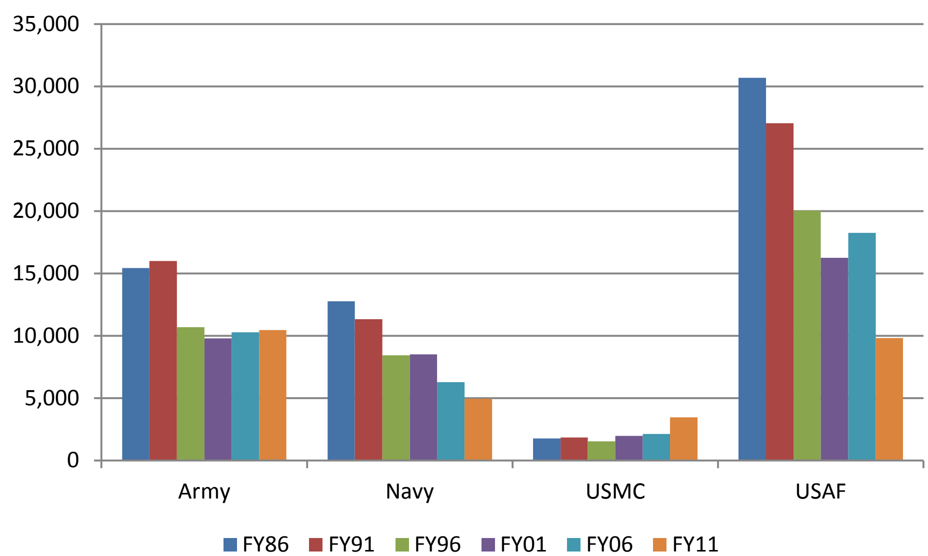


Figure E-5. Historical View of S&E Officers within Each Department

S&E Population at Senior Leader Ranks

Table E-3 identifies the Primary S&E-related Service Occupation Codes and the service affiliation of the general/flag officers identified within the S&E population. None were identified at the O-10 grade using the Primary Service Occupation Code, although as described before, 16 individuals in this grade were determined to have an S&E degree.

Table E-3. S&E Population at Senior Leader Ranks

Grade	Primary Service Occupation Code Title	Department
O-9	Acquisition Manager	Air Force
O-9	Communications-Electronics Engineer	Army
O-9	Director of Communications	Navy
O-8	Chemical Munitions and Materiel Management	Army
O-8	Communications-Electronics Engineer	Army
O-8	RL - Special Duty Officer Billet - Information Prof Officer	Navy
O-8	RL - Special Duty Officer Billet - Information Prof Officer	Navy
O-7	Developmental Engineer, Project	Air Force
O-7	Acquisition Manager	Air Force
O-7	Civil Engineer, General Engineer	Air Force
O-7	Communications-Electronics Engineer	Army
O-7	Communications-Electronics Engineer	Army
O-7	Communications-Electronics Engineer	Army
O-7	Communications-Electronics Engineer	Army
O-7	Chemical Munitions and Materiel Management	Army
O-7	Staff Communications Officer	Navy
O-7	Information Warfare Officer (Staff)	Navy
O-7	RL - Special Duty Officer Billet - Information Prof Officer	Navy
O-7	RL - Special Duty Officer Billet - Information Prof Officer	Navy
O-7	RL - Special Duty Officer Billet - Information Prof Officer	Navy
O-7	Information Warfare Officer (Staff)	Navy

O-10 Flag/General Officers Biographical Assessment

The official biographies of the current 40 O-10 flag and general officers were reviewed. They were assessed as being either STEM literate (i.e., STEM education) or STEM professional (STEM education and STEM military position experience).

From the official biographies, at least 13 (33%) have a STEM bachelor's degree and at least 9 (23%) have a STEM master's degree (many using military sponsorship). Some may have both degrees, but at least 16 (40%) have at least one STEM degree. Few appear to have had actual STEM occupational positions in their careers, however.

Appendix F.
List of Meetings and Focus Group Information

This appendix identifies the primary meetings conducted in the course of this project. As originally conceived, the plan was for four site visits to DOD organizations where members of the research team would conduct two 2-hour facilitated sessions, with approximately 6–10 participants at each site. The first session would consist of S&E military officers, and the second session would consist of military and civilian S&E managers. The participants were chosen by the organizations based on availability and interest, but may not be representative of the organization or DOD as a whole. In particular, except for a few participants in the lowest officer grades, most of the focus group participants had already decided to make the military a career and by the usual external standards such as promotion rates had what would normally be described as successful careers. An experimental psychologist from IDA served as the facilitator. Typically, two team members and 1 to 2 observers from OSTP were also in attendance. A handout with potential discussion topics was submitted in advance. The objective was to identify themes regarding utilization of DOD scientists and engineers and other information to supplement the more quantitative data.

A major goal was to collect information from various service workforce officials and from military scientists and engineers and their supervisors, whether serving in laboratory or non-laboratory positions. Focus-group participants who had the time and opportunity to serve were selected by their units in a particular organization. To make it easier for the participants to speak freely, the focus group discussions were conducted with the explicit understanding that there would be no attribution. Participants cannot be considered a scientifically selected group, and no claim can be made that their views are necessarily representative of the larger force. As a result, the information from them must be considered anecdotal. It is still valuable, however, in that several concepts and views were often common within and between groups. The information also provided background to help us understand and interpret information from the more quantitative analysis.

Visits were coordinated with the senior leaders in the military departments to identify organizations representative of each department's use of military scientists and engineers. The objective was to visit both research and non-research organizations to observe the use of bench scientists, as well as field engineers. The team wanted to conduct on-site meetings to enable broad participation in discussions. (When on-site interviews were not considered to be an efficient use of resources because of distance and expense, information was collected by telephone.)

At a given installation, two separate focus group meetings were usually held: one with managers and the other with non-managers. The management group consisted of military officers and some civilians with military scientists and engineers in their groups. Most but not all of these officers were military scientists and engineers at the O-5 level (lieutenant colonel/navy commander) and O-6 level (colonel/captain) who themselves had technical backgrounds.[5] The civilians were often retired military scientists and engineers. The non-manager group consisted of military S&E often at the O-4 (major/lieutenant commander), O-5, and O-6 level, although there were a number of O-1 (second lieutenant/ensign), O-2 (first lieutenant/lieutenant junior grade) and O-3 (captain/lieutenant). Most began their careers as officers, but a few began as enlisted. Their years in military service ranged from about 2 to 25 years. These individuals could be working in positions that did or did not require or use their technical background.

The following meetings were held:

- November 16, 2012, Air Force Acquisition Career Field Management Office, Pentagon.
- November 28, 2012, Office of Naval Research.
- December 4, 2012, National Geospatial-Intelligence Agency.
- December 18, 2012, Army Research and Development Engineering Command, Aberdeen Proving Ground.
- January 9, 2013, Army Medical Research and Materiel Command, Fort Detrick.
- January 17, 2013, National Air and Space Intelligence Center, Wright-Patterson Air Force Base.
- January 17, 2013, Air Force Life Cycle Management Center, Wright-Patterson Air Force Base.

[5] For the most part, the experienced military scientists and engineers who participated in the focus groups were considered to have successful military careers under the assumption that many of those with unsuccessful or unsatisfying careers would be expected to leave the military.

Bibliography

Military Science and Engineering

Aubin, D. 2011. *I'm Just a Mathematician: Why and How Mathematicians Collaborated with Military Ballisticians at Gâvre*. http://hal.upmc.fr/docs/00/63/98/95/PDF/08_Aubin2_lorez.pdf.

Clinton, Y. V., Foran-Cain, J. V. McQuaid, C. E. Norman, and W. H. Sims. 2010. *Congressionally Directed Assessment of the Human Terrain System*. Alexandria, VA: CAN. CRM D0024031Al. http://info.publicintelligence.net/CNA-HTS.pdf.

Defense Science Board (DSB). 2012. *Basic Research*. http://www.acq.osd.mil/dsb/reports/BasicResearch.pdf.

Delo, D. 1948. *Scientists in Uniform: World War II*. http://babel.hathitrust.org/cgi/pt?id=mdp.39015076679169;page=root;view=image;size=100;seq=7;num=i.

DePalma, T. J., and W. D. Brobst. 2008. *Does a Technical Education Improve Tactical Performance?* Alexandria, VA: CNA. http://www.cna.org/research/2008/does-technical-education-improve-tactical.

Department of Defense (DOD). 2001. *Department of Defense In-House RDT&E Activities: FY2000*, http://www.dtic.mil/dtic/tr/fulltext/u2/a392016.pdf.

Firestone, J. M. 1992. "Occupational Segregation: Comparing the Civilian and Military Work Force." *Armed Forces & Society* 18: 363. http://afs.sagepub.com/content/18/3/363.full.pdf+html.

Gotz, G. A., K. W. Tyson, L. S. Anderson, and D. Wink. 2005. *Comparative Costs of Air Force Military and Civilians in Selected Science and Engineering Specialties*. IDA Paper P-3791.

Hoffman, J. M. 2008. "Significant Factors in Predicting Promotion to Major, Lieutenant Colonel, and Colonel in the United States Marine Corps." Thesis, Monterey, CA: Naval Post Graduate School. http://www.foreignpolicy.com/images/090423_promotion_thesis.pdf.

House Armed Services Committee (HASC). 2010. *Another Crossroads? Professional Education Two Decades After the Goldwater-Nichols Act and the Skelton Panel*. Subcommittee on Oversight and Investigations. 111th Congress, 1st Session. HASC No. 11-67. http://usnwc.libguides.com/content.php?pid=335277&sid=2743178.

Kavetsky, R., R., M. Marshall, and D. K. Anand. 2010. *From Science to Seapower: A Roadmap for S&T Revitalization*. Center for Energetic Concepts Development, University of Maryland.

Mehuron, T. A. 2004. "So Far, So Good." *Air Force Magazine* (October) http://www.airforce-magazine.com/MagazineArchive/Documents/2004/October%202004/1004sofar.pdf.

MITRE Corporation. 2009. *S&T for National Security*. JASON Program Office. JSR-08-146, May. http://www.dtic.mil/dtic/tr/fulltext/u2/b360036.pdf.

National Research Council (NRC). 2010. *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*. National Academies Press: Washington, D.C., http://books.nap.edu/catalog.php?record_id=12718.

Norris, L. D., J. C. Milligan, and O. B. Faulk. 1998. *William H. Emory: Soldier-Scientist*. University of Arizona Press. http://books.google.com/books?hl=en&lr=&id=f6eHhGGX7MUC&oi=fnd&pg=PP11&ots=LUMSL83AR7&sig=H-1Wz4NmJgWvvIVPVFaPujr1idA#v=onepage&q&f=false.

Pidcock, R. 2011. "The Job Market: Science in the Military." *Science Career Magazine* (December 2). http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2011_12_02/caredit.a1100135.

Ruck, H. W., and J. L. Mitchell. 2009 "Perceived Need for Roles of Uniformed Behavioral Scientists in the United States Air Force." *Military Psychology* 5 (4), 17 November. http://www.tandfonline.com/doi/abs/10.1207/s15327876mp0504_2.

Thiesmeyer, L. R., and J. E. Burchard. 1947. *Combat Scientists*. Boston, MA: Little Brown and Company. http://babel.hathitrust.org/cgi/pt?id=mdp.39015014599099;page=root;view=image;size=100;seq=14;num=x.

U.S. Air Force Personnel Center. 2012. *Military Demographics*. http://www.afpc.af.mil/library/airforcepersonneldemographics.asp.

U.S. Army. 2010. "Commissioned Officer Professional Development and Career Management." Pamphlet 600-3. http://www.apd.army.mil/pdffiles/p600_3.pdf.

U.S. Army Human Terrain System Website. http://humanterrainsystem.army.mil/.

U.S. Army Science Board. 2013. "The Strategic Direction for Army Science and Technology." http://www.dtic.mil/docs/citations/ADA571038.

Van Valkenburg, M. E., and L. E. Peterson. 2011. "The United States Air Force Road to 'Bright Horizons'." *Astropolitics: The International Journal of Space Politics & Policy* 9 (2–3): 173–192.

General

Amato, I. 1998. *Pushing the Horizon: Seventy-Five Years of High Stakes Science and Technology at the National Research Laboratory*. http://www.nrl.navy.mil/content_images/horizon.pdf.

Defense Acquisition Portal. 2011. "FY 11 (as of September 30, 2011) – OVERALL Defense Acquisition Workforce Count." https://dap.dau.mil/workforce/Documents/End-FY11%20DAW%20Snapshot%20Count%20Matrix.pdf.

Defense Acquisition University (DAU). 2010. *Defense Acquisition Workforce Report – Online Version.* https://acc.dau.mil/acquisitionworkforce.

——. 2010. *OUSD(AT&L) Defense Acquisition Workforce Analysis, FY 2010*. "AT&L Workforce Count & Composition by Component." https://dap.dau.mil/workforce/Documents/FY10_Overall_DAW_Analysis.pdf.

——. 2013. "AT&L Workforce Position Category Description (PCD)." https://myclass.dau.mil/bbcswebdav/institution/Courses/Deployed/01_CurriculumDocumentation/Position_Category_Descriptions/PCD%20T%26E.pdf.

Department of Defense (DOD). 2012. *Defense Manpower Requirement Report: Fiscal Year 2012.*

——. 2004. *Automated Extracts of Manpower and Unit Organizational Element Files*. DOD I 7730-64, Enclosure 4, Billet Master File Format. December 11. http://www.dtic.mil/whs/directives/corres/pdf/773064p.pdf.

Fricker, R. D. 2002. *The Effects of Perstempo on Officer Retention in the U. S. Military*. RAND. http://www.rand.org/content/dam/rand/pubs/monograph_reports/2007/MR1556.pdf.

National Science Foundation (NSF), Division of Science Resources Statistics. 2008. *Science and Engineering Indicators*, Arlington, VA: National Science Foundation.

Seng, J. M., and P. E. Flattau. 2009. *Assessment of the DOD Laboratory Civilian Science and Engineering Workforce*. Alexandria, VA: Institute for Defense Analyses. IDA Paper P-4469.

References

Army Science Board. 2013. “The Strategic Direction for Army Science and Technology.” http://www.dtic.mil/docs/citations/ADA571038.

Brown, A. 2007. “Information Paper: Uniformed Army Scientist and Engineer (UAS&E) Program.” http://asc.army.mil/docs/divisions/acd/Info_Papers.pdf.

Calandra, B. 2003. “Uniformed Scientists Do Unique Work.” *The Scientist* (November 3). http://www.the-scientist.com/?articles.view/articleNo/15215/title/Uniformed-Scientists-Do-Unique-Work/.

Conway, E. M. 2006. “Blind Landings: Low-Visibility Operations in American Aviation, 1918–1958.” Johns Hopkins University Press.

Defense Science Board. 2012. *Report of the Defense Science Board Task Force on Basic Research*. January. http://www.acq.osd.mil/dsb/reports/BasicResearch.pdf.

DePalma, T. J., and W. D. Brobst. 2008. *Does a Technical Education Improve Tactical Performance*? Alexandria, VA: CNA. http://www.cna.org/research/2008/does-technical-education-improve-tactical.

Department of Defense (DOD). 2013. “Department of Defense Occupational Information Collection and Reporting.” DOD Instruction 1312.01. http://www.dtic.mil/whs/directives/corres/pdf/131201p.pdf.

——. 2009. “Automated Extract of Active Duty Military personnel Records.” http://www.dtic.mil/whs/directives/corres/pdf/133605_instruction.pdf.

Dodge, Jr., R. C. 2004. “Do Military Forces Need PhD’s?” in *Information Security Management, Education and Privacy*, edited by Y. Deswarte, et al. Springer.

Drewen, K. J. 2003. “New Program to Develop Army Scientists and Engineers.” *Army AL&T* (November-December). http://asc.army.mil/docs/pubs/alt/archives/2003/Nov-Dec_2003.pdf.

Fricker, R. D. 2002. “The Effects of Perstempo on Officer Retention in the U. S. Military.” RAND. http://www.rand.org/content/dam/rand/pubs/monograph_reports/2007/MR1556.pdf.

Gates, R. 2011. United States Military Academy speech. West Point, NY. February 25. http://www.defense.gov/speeches/speech.aspx?speechid=1539.

Gosselin, B. 2010. “Air Force Officials Reinstate Captain Central Selection Board,” *Air Force Public Affairs* (October 13). http://www.af.mil/news/story.asp?id=123226118.

Hallion, R. P. 2010. “Scientists, Engineers, and the Air Force: An Uncertain Legacy.” Appendix G in *Examination of the U.S. Air Force’s STEM Workforce Needs in the*

Future and its Strategy to Meet Those Needs. Washington, DC: National Academies Press. http://www.nap.edu/openbook.php?record_id=12718&page=145.

Hoeber, A. M., I. C. Peden, J. Bramley, and M. A. Seagraves. 1985. "Women Engineers and Scientists in the Army." *IEEE Transactions on Education* E-28 (4, November): 222–228. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4321781.

Hoffman, J. M. 2008. "Significant Factors in Predicting Promotion to Major, Lieutenant Colonel, and Colonel in the United States Marine Corps." Thesis, Monterey, CA: Naval Post Graduate School. http://www.foreignpolicy.com/images/090423_promotion_thesis.pdf.

House Armed Services Committee (HASC). 2010. *Another Crossroads? Professional Education Two Decades after the Goldwater-Nichols Act and the Skelton Panel*. Subcommittee on Oversight and Investigations. 111th Congress, 1st Session. HASC No. 11-67. http://usnwc.libguides.com/content.php?pid=335277&sid=2743178.

——. 2012. *Hearing on National Defense Authorization Act for Fiscal Year 2013 and Oversight of Previously Authorized Programs.* Statement of Rear Admiral Matthew L. Klunder, Chief of Naval Research. House Subcommittee on Emerging Threats and Capabilities. 112th Congress, 2nd Session. HASC No. 112-107. http://www.gpo.gov/fdsys/pkg/CHRG-112hhrg73433/html/CHRG-112hhrg73433.htm.

Jones, V. C. 1985. *U.S. Army in World War II: Special Studies—Manhattan: The Army and the Atomic Bomb*. Center of Military History. http://www.history.army.mil/html/books/011/11-10/index.html.

MITRE Corporation, 2009. *S&T for National Security*. JASON Program Office. JSR-08-146, May. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADB360036.

National Science Foundation (NSF). 2012. *Science and Engineering Indicators: 2012*. http://www.nsf.gov/statistics/seind12/.

Naval Research Advisory Committee (NRAC). 2010. "Status and Future of the Naval R&D Establishment." http://www.nrac.navy.mil/docs/2010_Summer_Study_Report.pdf.

National Research Council (NRC). 2010. *Examination of the U. S. Science, Technology, Engineering, and Mathematics Workforce Needs in the Future and Its Strategy to Meet Those Needs*. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=12718.

——. 2011. *2009–2010 Assessment of the Army Research Laboratory*. Washington, DC: National Academies Press. http://www.nap.edu/openbook.php?record_id=13137&page=R1.

——. 2012. *Assuring the U.S. Department of Defense a Strong Science. Technology, Engineering, and Mathematics (STEM) Workforce*. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=13467.

Naval Research Laboratory (NRL). 2010. *NRL Factbook: 2010*. http://www.nrl.navy.mil/content_images/factbook.pdf.

Nichols, C. 2002. "Scientific Warriors," *Acquisition Quarterly Review* (Fall). http://www.dtic.mil/docs/citations/ADA487604.

Naval Research Advisory Committee (NRAC). 2010. *Status and Future of the Naval R&D Establishment.* September. http://www.nrac.navy.mil/docs/2010_Summer_Study_Report.pdf.

Oak Ridge Special Engineer Detachment (SED). 1945. "Oak Ridge SED Yearbook – 1945." http://www.mphpa.org/classic/SED/OR/YB-1945/Pages-1/SEDYB_Gallery_01.htm.

Ruck, H. W., and J. L. Mitchell. 1993. "Perceived Need for and Roles of Uniformed Behavioral Scientists in the United States Air Force." *Military Psychology* 5 (4): 219–233. http://www.tandfonline.com/doi/abs/10.1207/s15327876mp0504_2.

Seng, J. M., and P. E. Flattau. 2009. *Assessment of the DOD Laboratory Civilian Science and Engineering Workforce*. Alexandria, VA: Institute for Defense Analyses. IDA Paper P-4469.

Shoop, B. L., and K. L. Alford. 2002. "Army Transformation: Uniformed Army Scientists and Engineers." *Journal of Defense Software Engineering* (December). http://www.crosstalkonline.org/storage/issue-archives/2002/200212/200212-Shoop.pdf.

Stewart, I. 1948. *Organizing Scientific Research for War*. Boston, MA: Little, Brown and Company. http://bhl.ala.org.au/item/27028#page/294/mode/1up.

Thane, J. M. 2007. "The Future of the Uniformed Army Scientist and Engineer Program." *Military Review*. November-December 2007. http://usacac.army.mil/CAC2/MilitaryReview/Archives/English/MilitaryReview_20071231_art012.pdf.

U.S. Air Force. 2011. "Bright Horizons—The Air Force STEM Workforce Strategic Roadmap." http://afsoco.afciviliancareers.com/uploaded_images/Bright_Horizons.pdf.

U.S. Air Force Personnel Center. 2012. "Military Demographics." http://www.afpc.af.mil/library/airforcepersonneldemographics.asp.

U.S. Army. 1948. *Scientists in Uniform, World War II*. Washington, D.C. http://babel.hathitrust.org/cgi/pt?id=mdp.39015076679169;view=1up;seq=5.

——. 2007. "Stand-To," June 11, 2007, http://www.army.mil/standto/archive/2007/06/11/.

——. 2010. "Commissioned Officer Professional Development and Career Management." Pamphlet 600-3. http://www.apd.army.mil/pdffiles/p600_3.pdf.

U.S. Army Science Board. 2013. "The Strategic Direction for Army Science and Technology." http://www.dtic.mil/docs/citations/ADA571038.

U.S. Navy. n.d. *Dictionary of American Naval Fighting Ships: Parsons*. Naval Historical Center: Washington, D.C. http://www.history.navy.mil/danfs/p2/parsons.htm.

von Karman, T. 1945. “Science – The Key to Air Superiority.” Reprinted in M. H. Gorn, ed. “*Prophecy Fulfilled*. 1994. http://csat.au.af.mil/documents/karman_study.pdf.

Weir, G. E. 2001. *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment*. Texas A&M University Press. http://books.google.com/books?id=mEIFgmmxgMAC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

Williams, K. B. 1999. “Scientists in Uniform: The Harvard Computation Laboratory in World War II.” *Naval War College Review* 52 (3, summer): 90–110. http://www.usnwc.edu/NavalWarCollegeReviewArchives/1990s/1999%20Summer.pdf.

Abbreviations

CIP	Classification of Instructional Programs
DAU	Defense Acquisition University
DMDC	Defense Manpower Data Center
DOD	Department of Defense
DSB	Defense Science Board
FY	fiscal year
HASC	House Armed Services Committee
IDA	Institute for Defense Analyses
MIT	Massachusetts Institute of Technology
MOS	Military Occupational Specialty
NRAC	Naval Research Advisory Committee
NRC	National Research Council
NRL	Naval Research Laboratory
NSF	National Science Foundation
OPM	Office of Personnel Management
OSD	Office of the Secretary of Defense
OSTP	Office of Science and Technology Policy
R&D	research and development
RD&A	research, development, and acquisition
RDECOM	(U.S. Army) Research, Development and Engineering Command
S&E	science and engineering
S&T	science and technology
SED	Special Engineer Detachment
SPAWAR	Space and Naval Warfare Systems Command
STEM	science, technology, engineering, and mathematics
STPI	Science and Technology Policy Institute
UAS&E	Uniformed Army Scientist and Engineer
USAFA	U.S. Air Force Academy
USMC	United States Marine Corps

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
XX-03-2014	Final	Jul 2013 - Oct 2013

4. TITLE AND SUBTITLE
Department of Defense Utilization of Military Scientists and Engineers

5a. CONTRACT NUMBER
NSFOIA0408601

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER
TP-20-1000.AH

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Science and Technology Policy Institute
1899 Pennsylvania Avenue, NW, Suite 520
Washington, DC 20006-3602

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Paper P-5082

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Science and Technology Policy
Executive Office of the President
Eisenhower Executive Office Building
1650 Pennsylvania Avenue
Washington, DC 20504

10. SPONSOR/MONITOR'S ACRONYM(S)
OSTP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited (17 April 2014).

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report characterizes the demographics of military scientists and engineers within the Department of Defense (DOD) as part of an effort to evaluate the overall health and sufficiency of the U.S. scientific and engineering workforce.

15. SUBJECT TERMS
scientists and engineers, promotion opportunities, career path, DoD Defense Manpower Data Center (DMDC), Military Occupational Specialty (MOS)

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	Same as Report	78	Skaggs, Reed R.
					19b. TELEPHONE NUMBER *(Include area code)* 202-456-6120