U.S. Department of Defense
Mechanisms for Attracting and Retaining High Quality Talent in the Department of Defense

Report to Congress on Section 252 of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law 116-283)

Office of the Under Secretary of Defense for Research and Engineering

July 2024

The estimated cost of this report or study for the Department of Defense is approximately $171,000 in Fiscal Years 2021 - 2024. This includes $165,000 in expenses and $6,210 in DoD labor.
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1. Summary

This report consolidates both the initial and final report in response to section 252 of the William M. (Mac) Thornberry National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2021 (Public Law 116-283), "Mechanisms for Attracting and Retaining High Quality Talent in the Department of Defense." The Department did not submit an initial report; however, this report satisfies all other requirements within section 252. Section 252(a) directs the Secretary of Defense to enter into an agreement with an independent academic institution to conduct a study to develop policy options and recommendations for the establishment of a program to attract and retain persons who are engaged in work to promote and protect U.S. national security, engaged in Department of Defense (DoD) -funded research, and posess scientific or technical expertise that will advance the development of critical technologies (hereinafter "covered individuals") for employment in the DoD. Section 252(b) outlines required elements of the study:

(1) An analysis of mechanisms the Department may use to engage public and private sector organizations to assist in the identification and recruitment of covered individuals for employment in the Department of Defense.

(2) Identification of statutory, regulatory, and organizational barriers to the development of the program described in subsection (a).

(3) An analysis of monetary and nonmonetary incentives that may be provided to retain covered individuals in positions in the Department.

(4) An analysis of methods that may be implemented to ensure appropriate vetting of covered individuals.

(5) An analysis of the size of a program required to advance the competitiveness of the research, development, test, and evaluation efforts of the Department in the critical technologies identified in the National Defense Strategy.

(6) The type and amount of resources required to implement the program described in subsection (a).

2. Study

The Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) contracted with the Johns Hopkins University Applied Physics Laboratory (JHU-APL), a university-affiliated research center, to conduct a study to develop policy options and recommendations for the establishment of a program to attract and retain covered individuals for employment in the DoD. The report associated with the study that was conducted is provided as

Appendix A. It is important to note that the study did not address all of the items indicated in section 252(b). The options and recommendations to establish a program as indicated in section 252 are discussed in subsequent portions of this report. In summary, the study concluded that the Department does not need to establish a separate program to attract and retain covered individuals for employment in the DoD because sufficient flexibilities (hiring, recruiting, and retention authorities) and programs already exist that allow the Department to attract and retain "covered individuals" as defined in section 252(d).

a. Mechanisms the Department may use to engage public and private sector organizations to assist in the identification and recruitment of covered individuals for employment in the Department of Defense.

The study identified many existing DoD/university partnerships and on-campus programs that introduce technical challenges that the DoD faces to academia as a way to engage and assist in recruiting covered individuals into the DoD. The Department also has several programs that partner with private sector organizations that serve to assist in the recruitment of covered individuals. These programs are successful in bringing additional covered individuals into the DoD and the Department can leverage these partnerships to identify and recruit covered individuals.[1]

b. Identification of statutory, regulatory, and organizational barriers.

The study did not identified any statutory, regulatory, or organizational barriers to establishing a program to attract and retain covered individuals for employment in the DoD. Furthermore, the Department has not identified a need to establish such a program, given the number of existing programs designed to attract and retain covered individuals within the Department, such as the Science, Mathematics, and Research for Transformation (SMART) scholarship for service program, or attracting and retaining talent through the multitude of personnel authorities granted to the Department over the past several decades. However, the study did identify security and clearance-related barriers that sometimes prohibit or delay attracting and recruiting covered individuals.[2]

c. Monetary and nonmonetary incentives that may be provided to retain covered individuals in positions in the Department.

The study did not identify any monetary or nonmonetary incentives to retain covered individuals in positions in the Department.

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[1] Michael Moskowitz, Dr. Lauren Ice, Emma Bell, and Dr. Stephanie Tolbert, *Identifying and Vetting Technical Talent*, (Laurel, MD: Johns Hopkins Applied Physics Laboratory, December 2022), 21-23.
[2] Ibid, 14, 16.

d. Methods that may be implemented to ensure appropriate vetting of covered individuals.

The study identified very few vetting mechanisms that the Department is not already using. However, the study identified challenges that may further strain the ability of covered individuals to obtain the requisite security clearances to work for the Department in the future, such as marijuana use, student debt, and increased foreign contact.[3]

e. Analysis of the size of a program required to advance the competitiveness of the research, development, test, and evaluation efforts of the Department in the critical technologies identified in the National Defense Strategy.

The study did not estimate the size of a program to advance the competitiveness of the Department's research, development, test, and evaluation efforts. The study did identify that the DoD lacks a holistic strategy for resolving recruitment/retention (talent management) challenges as a potential gap; however, the study also indicated that there was not a one-size-fits-all solution to talent management due to the uniqueness of the technical areas across the Department.[4]

f. The type and amount of resources required to implement a program to hire and retain covered individuals.

The study did not provide any insight or recommendations on the type and amount of resources required to implement a program for the Department to hire and retain covered inviduals, and the Department also does not see the value of creating such a program. Hiring and retention are the responsibilities of the organizations within the Department that employ covered individuals, and such DoD organization already have programs and authorities to recruit and retain covered individuals.

3. Summary

The DoD is committed to hiring and retaining individuals who possess scientific or technical expertise that can advance the development of critical technologies, as identified in the National Defense Strategy or National Defense Science and Technology Strategy. However, creating a unique program for such purpose is not an appropriate response to address challenges to hiring and retaining covered individuals. The Department thanks Congress for their leadership and support in addressing the issue of recruitment and retention strategies to ensure a robust and technically proficient workforce to address science and technology challenges of importance to U.S. national security.

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[3] Ibid, 31-32.
[4] Ibid, 34.

Appendix A: Identifying and Vetting Technical Talent

The report of the study by Michael Moskowitz, Dr. Lauren Ice, Emma Bell, and Dr. Stephanie Tolbert, titled: "Identifying and Vetting Technical Talent," is attached. The authors of the report are from the John Hopkins University Applied Physics Laboratory. The report is dated December 2022.

Appendix A

IDENTIFYING AND VETTING TECHNICAL TALENT

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IDENTIFYING AND VETTING TECHNICAL TALENT

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Summary

The Fiscal Year 2021 National Defense Authorization Act included Section 252, requiring a study on mechanisms for attracting and retaining high-quality talent in the Department of Defense (DoD). The Basic Research Office within the Office of the Under-secretary of Defense for Research and Engineering tasked the Johns Hopkins University Applied Physics Laboratory with supporting its response to Section 252 by analyzing methods to ensure appropriate identification and vetting of research talent within DoD-designated critical technology areas (CTAs).

For this effort, "identifying" includes knowing where to find individuals with the relevant skillsets and considerations related to their proclivity to apply for DoD-related jobs, as well as the recruiting and hiring processes within the research enterprise. "Vet-ting" includes ensuring DoD has the ability to access talent to support its missions in ways that will not jeopardize national security as a result of foreign influence. The study team also took "vetting" to include elements of screening for technical skill and job fit.

Through research, interviews, and analysis of available job requisition data, the study team explored the skillsets required within the CTAs as well as the existing workforce challenges facing the DoD research enterprise. This enterprise includes not only civilian employees of DoD research laboratories, but also researchers at University Affiliated Research Centers and Federally Funded Research and Development Centers, defense contractors, and academia. From this analysis, the study team identified a number of potential mechanisms for DoD to employ to improve its identification and vetting of its research workforce.

The mechanisms proposed in this effort include opportunities to expand on pro-grams already employed within DoD, such as special compensation and hiring authorities for Science and Technology Reinvention Laboratories, as well as creation of new partner-ships and programs to increase and diversify the pool of research talent that DoD can access. Across the array of potential mechanisms for DoD to consider, two stand out as recommendations to pursue: developing talent management strategies for the DoD research ecosystem and identifying risk management approaches to define which research can be done openly and which areas must be protected. A full cost-benefit analysis of each mechanism was beyond the scope of this effort; implementation of any mechanism requires further study to determine suitability, benefits, and costs.

Introduction

There is tension between an open and collaborative research environment that fosters scientific discovery and innovation, and the research security environment ensuring U.S. adversaries cannot exploit the outcomes from U.S. research, especially in defense-related technology areas. While research and development across critical technologies has become increasingly globalized, peer competition from China has become a specific area of concern.

Recent reports have noted the rise of China within the research and develop-ment enterprise. China has shown willingness to "use its talent abroad to advance its technological aims" [1] as well as "through the theft of intellectual property" [2]. The National Academies of Sciences, Engineering, and Medicine (hereafter "National Academies") report goes on to note how China "has learned that the United States will often react to such actions by instituting bureaucracies that impede the United States' own capacity to innovate." [2]

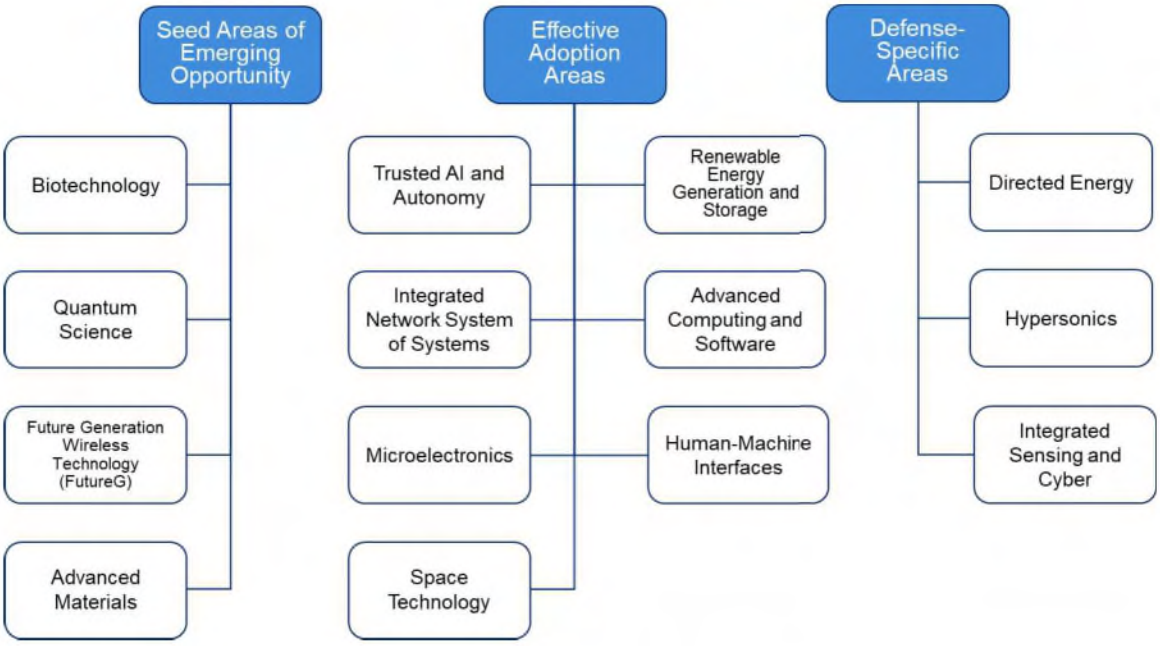
In this context, the U.S. has undertaken different initiatives aimed at main-taining its research advantage by protecting intellectual capital without overly disrupting collaborative science. As the National Science and Technology Council [3] states, "[t]he Biden-Harris Administration is strongly committed to both protecting research security and maintaining the core ideals behind America's scientific leadership, including openness, transparency, honesty, equity, fair competition, objectivity, and democratic values." More recently, the National Counterintelligence and Security Center developed a "Safeguarding Science" initiative to protect research and innovation in emerging technology sectors [4].

The Department of Defense (DoD) has identified 14 technology areas that are critical to enabling the U.S. national defense strategy [5].[1] These critical technology areas (CTAs) are depicted in Figure 1.[2] The ability to maintain research advantage in these areas depends on DoD having access to the scientific minds that bring about breakthroughs in both basic and applied research in these fields, while also pro-tecting certain advances from adversaries. DoD needs mechanisms to bring in the right technical research talent at the time and places needed, while also vetting that

[1] The Office of the Undersecretary of Defense for Research and Engineering's (OUSD(R&E)'s) definition for each technology area can be found in Appendix A.

[2] Figure 1 was created by the study team using information found in the OUSD (R&E) website [4].

talent to an appropriate degree to ensure research security. DoD also needs to be flexible and adaptable with its talent management approaches as the CTAs evolve.



AI: Artificial Intelligence

Figure 1. DoD's Critical Technology Areas

With this backdrop, the Fiscal Year 2021 (FY21) National Defense Author-ization Act (NDAA) included Section 252, which called for a study analyzing, among other things, mechanisms to identify and recruit research talent as well as methods to ensure appropriate vetting of individuals engaged in basic or applied research in the CTAs in support of DoD [6].[3] The Basic Research Office within the Office of the Undersecretary of Defense for Research and Engineering (OUSD(R&E)) tasked the Johns Hopkins University Applied Physics Laboratory (JHU/APL) with supporting its response to Section 252 by analyzing methods to ensure appropriate identification and vetting of that research talent.

Study Overview and Approach

Because Section 252 is focused on mechanisms to identify and recruit research talent as well as methods to ensure appropriate vetting of individuals, this study

[3] The full text of the NDAA section can be found in Appendix B.

concentrated on better understanding the current research environment and talent management approach within the DoD research enterprise. This focus enabled an assessment of potential mechanisms DoD could employ to improve talent acquisition of basic and applied researchers in these critical fields.

As a starting point, the study team explored the technical talent needs within the CTAs to identify skillsets common to multiple technology areas as well as skill-sets unique to a single CTA. Next, the team sought to understand where that tech-nical talent resides by analyzing the current pools of research talent DoD leverages across the relevant fields. The team also considered other potential pools of talent that DoD does not, or cannot, currently access.

In addition, to get a sense of the current landscape of research talent management, the study team interviewed human resources (HR) professionals at DoD and specific DoD laboratories, as well as their own organization, JHU/APL, and engaged other stakeholders in the DoD research enterprise as well. The study team aimed to understand the current approaches that DoD takes to identifying and vetting its technical talent, as well as the current barriers to accomplishing those tasks.

Based on the data from semi-structured interviews, as well as relevant studies and reports, the study team identified a series of potential challenges that DoD should address and developed options for DoD to consider in tackling those challenges.

Study Scope

The study considers the DoD research enterprise broadly, rather than solely focusing on permanent DoD employees. This includes researchers at DoD laboratories, University Affiliated Research Centers (UARCs), Federally Funded Research and Development Centers (FFRDCs), and academia (through DoD-funded grants). The study explores the pool of researchers DoD can access, with the aim of identifying mechanisms for DoD to improve the quality, quantity, and/or security of that talent pool.

Per the NDAA Section 252 language, the study centers on individuals conduc-ting basic and applied research in DoD CTAs. The capabilities and talent needed for DoD to translate applied research to fielded capabilities, e.g., improved manufac-turing capabilities, are out of scope. The talent required to enable the research—

such as information system security officers for highly classified computing systems—is also out of scope.

Similarly, the study focuses specifically on two portions of the NDAA Section 252: identifying and vetting the relevant technical talent. "Identifying" refers to knowing where to find individuals with the relevant skillsets, and includes con-siderations related to their proclivity to apply for DoD-related jobs, as well as the recruiting and hiring processes within the DoD research enterprise. "Vetting" includes ensuring DoD has access to the talent that will likely not jeopardize U.S. national security as a result of affiliations with or susceptibility to foreign influence. The study team also took "vetting" to include elements of screening for technical skill and job fit, as DoD aims to access the best and brightest researchers within these fields. Talent retention is out of scope, although mechanisms aimed at im-proving recruiting and screening of talent may have positive effects on retention.

Desired Study End State

The aim of this effort is to highlight potential challenges and gaps in DoD research talent management and identify mechanisms DoD could employ to address those perceived problem areas. This report serves as a contribution to OUSD(R&E)'s broader response to the FY21 NDAA Section 252 requirement.

Structure of the Report

This document first summarizes the exploration of the CTAs and an analysis of job requisitions to understand what skillsets and experience the DoD research enterprise needs. The report then summarizes the array of potential workforce challenges DoD may face regarding identifying and vetting that needed talent. The study team then describes potential mechanisms to overcome those challenges. The report concludes with recommendations related to implementation of proposed mechanisms and areas for further study.

Critical Technology Areas

To begin exploring the problem space, the study team first aimed to better understand the CTAs and determine the skills required within the research enter-prise for those CTAs. This was accomplished via two separate efforts. The first effort looked at the organization of CTAs to glean overarching workforce requirements

and possible challenges and solutions for identifying and vetting technical talent. The second effort analyzed current job requisitions to determine required skillsets for each CTA and identify skillsets common among CTAs.

The DoD organizes the CTAs into three groups based on the Department's strategy for advancing the CTAs through investment, development, and application of the technologies to address national security challenges [5]. As shown in Figure 1 in the introduction, the three groups are Seed Areas of Emerging Opportunity, Effective Adoption Areas, and Defense-Specific Areas. The groupings give possible insights to the role of DoD-funded and -directed research in these areas and possible workforce requirements.

The Seed Areas of Emerging Opportunity include biotechnology, quantum science, future generation wireless technology, and advanced materials. Research and development of these emerging fields is taking place throughout government organizations, academia, and industry. Although the DoD participates in and helps to guide research in these areas, most of the work likely resides within non-DoD organizations. As such, the DoD will require a workforce that can participate in the research while promoting DoD interests and exploring military and defense applications. Since these areas are emerging research, the pools of candidates may be smaller and the DoD will need to compete with academia and industry to recruit personnel. The required skillsets for these emerging fields may rapidly evolve, adding to the complexity of predicting the desired workforce and evaluating candidates. Given their technological maturity, these CTAs are likely to require more basic research and collaboration with entities outside of the DoD. Because of this, a larger fraction of the workforce may not require access to sensitive information.

Effective adoption areas are those "where there is existing vibrant commercial sector activity." [7] This includes trusted artificial intelligence (AI) and autonomy, integrated network systems-of-systems, microelectronics, space technology, renewable energy generation and storage, advanced computing and software, and human-machine interfaces. While DoD can leverage technological advancements in the commercial sector, it will need a workforce to develop and explore DoD- and military-specific applications and areas of interest. Because these CTAs have commercial activity, it is likely the pool of qualified candidates is larger; however, the Department will face more competition from industry to recruit top talent. For assessing and vetting technical talent, DoD may be able to more readily leverage established commercial practices. It is likely the Department will require a larger

workforce with access to sensitive information since their focus will be on military and national security applications of the technology.

Defense-specific areas, directed energy, hypersonics, and integrated sensing and cyber, are those driven by DoD needs and interests. As such, DoD will likely lead and almost exclusively fund these areas. The candidate pool with expertise speci-fically in these areas is likely to be smaller, but the DoD will face less competition from other organizations to recruit these personnel. For these CTAs, the majority of the workforce will require access to sensitive information and security concerns are a higher priority.

The CTAs are interconnected and dependent on each other. As identified in the National Academies study, "[m]any modern technologies are multipurpose, have diffuse origins, and are highly interdependent on other technologies..." [2] Breakthroughs in one CTA could drive and accelerate successes in others, while failures may hinder or limit progress for multiple other CTAs. For example, if the U.S. fell behind in the development or procurement of microelectronics, such a deficit could challenge and perhaps halt research across other CTAs. There are many general skillsets, including but not limited to mathematics, systems engineering, and software development, that are broadly applicable across all CTAs. Because of the dependencies among CTAs, the pertinent candidate pools and skillsets for are not discrete and separable. As a result, multiple CTAs may be competing for the same talent.

Skillset Requirements

A significant number of federal agencies, industries, and academic institutions actively publish job requisitions in an effort to identify highly skilled and qualified candidates. Online job requisitions typically include essential details such as duties of the position, required candidate qualifications, and skills and/or educational backgrounds desired by the organization. With this digital information publicly available, there is potentially an information-abundant repository of data to support assessment of the current professional needs in various specialized areas of work. These job requisitions can be used to identify standards for careers in various CTA fields, the educational backgrounds required of potential candidates, and the current competitive status for talented professionals in specific fields among various institutions.

To better understand the demand signal for research professionals in CTA-related fields, an initial high-level analysis was performed by surveying and pro-filing existing CTA job requisitions. The intent of the job requisition analysis was to:(1) determine common areas among careers in CTA fields such as required and/or desired skills, educational backgrounds, and experience levels; (2) identify any key metrics used to define the quality of potential candidates and enable recognition of highly skilled professionals; and (3) assess the required and desired qualities in candidates in industry, academia, and federal agencies to shape potential mechanisms in terms of the degree field, experience level, or other quality sought by hiring managers.

Although resources and time prevented a comprehensive assessment of all job requisitions, the study team was able to collect and analyze data across multiple efforts. First, the study team looked broadly at research-related positions across many DoD agencies, UARCs, and FFRDCs. This dataset was augmented with similar requisitions in the Department of Energy (DOE), as well as other federal departments and agencies, to increase the sample size and allow for additional comparisons. Beyond this initial look across CTA fields, the study team then conducted targeted analyses into both quantum sciences and hypersonics. Consortium data for each of those CTAs enabled a look across government, industry, and academia. Quantum sciences and hypersonics also provide a helpful comparison point, given the different stages of research in those fields: quantum science is designated as a seed area of emerging opportunity and hypersonics is a defense-specific technology area. A deeper discussion of the methodology for these analyses can be found in Appendix C.

High-level Requisition Analysis

The study team collected a sample of 1,668 research-related job requisitions across federal agencies and research centers for this analysis. While only 14% of these requisitions were posted directly by DoD research institutions, the larger dataset provides insights into the types of skillsets required for CTA-related fields within government and government-supporting research organizations.

Each job requisition was binned into a single field based on position classification standards from the Office of Personnel Management (OPM) (Figure 2)[8]. This resulted in 42% (702 positions) assigned as engineering and 28% (407) assigned as physical science positions. However, each of those fields includes more

than 60 unique subfields, with engineering containing subfields such as aerospace and electrical, and physical sciences including advanced materials, chemistry, and quantum. These fields involved a mix of general areas, like chemistry in physical sciences or biology in the biological sciences, as well as more specific focus areas, such as aerothermal in the engineering field, and plant pathology in biological sciences. Each of these aspects may pose different challenges to talent management—general capabilities apply across a wider set of technology areas, both within DoD's CTAs and more broadly, increasing the competition for that talent; specialty capabilities apply more narrowly but are likely seeking out a more limited pool of potential applicants who meet the requirements.

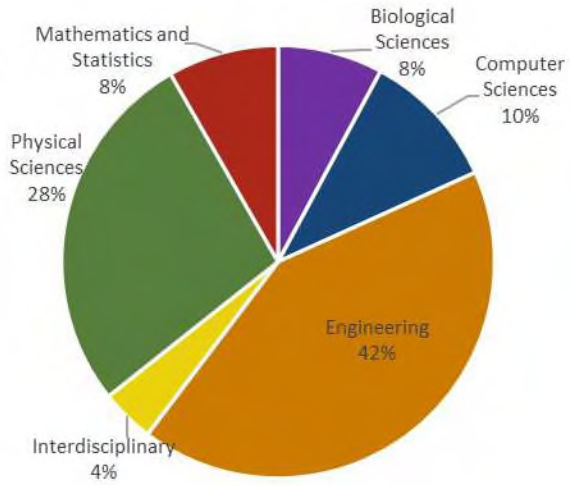


Figure 2. Job Requisitions by Field

In addition to the relevant field, the requisitions typically included the level of education required and desired for the position. Figure 3 presents the breakdown by field of the degree required or preferred within the job requisitions. If a single degree is listed in the figure, it represents the required degree; where multiple degrees are indicated, the first one is required for the position while the other degree(s) would be preferred. For example, "BS, MS Preferred" indicates that a Bachelor of Science degree is required for the position, but candidates with a Master of Science degree are preferred.

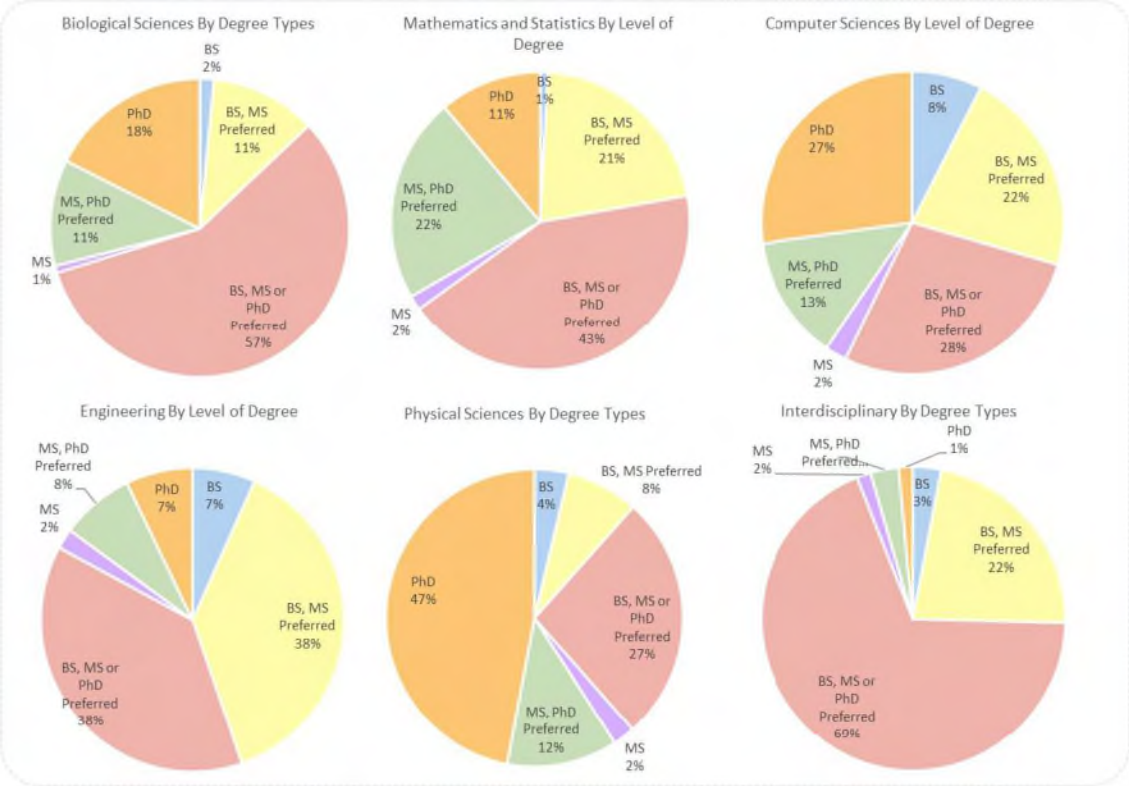


Figure 3. Job Requisitions by Field and Degree Level

Although some positions require only a bachelor's degree, the majority of those prefer higher educational attainment. In some fields, however, the minimum education requirement is much higher: the physical sciences field overwhelmingly required a PhD-level education (47%) compared to other degree levels; computer science positions required a PhD in 27% of postings. The dataset may be somewhat skewed, however, as a large number of physical science requisitions were postdoctoral positions. Of the 1668 job requisitions, 276 (17%) were for postdoctoral positions, and of those, 273 (98%) were posted by DOE (173, or 63%) or the National Nuclear Security Administration (100, or 36%). Overall, however, the higher degree requirements (or even preferences) affect the available candidate pool, especially when coupled with security clearance requirements, given the shape of domestic PhDs as compared with international students. According to [9], "International students made up about 42 percent of Science, Technology, Engineering, and Mathematics (STEM) PhD graduates in the United States between 2010 and 2019, with especially high shares in computer science and engineering."

The study team looked at the security clearance requirement for job requi-sitions as well. For this discussion, the dataset is narrowed to DoD requisitions only: among DoD job postings included in this analysis, 71% required some form of clearance, including 29% requiring top secret or top secret with sensitive compart-mented information. Security clearance requirements can have a large impact on the eligible pool of candidates, especially related to foreign nationals. In addition, stake-holders interviewed noted the security clearance process as a disincentive, even to those potentially capable of obtaining the clearance, because of hiring delays while awaiting a clearance and other challenges related to cleared work.

Quantum Sciences

The next scope of analysis involved studying job requisitions for the quantum science field across industry, academia, and U.S. federal government. This analysis provides a focused look within a specific technology area, and allows for comparison with research positions in industry. The study team collected 99 quantum science job requisitions from the Quantum Sciences Consortium, a group of organizations aiming to further quantum sciences research and development [10]. The dataset includes 42 industry postings, 38 government postings, and 19 academic postings.

The quantum science requisitions were skewed heavily toward PhD holders, with 81% of the positions requiring that level of education (Figure 4). While many of these degrees centered on the physical sciences (87% of the dataset), there were also opportunities in other fields, including 5% in engineering and 4% in computer science. Within the area of study required, there were 16 different fields mentioned, and many postings listed multiple relevant fields.

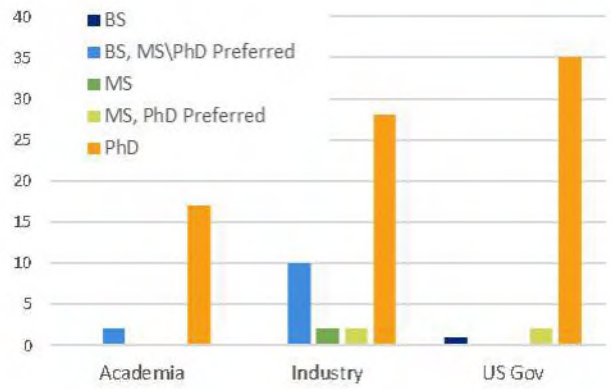


Figure 4. Quantum Science Job Requisitions by Degree Level and Hiring Organization

Based on the structure of the job postings for this dataset, the study team was able to look across the requisitions for keywords that might reveal the skills re-quired by this community. By performing such analyses, essential skills and sub-fields in quantum sciences (or adjacent to quantum sciences) can be surmised and utilized to better recognize potential candidates. For example, 36% of the job requisitions mentioned C, C++, or C#, and 31% mentioned Python. From this, it can be concluded that having coding capabilities and/or experience is essential for quantum science candidates, even though only 4% of the quantum science requisitions were strictly computer science positions. This keyword analysis can aid in identifying more specific capabilities required to conduct CTA research, as well as enable clearer articulation of what may be lacking within DoD.

Hypersonics

Similar to the quantum science analysis, the University Consortium for Applied Hypersonics (UCAH) website includes hypersonics job requisitions that the study team explored to understand the skill and degree requirements in that field [11]. In contrast to the quantum science requisition data, hypersonics postings were skewed more toward industry, with 59% of the postings, compared to 26% and 15% for government and academia, respectively. This is somewhat surprising given the defense-specific focus of hypersonics, although it may simply be that industry leverages the UCAH website to advertise more than government and academia.

The degree requirements for positions in the hypersonics field are not as skewed toward PhDs as those in quantum science. As Figure 5 shows, there are a number of positions requiring only a BS, although a sizable portion prefer advanced degrees. This is especially true of the opportunities within industry. One potential explanation is that hypersonics is a more established field, with more emphasis on applied research and engineering than quantum science, which continues to include basic research in a variety of subareas. The analysis of the job field bears this out, with industry jobs primarily focusing on engineering degrees, while government and academia were more split between physical sciences and engineering. The areas of study were again diverse, with 18 different areas occurring across the job requisitions, including many postings encompassing multiple areas. The area of study showed an emphasis on mechanical engineering (22% of requisitions), aerospace engineering (21%), and materials science (14%).

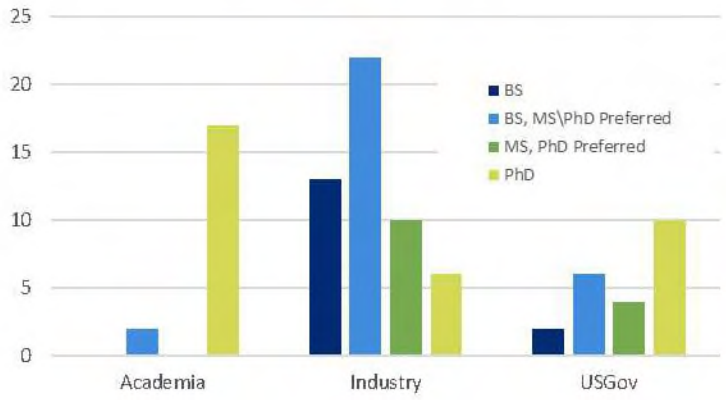


Figure 5. Hypersonics Job Requisitions by Degree Level and Hiring Organization

Of note, all of the government positions listed required some form of clearance, as did 57% of the industry postings and 8% of academic opportunities. This also aligns with hypersonics centering on applied research and the designation as a defense-specific field.

CTA Analysis Summary

Through exploration of the technology areas and related requisition data, the study team aimed to identify both common and unique requirements that shape DoD's research workforce challenges. The strong interdependency within the CTAs and the high-level requisition analysis suggest that there is likely competition for

the same talent occurring across these areas. This also suggests that an independent assessment of workforce needs within each individual CTA may mask some of the broader challenges facing the DoD research enterprise as a whole.

The analysis of the level of degree and the degree fields sought in the requisitions showed a mix of advanced technical degrees, sometimes in narrower fields, along with a large need for general degrees, especially in engineering. This dual focus may be aligned with where the technology area lies on the spectrum between emphasizing basic or applied research. These findings suggest that talent management strategies, including mechanisms to better identify and vet the research talent, likely will differ across CTAs. It also suggests that flexibility may be required within a given technology area, as the research progresses beyond basic discovery into a more applied research focus.

DoD Research Enterprise

As discussed in the study scope section, this effort looks across the DoD re-search enterprise to understand the pool of research talent that DoD can access. This research enterprise includes civilian employees of DoD research laboratories, as well as researchers at UARCs and FFRDCs, defense contractors, and academia supporting DoD through research grants. In addition, the DoD research enterprise is broadened through collaborations and partnerships DoD and its components have with U.S. universities, industry partners, and foreign government partners.

At each layer of the DoD research enterprise, there are different characteristics that affect the capability to support basic and applied research in the CTAs. These characteristics include the number of researchers, the security clearance levels within that pool, and the operational or mission-centric expertise that enables and supports the applied research, especially. These characteristics can be at odds. For example, the pool of academic researchers who could potentially support DoD re-search is large, but they exist at a low level of "trust" (in terms of security clearance) compared to other layers, and often do not have the same levels of operational understanding. This informs what research DoD attempts to conduct via different mechanisms, but the study team did not find any clear strategy documentation that articulated this approach, either generally or for specific CTAs. Similarly, the study team explored the literature and data sources to get a sense of the characteristics—size, degree level, years of experience, etc.—of each layer of the research enterprise but found only limited data, preventing a fuller discussion in this section.

Research for each CTA appears to be broadly distributed across the DoD enterprise. There are a few organizations within the DoD or DoD research enterprise that focus on a single CTA, such as the Institute for Collaborative Biotechnologies, but most cover a wide range of technology areas. Because of this, it is not immediately clear where the work for each CTA is predominantly taking place, how the research is coordinated between the organizations, or what the level of communication between the organizations and DoD leadership is. This makes DoD-wide workforce gaps and challenges opaque. While our discussions with Science and Technology Reinvention Labs (STRLs) and UARCs have shown there are CTAs and areas where they struggle to hire, it is unclear where those organizations are competing primarily against other DoD organizations and where there are broader workforce issues.

Foreign Nationals

One specific sub-category of research talent—foreign nationals—has received a lot of attention in recent years, both as a potentially large, under-tapped source of research talent and as a potential concern related to research security and vetting. In an OUSD(R&E) report to Congress in 2022 [12], the authors noted STRLs have flexibility to hire non-citizens, although the implementation has been limited. It notes other mechanisms for engaging this talent more as well, including exchange programs, research fellowships, and collaborations with universities.

However, there are barriers to engaging this talent. The delays for getting security clearances remain lengthy, and foreign nationals can have difficulty accessing government facilities to do some of this research work. The OUSD(R&E) report also notes the burden within policy to prove domestic talent cannot be acquired to meet the need, to enable hiring of foreign talent [12].

Exploring the Research Talent Problem Space

The NDAA Section 252 language does not explicitly identify a challenge that the study it requests would overcome. However, there are a number of existing challenges and concerns related to talent management within DoD's research ecosystem. To capture this, the team conducted a literature review including reports and articles on DoD workforce development as well as security concerns and risks. The team also engaged HR professionals and other stakeholders in the DoD research enterprise.

This section captures a variety of challenges the DoD faces for identifying, recruiting, and vetting talent into the DoD research enterprise. A better understanding of the challenges DoD aims to overcome will enable development of tailored and targeted solutions. Beyond these challenges, however, the study team recognizes that the Department has interest in generally improving its overall ability to identify, recruit, assess, and vet technical staff throughout the DoD research enterprise and across CTAs.

Discussions with HR professionals and the literature review revealed a general perception that the pools of candidates for many CTA-related positions within DoD are shrinking. As identified in the National Academies study, "the United States lags behind other countries in preparing its citizens for participation in technology-intensive areas." [2] There are many proposals to rectify this, although most are geared toward students in grades K-12; there will be a time lag before those students are ready to enter the workforce. Discussions with the Army Research Laboratory (ARL) revealed that hiring managers often prefer candidates with PhDs, which further narrows the number of qualified candidates. While the pool of candidates may be shrinking, demand for experts in these CTAs is growing within DoD. A report to Congress in response to section 217 of the FY21 NDAA [13] detailed a number of workforce-related insights, including an insufficient supply of AI-related researchers, capacity gaps in the biotechnology workforce, and the need for a larger, more capable workforce in hypersonics.

Discussions with HR professionals from ARL and the Naval Research Labor-atory (NRL) both illuminated a lack of public awareness of DoD research oppor-tunities. Potential candidates from academia and industry are occasionally unaware that DoD is conducting basic and applied research across many of these areas and that research positions are open to civilians. Negative perceptions of the DoD mission also exist within candidate pools.

The DoD also faces challenges in recruiting top staff because of compensation limitations and competition with industry and other organizations. The U.S. OPM regulates the pay systems for the majority of civilian federal employees. This pay system is based on General Schedule (GS) classification and geographical location. While each agency can determine the GS grade for an open position within their agency, the salaries and additional compensation for each grade are tightly regulated by law. For highly competitive fields, this limits DoD's ability to compete with industry for top talent. Some DoD laboratories, designated as STRLs, have authority to provide additional compensation above the regulated GS pay grade. However,

there are still limitations and they struggle to compete with industry, especially for mid-level or senior staff. While UARCs and similar entities do not have the same compensation limitations as DoD, they also do not have the same revenue structure as the private sector. Therefore, funds are still, to some extent, limited to attract and retain certain skillsets.

Conversations with HR professionals indicated a competitive landscape for acquiring the desired talent. While some of this competition is with industry, there is also competition within the research ecosystem as the various laboratories, FFRDCs, UARCs, and defense contractors endeavor to bring in the same types of personnel to engage in the relevant research that DoD needs. For technology areas requiring specialized degrees or expertise, the already small pool of potential applicants becomes even more diffuse as numerous organizations strive to bring those capabilities onboard.

For positions that require a clearance, the candidates are often forced to wait until they receive their final clearance before they can begin work. The long wait times for security clearances, especially higher levels of clearance, can create sig-nificant financial burdens on candidates and dissuade personnel from pursuing covered positions. This produces an additional burden on individuals who might expect their clearance adjudication to take a longer period of time because of travel abroad, relatives who are foreign nationals, or student debt. This holds especially true for highly sought individuals who are foreign nationals. Even for organizations that are authorized to hire foreign nationals, the wait times for security processing make it practically infeasible. This issue may hamper some technology areas more significantly than others; as [13] notes, "the skilled workforce required to implement key elements of advanced [microelectronics] technology is increasingly located outside of the U.S. The DoD needs a domestic workforce qualified to work on sensitive programs."

Security concerns are affecting the funding of basic and applied research, potentially challenging DoD's access to a broader pool of research talent. Recent guidance identifies additional disclosure requirements on federal grants, as well as development of research security programs for institutions receiving more than $50M in federal science and engineering funding [3]. These additional disclosure requirements may support research security considerations, but there is concern that they will also disincentivize applications and create additional barriers for working with capable researchers. In a congressional hearing related to foreign influence, a university representative noted that "[t]he process of doing this vetting

stigmatizes the entire community that is being vetted and decreases their enthusiasm for coming to the United States to advance our science. I'm worried that it will diminish our own ability to innovate." [14] This aligns with the notion China "has learned that the United States will often react to [research security threats] by instituting bureaucracies that impede the United States' own capacity to innovate." [2]

Security concerns and competition with China are drivers behind many recent DoD STEM workforce studies. Most recently, the National Academies conducted a thorough study exploring these concerns [2]. The National Academies study recognized the challenge that "China has been making massive investments in R&D [research and development], greater, in some areas, than those of the United States; has a well-educated labor force that is three times larger; and has sought to attract talent from other countries." [2] Moreover, a large concern is that "China also does not play by the same rules as the United States, and makes decisions based on a worldview quite different from that of the United States and its allies." [2] This gives China an asymmetric advantage when competing with the U.S. for leadership in technology innovation. The National Academies study provides recommendations to counter these security concerns; these concerns and recommendations are considered when exploring possible mechanisms throughout this paper.

Potential Mechanisms to Improve Identification, Screening, and Vetting

The primary goal of this research effort is to identify potential mechanisms DoD could employ to improve its access to the right talent in the CTAs. This section describes a variety of mechanisms DoD could employ. Given the limited time and bandwidth for this effort, the study team has not conducted a full cost-benefit analysis of any proposed mechanism. Nonetheless, this report does provide an articulation of the issues with supporting background material related to the topic and lays out a potential solution. For each mechanism, the study team describes qualitative pros and cons, where identified, to aid in subsequent analysis. To implement any of these mechanisms, further study would be required to achieve the detail necessary to fully shape the solution.

The majority of the proposed mechanisms represent an expansion of some-thing that is already occurring within the DoD research enterprise, rather than a wholly new path forward for DoD. Further, the vast majority of potential mechan-isms address challenges related to identification and recruitment of talent. However,

while mechanisms are organized across bins of identification and recruitment, talent screening, and security vetting, these areas are interdependent. For example, where Congress may desire mechanisms to improve DoD's approaches to security vetting, solutions aimed at increasing or maintaining access to already vetted talent could have a similar result by helping prevent DoD's talent pool from shrinking.

Identification and Recruitment

As highlighted in the "Identifying the Problem" section, there are a number of challenges DoD faces related to finding and recruiting the needed talent. This section includes potential mechanisms that would help DoD address aspects of those challenges, including efforts aimed at increasing candidate pools and improving DoD's ability to access potential candidates in those pools. Mechanisms are grouped where the underlying focus is similar; they are presented in no particular order, as the scope of the analysis did not account for data needed to prioritize these opportunities.

Expand Available STRL Flexibilities, Extend Flexibilities to other Organizations, and/or Designate Additional STRLs

The first set of mechanisms relate to DoD's STRLs. Through discussions with the DoD laboratories office within OUSD(R&E), as well as engagements with STRL HR personnel, there are potential opportunities to build upon this capability and increase the size and capability of DoD's civilian research workforce.

For background, organizations designated as STRLs "can avail themselves of certain legislated authorities directed towards STRLs such as personnel flexibilities, minor military construction flexibilities, ability to adopt mechanisms that give the STRL Directors discretionary funding flexibility, etc." [15] Personnel flexibilities include compensation and benefit changes, direct hire authorities, and other hiring policy changes. Flexibilities, once created, are available to all STRLs, although discussions with stakeholders indicated a lot of variability in terms of which flexibilities are used across STRLs [16].

The DoD instruction on STRL projects [16] also includes details on evaluating flexibilities to identify best practices and unsuccessful initiatives. The study team did not identify whether or how many of these assessments have taken place, but the sharing of best practices across STRLs could lead to an expansion of the use of already available capabilities. DoD could also pursue expansions of the flexibilities

themselves, such as increasing compensation limits for critical research positions in emerging fields. The existing designations and structure for STRL flexibilities would make these changes straightforward to implement. However, there are clear cost implications of any additional flexibilities, and a targeted assessment of what positions would most benefit would be needed.

In addition, there are processes available for designating additional labor-atories as STRLs, including the ability for Congress to designate them [16]. New STRLs would have access to the full set of flexibilities, enabling them to compete better to gain necessary talent. This would also increase the competition within the DoD research enterprise, but broadening availability of these benefits to additional laboratories conducting CTA research would likely open up more geographic locations to potential applicants and therefore interest a larger pool of talent. A similar recommendation, though potentially harder to implement, would be to extend the flexibilities to other organizations without designation as an STRL.

Expand Fellowship and Internship Programs, and Broaden STEM and CTA-specific Development and Outreach Programs

The Department of Defense (DoD) and military services have spent consi-derable efforts fostering the development of a highly skilled STEM workforce that can conduct work to support national security [17]. The variety of available pro-grams include internship and apprenticeship programs for high school, under-graduate (including cadets and midshipmen), and graduate students to gain practical work experience; scholarships and fellowships to support graduate and postdoctoral students conducting research that aligns with DoD priorities; and educational outreach programs for instructors and K-12 students to raise aware-ness of STEM disciplines and their application to DoD. A non-comprehensive list of available programs, organized by affiliation, is presented in Appendix D.

In interviews for this study, the National Defense Science and Engineering Graduate (NDSEG) Fellowship [18] and the Science, Mathematics, and Research for Transformation (SMART) Scholarship Program [19] were repeatedly mentioned as premier opportunities to bring in necessary talent for DoD.

The NDSEG Fellowship is awarded to U.S. citizens, U.S. nationals, and U.S. dual citizens who intend to pursue a doctorate degree and conduct research that is aligned to the DoD Services Broad Agency Announcements (BAAs) in research and development. The fellowship lasts for three years and pays full tuition and fees, a

monthly stipend, a travel budget, and an allotment toward health insurance. The NDSEG Fellowship aims to increase the number of U.S. citizens or nationals trained in disciplines of science and engineering of military importance, develop continuing relationships with recipients and the sponsoring military services (each service is responsible for mentoring and interacting with its selected awardees), and attract science and engineering baccalaureate graduates to pursue doctorates in DoD-mission-related research areas from U.S. institutions.

The SMART Scholarship Program is a combined educational and workforce development scholarship program for undergraduate, masters, and doctoral students currently pursuing a degree in one of 21 designated STEM disciplines. The scholarship provides full tuition, annual stipend, internships, book and health allowance, and guaranteed employment with the DoD after graduation to students pursuing STEM degrees. Objectives of the program include enhancing the DoD civilian workforce with innovative scientists, engineers, and researchers across the U.S., and creating a highly skilled DoD STEM workforce that competes with the dynamic trends in technology and innovation to protect national security.

Given the existence of the wide variety of programs DoD already supports, one potential mechanism is to expand the size of existing programs to fund additional applicants each year, especially those programs viewed as successful in meeting their objectives. The study team was not able to identify data related to success metrics for these programs, however, nor assess how well current programs are used. Expanding the programs would likely be relatively straightforward to implement, as the structures already exist for application and selection, but, as with most of the mechanisms suggested here, cost is a significant factor for these programs.

Beyond simple expansion of the programs, DoD could more narrowly target existing opportunities to CTA-related fields or other refined categories. Alternatively, new programs targeting those CTA-related specialties or subspecialties could be created. One recent example of a CTA-focused program is the Scalable Asymmetric Lifecycle Engagement (SCALE), aimed at rapidly increasing the skilled microelectronics workforce within the defense sector. Funded by DoD, led by Purdue University, and managed by Naval Surface Warfare Center, Crane Division, "SCALE provides unique courses, mentoring, internship matching and targeted research projects for college students interested in five microelectronics specialty areas: radiation-hardening, heterogeneous integration/advanced packaging, system on a chip, embedded system security/trusted AI, and supply chain awareness." [20] It

has more than 200 students, with 17 universities and more than 67 participating staff and $30M in DoD funding [20].

A proliferation of programs targeting specific fields could help by bringing in the specific talent DoD desires, but could also face challenges with administration, as well as awareness and messaging of the individual programs. A recent report on policy options for improving STEM workforce development noted that "DoD STEM should lead a collaborative effort to build an Intern Portal that communicates all available opportunities; provides a single application process; supports tracking of interns; and enables communications to the entire intern pool to expand awareness of career opportunities within DoD." [21] A related alternative would be to consolidate the numerous programs to ensure focus on what DoD values most, streamlining administration and management of the programs, to include getting the word out to potential candidates.

Create Additional CTA-focused Partnerships at U.S. Academic Institutions and Better Enable those Partnerships to Conduct Classified Research

There are a number of existing university partnerships supporting DoD as well as on-campus programs to bring DoD researchers into academia. These programs broadly appear successful in bringing additional research talent into the DoD mission space, including some partnerships that include classified research. The majority of concern related to foreign influence seems to arise within academia, so identifying best practices and better enabling these partnerships is critical.

The university partnerships provide students with a broader understanding of the types of problems they can work on and expose the students to the DoD re-search enterprise as a potential career path. Beyond individual federal grants to university researchers, several academic institutions have created broader capa-bility to engage with DoD on critical technology research, including development of facilities (and processes) to conduct sensitive research.

Some of the partnerships go beyond a single DoD-university partnership. There are research consortia, such as UCAH, bringing together a broader set of stakeholders. UCAH is "an inclusive, collaborative network of universities working with government, industry, national laboratories, federally funded research centers, and existing university affiliated research centers. It aims to deliver the innovation and workforce needed to advance modern hypersonic flight systems in support of national defense." [11] One stakeholder interview also highlighted an Air Force

Research Laboratory (AFRL) program to create regional research hubs, which bring together universities, small businesses, and innovators and entrepreneurs to collaborate and contribute to DoD mission challenges.

DoD has also reached into campuses more directly through open-campus-type initiatives. ARL's Open Campus Initiative aims to build "a global science and technology ecosystem that will foster an agile, efficient, and effective research environment supporting the continuous flow of people and ideas to ensure transformative scientific discovery, innovation, and technology transition beneficial to national security." [22] Similar to the AFRL example cited earlier, ARL's Open Campus Initiative is creating a hub-and-spoke infrastructure, with 13 research centers established as "a consortium of Open Campus partner organizations leveraging expertise, facilities, and capabilities on an international scale to address challenging research problems critical to the U.S."

The study team also learned of an embedded AFRL researcher working at Carnegie Mellon University (CMU), with the aim of accelerating research collaborations beyond isolated grants. This program has the researcher fully integrated into CMU's campus while remaining an AFRL civilian employee. The partnership helps students learn about the mission-oriented problem sets and also learn more about the available fellowship and internship programs. The initiative allows AFRL access to the on-campus research talent while also creating better awareness of DoD as a potential career path, potentially leading to a more long-term relationship as part of DoD's research ecosystem. A similar DOE program at Purdue University has Sandia personnel on campus full-time. These on-campus representatives serve as advocates for DoD career fields and increase awareness within the potential candidate population. "Stewards of STEM programs should support and expand advocacy networks (e.g., between university students and experienced advocates) as a way to grow the pipeline of cleared workers for defense missions." [21]

Potential mechanisms for DoD include expansion of existing partnerships as well as creation of partnership relationships for any CTAs where DoD feels it needs better access to academic talent. Where possible, DoD should explore ways to partner or assist in the creation of these university institutions to overcome some of the natural barriers to the university creating them on their own, namely the university using its own funds to create facilities and capabilities that DoD might desire.

A related recommendation would be to gather and disseminate best practices from the university partners conducting classified research, to ease the transition

for new universities aiming to do this work and reducing security incidents and concerns. Gaining access to controlled or classified information takes time and resources, and the processes and rules for things like controlled unclassified information (CUI) can be murky for those not continuously engaged in those areas. Supporting academic institutions in these areas, especially smaller institutions with fewer resources to devote, could increase the pool of available academic talent supporting the CTA fields.

Additional mechanisms that also relate to the security vetting process could include better leveraging the existing cleared personnel on university campuses. There are professors and researchers at universities who have received clearances either through direct funding opportunities or through roles outside the academic setting. Supporting the maintenance of those clearances, and ensuring awareness of and access to that talent, would support the overall pool of trusted research talent within DoD, and potentially reduce the burden on new or increased security vetting needs.

Similarly, one stakeholder noted that the DoD contract environment could lead to lapses of clearances if follow-on funding is not received to maintain those clearances. Exploration of waivers or alternate methods to help both principal investigators and cleared student researchers maintain clearances would similarly help with the pool of vetted talent DoD can access.

Broaden Outreach and Engagement with Underrepresented Communities

Throughout conversations with HR professionals, the topic of diversity in hiring repeatedly arose. Diversity of thought is a key enabler of innovation, and DoD has numerous programs aimed at increasing the diversity of its workforce, including its STEM workforce.

One such program is DoD's summer research program for undergraduate and graduate students at Historically Black Colleges and Universities (HBCUs) and Minority-Serving Institutions (MIs) [23]. Students participate in a research experience at DoD facilities across the nation under the supervision of DoD scientists and engineers. The main objective of the program is to increase the number of minority scientists and engineers throughout the DoD.

In addition, DoD is pursuing a formal designation of an HBCU as a UARC, with core competencies tied specifically to the CTA-related field of tactical autonomy.

This partnership has the potential for many benefits, including increasing DoD's access to a large pool of diverse STEM graduates, as well as "help participating HBCUs increase their own research capacity," potentially paying even more dividends for DoD in the future [24].

Recent studies have continued to highlight that more needs to be done to engage diverse talent within specific technology and STEM fields. The Interagency Roadmap to Support Space-Related STEM Education and Workforce report notes that "[p]ersistent obstacles encountered by some workers include practices like biased hiring and unequal compensation practices, inequitable access to development opportunities, and identity-based harassment and discrimination. To improve retention in the space workforce and address occupational segregation there must be targeted strategies enacted to mitigate these barriers. In addition to recruitment and retention efforts, career growth initiatives are important for promotion and advancement to leadership positions throughout the industry." [25]

DoD can continue to build on existing outreach plans with HBCU and MI institutions to tap into this pool of talent. In addition to the planned UARC relationship cited here, creating more CTA-focused partnerships with HBCUs and MIs, including potentially supporting development of classified facilities at some of those institutions, would increase DoD's access to this under-tapped pool of talent. Further, DoD should continue to study any barriers to hiring, as well as career advancement, that might be occurring within the research enterprise and adopt strategies to reduce those barriers.

Expand Immigration and Naturalization Options for Highly Skilled Technical Professionals

The issue of leveraging foreign-born talent within the DoD research enterprise hits at the heart of the tension between wanting more and better access to research talent, while being concerned with the loss or theft of intellectual property through undue foreign influence. Foreign-born talent accounts for a substantial research capability, however, especially those educated in U.S. universities. According to the National Academies study, 70% of foreign students that receive degrees from U.S. universities intend to stay and work in the U.S., but U.S. temporary work visas are capped. This makes the U.S. less appealing compared with other English-speaking nations, such as the UK, Australia, and Canada who have more flexible and skill-based immigration processes [2].

The Space-Related Workforce report includes the goal of "addressing immigration policy to attract and retain non-citizens." [25] The Quantum workforce similarly promotes engaging foreign talent, recommending "[t]he United States should continue to develop and support policies that welcome talented individuals from all over the world, while implementing appropriately balanced protections that mitigate potential research security concerns." [26]

The OUSD(R&E) report on foreign nationals [12] recommended streamlining security processes to employ foreign national talent, along with recommendations to support self-employment, entrepreneurship, and permanent residence applications. When targeted toward CTA-related fields especially, these mechanisms would improve DoD's ability to access additional research talent, at least for unclassified research.

In addition, one stakeholder mentioned a proposed program to enable naturalization through DoD-related research and technology development. This notion aligns with the process of naturalization through military service [27] and would expedite the path to citizenship for critical technology researchers. The proposed program could also pave the way for this talent to attain security clearances and support more applied and sensitive research.

Develop Additional Onramps for Mid-career Technical Professionals

Discussions with HR personnel and literature review highlighted the need to expand the DoD's ability to hire mid-career staff. While there is work across the DoD to develop the next generation of CTA-focused staff, the Department struggles to identify and recruit mid-career and senior-level staff. The study team identified two mechanisms to increase the pool of mid-career staff: developing a path for service members into DoD-related research and technology development careers, and providing opportunities for mid-career staff to reskill or upskill.

Developing additional paths for service members to transition into technical positions at DoD-affiliated laboratories and the larger DoD research enterprise was recommended in the Systems Engineering and Research Center (SERC) report. Specifically, that "[t]he DoD, in collaboration with the DIB [Defense Innovation Board] should seek to increase and facilitate internship opportunities for GI Bill beneficiaries in STEM/[skilled technical workforce] fields" and encourage support of the Veteran Employment Through Technology Education Courses program [21]. These processes should be considered as methods to create larger mid-career and

senior-level candidate pools for CTA fields. Other benefits may also accrue from this approach, including possible benefits of increasing the trusted candidate pools and reaching an audience that is already aware of the importance these technologies play in national security.

DoD should also consider developing new opportunities for mid-career personnel to develop and gain the skills necessary to contribute to these technology areas. These opportunities may be targeted toward personnel already working in defense-related areas, as well as personnel from non-DoD fields, and could provide clear paths for promotion and career advancement. The Space-Related Workforce report emphasized the importance of making "reskilling and upskilling opportunities available for those who missed opportunities or lack access through traditional education structures so they are able to join the space workforce at any career or educational stage." [25] Not only would this provide additional onramps into DoD-related research and technology development, but it would also help to create a more diverse and equitable workforce.

Expand Outreach to Increase Visibility of STEM Careers within the DoD Research Enterprise and Make Pathways to Employment Clear, Accessible, and Desirable

As noted earlier in this report, there is a lack of public awareness of DoD re-search opportunities, basic and applied research topics of interest to the DoD, and requirements and restrictions of personnel. DoD should consider increasing visibility of STEM careers within the DoD research enterprise, as well as requirements and restrictions of personnel, and provide clear pathways to employment.

The Space-Related Workforce report recommends that space-related agencies and organizations "[t]ake a 'whole-of-government' approach to leverage federal agencies' collective networks and relationships to magnify the reach of space-related STEM content and create new space-related STEM activities, program and collaboration." [25] Expanding this suggestion to multiple or all CTAs would allow both the DoD and the larger U.S. research enterprise to reach a broader audience while pooling resources. This report emphasized the importance of increasing outreach to underrepresented communities in particular and providing education and preparation activities, such as "hands-on activities and experimental learning opportunities like internships, apprenticeships, and fellowships." [25]

For Defense-specific CTAs (direct energy, hypersonics, and integrated sensing and cyber), one stakeholder indicated that foreign nationals often incorrectly

assume that there are no opportunities for them to contribute to these technology areas. Although many positions within the DoD research enterprise in these areas will require U.S. citizenship, these technologies also have dual purposes. For example, hypersonic weapons and civilian spacecraft reentry vehicles may use many of the same technologies. Moreover, these CTAs also require research in the underlying scientific principles and technologies, which may not require access to sensitive information. DoD should explore how to message workforce requirements for these CTAs to increase participation of foreign nationals on non-sensitive topics.

Many individuals, even those who are aware of DoD-related research and careers, may not be aware of pathways to employment or find that those pathways are not accessible to them or they are not desirable. The Space-Related Workforce report recognized this challenge and emphasized the important of creating path-ways that are clear, accessible, and desirable, "because having STEM experts, at all levels, with a diversity of backgrounds, experiences, and ideas is essential to innovation." [25] Moreover, individuals may not be completely aware of which skillsets are required for each CTA. The Quantum Information Science and Technology (QIST) Workforce paper highlighted the diversity of skillsets required for QIST and that the future QIST workforce will predominantly come from "computer science and engineering, electrical engineering, and other closely related fields" as opposed to "previous QIST educational strategies which focused mainly on physics departments." [26] Moreover, individuals may be unaware of the need for not only PhD researchers, but also a skilled technical workforce including mechanics and technicians.

Align UARC/FFRDC Core Competencies with Existing CTAs and/or Create New FFRDCs/ UARCs with Targeted Core Competencies Aligned with CTAs

An additional set of mechanisms the study team explored related to the core competencies within the UARCs and FFRDCs.

"FFRDCs are unique nonprofit entities sponsored and funded by the U.S. government to meet some special long-term research or development need which cannot be met as effectively by existing in-house or contractor resources." Within the 10 DoD-sponsored FFRDCs, three are considered Research and Development Centers (as opposed to Study and Analysis Centers or Systems Engineering and Integration Centers). Each FFRDC has a unique sponsoring agreement that details the purpose and mission of the FFRDC [28].

UARCs are research organizations within a university or college providing "DoD essential engineering, research, and/or development capabilities defined as core." UARCs receive sole-source funding from DoD and maintain long-term strategic relationships with DoD [29].

These two types of institution provide specialized, long-term research and development support to DoD. Through a review of the core technical capabilities and core competencies of the existing institutions, the study team identified there is not clear alignment with the CTAs. However, most UARC and FFRDCs are currently engaged in research across a multitude, if not all, of the CTAs. It is unclear whether a distinct, explicit tie to the CTAs within the officially defined core competencies would be beneficial. If this explicit assignment created a clearer "home" for the work within a CTA, that could help the individual UARC or FFRDC attract talent in that area. Within the context of the inter-DoD research enterprise competition for talent, a clear alignment and separation of focus areas could help with that issue. This approach runs the risk of reducing diversity of thought, however. Changing core competencies in line with more dynamic emerging technology areas also runs the risk of creating repeated churn within these institutions and their workforces.

Another potential mechanism would be to create new FFRDC or UARC arrangements to address any perceived gaps in critical technology focus areas. DoD already plans to engage with an HBCU to create a tactical autonomy UARC for the Air Force [24], and this process could be repeated for other technical areas as needed. There are clear cost considerations in establishing these types of arrangements, and stakeholders we interviewed implied that creating new UARCs or FFRDCs was undesirable. However, expanding the number of these organizations, linking their core competencies explicitly to current CTAs, and enabling those organizations with support for classified research facilities, would allow DoD to tap into additional pools of trusted talent, potentially in additional geographic areas.

A supporting recommendation to consider aligns with the university partner-ship model related to hubs and consortia. SERC is a UARC, but rather than a single university, "leverages the research and expertise of senior lead researchers from 22 collaborator universities throughout the United States" and "delivers impact well beyond what any one university could accomplish." [30] To broaden access to talent across the U.S., the consortium approach to UARCs or FFRDCs could work well.

Explore Centralization of Research for each CTA within an Entity or Subset of Entities

Building on the notion of consolidating the CTA focus within individual UARCs or FFRDCs, there is a broader mechanism to consider regarding centralizing CTA research within the DoD enterprise. As noted earlier in this report, there is a wide distribution of CTAs across organizations within DoD and the larger research ecosystem, with most organizations working across multiple CTAs. It is difficult to assess the level of capability and capacity DoD has for any given technology area, and it is unclear whether the talent management concerns are driven by an overall lack of capability, or rather a diffusion of this talent across so many organizations (and the underlying issues may differ across CTAs).

DoD should explore different mechanisms for organizing and conducting emerging technology research to optimize its available resources. One potential approach would be to identify dedicated organizations for each CTA and centralize the research of that technology. There are potential benefits as well as drawbacks from such an approach, in addition to those mentioned in the UARC/FFRDC section. The focus could improve coordination outside DoD with both industry and academia for that technology area, it would be easier to develop and evaluate talent management strategies for the CTAs, and it would reduce competition for a potentially small pool of candidates. Conversely, this centralized focus would reduce diversity of thought as well as reduce some of the beneficial competition that comes from multiple organizations and groups exploring the same problem sets. Consolidation would also result in fewer choices for potential applicants in terms of employers and work locations. Finally, consolidating applied research could challenge the ability to develop service-specific applications for the technology areas, although joint organizations with proper representation across the services could overcome this. The Joint Hypersonics Transition Office is a potential model to learn from for that type of agency.

Talent Screening

This section includes a single, broad mechanism aimed at improving talent screening within DoD. This area was not highlighted in many of the stakeholder interviews for this study; in fact, when asked about how DoD could better screen its applicant pool, many interviewees indicated they had not really thought about that aspect of the problem.

Promote Robust Personnel Assessment Strategies across the DoD Research Enterprise

This study did not include an evaluation of the DoD research enterprise's personnel assessment strategies or the effectiveness of these strategies. However, discussions with HR professionals revealed that personnel assessment was often left up to individual hiring and project managers as the subject-matter experts; it is possible that the approaches and the results and quality of these assessments vary significantly across the enterprise. If future studies uncover systemic issues with retention or job performance that indicate DoD is not adequately screening its applicants, the DoD should consider establishing robust and data-based personnel assessment strategies for civilian positions and encourage these practices across the DoD research enterprise.

Personnel assessment is an established area of research. In a 2001 review, Ivan T. Robertson and Mike Smith provide a good, albeit slightly dated, overview of personnel assessment strategies [31]. The U.S. OPM also provides information and training material on personnel assessment [32].

Both [31] and [32] describe personnel assessment as an iterative process with three steps that works best when structured and deliberate. This process starts with job analysis to determine psychological attributes required for the position. There is ongoing research in best practices for job analysis and more recent studies emphasize the importance of evaluating cross-functional skills rather than task focused skillsets. Looking at cross-functional skills ensures personnel are able to adapt and contribute to quickly evolving technology areas. While job analysis is often conducted by high performers within those positions, other resources like O*Net [33] are commonly used to determine positive worker behaviors and attributes. DoD may already implement this process. Exploration of job requisitions on USAJobs revealed they use Knowledge, Skills, Attributes, and Tasks, which are likely equivalent.

The second step is to implement candidate assessment methods. These methods include processes like structured interviews, cognitive ability tests, and assessment centers. The validity of these methods, risks of bias and adverse im-pacts, development costs, and administration costs vary. The tradeoffs of these methods have been studied and are summarized in both [31]and [32].

The last step is to evaluate the effectiveness of the job analysis and candidate assessment methods and to modify these steps to improve outcomes. The data for this evaluation will often come from organized records of employee performance or ratings by supervisors and colleagues within the organization.

DoD is currently testing a new personnel assessment process across multiple research organizations called the ePortfolio Pilot Program. This program is testing the use of electronic portfolios, "[a]n electronic collection of meaningful artifacts, which provides evidence of learning, competencies, and employability," for technical positions within DoD [34]. This program includes the three steps for developing a personnel assessment program as described above. The ePortfolio program will terminate in 2026 and reports will provide information on its benefits and costs, as well as program efficacy as part of the DoD Human Capital Framework [34].

Establishing robust and evidence-driven personnel assessment strategies can help ensure that DoD is able to correctly assess candidates' technical and soft skills to improve retention and job performance. Moreover, encouraging these practices across the DoD research enterprise can address possible inconsistencies and variance in the validity of personnel assessment.

Security Vetting

The study team's research into security vetting identified very few additional mechanisms to pursue. The security clearance investigation and adjudication pro-cess has been reviewed in other efforts, and a detailed analysis of that process was beyond the scope of this effort. Similarly, additional grant disclosure guidelines emerged between the publication of the NDAA prompting this study and the study itself; the study team recommends assessing those new requirements to evaluate both their ability to increase research security and their potential negative effects on the quantity and quality of grant applicants [3]. Nevertheless, this section provides some mechanisms to consider that relate to the ability of DoD to vet its talent and manage its research security concerns.

Continue to Explore Security Vetting Processes to Decrease Burden on Candidates and Institutions, while Maintaining a Secure Workforce

Although this study effort did not directly address the security clearance pro-cess, the delays and burdens related to obtaining a security clearance came up repeatedly. The concerns related to these issues were not limited to foreign-born

talent. A recent RAND report notes "[t]he United States could face challenges in the near future with recruiting and retaining younger generations into both public trust positions and, specifically, sensitive positions that require more in-depth personnel vetting for the purposes of receiving security clearance." [35] Conditions related to marijuana use, student debt, and increased foreign contacts will strain the security investigation and adjudication processes. As noted elsewhere in this report, delays related to obtaining a security clearance can be a strong disincentive for potential researchers to work within the DoD enterprise.

DoD should continue to explore ways to ensure security concerns are mitigated while also reducing burdens on candidates and institutions. Initiatives like continuous monitoring, rather than periodic investigations, are helpful, and similar approaches that can improve the timeliness of initial investigations, without sacrificing the accuracy, are needed. This is especially pertinent for university students, where the timelines for clearance adjudication match up poorly with the academic cycle.

Develop Risk Management Approach for Basic and Applied Research

Although individual vetting mechanisms could help with DoD's research secu-rity concerns, the research and interviews for this study indicated a larger need for a clearly articulated risk management approach for DoD-funded research. The stakeholders interviewed for this study indicated that overarching security guidance across the CTAs does not exist, and that determinations on what information and research must be protected often happens at the service or even individual program level.

Anecdotally, it was also suggested that there is a lack of clarity on what is funded with basic and applied research dollars. The general sentiment is that basic research can or should often remain open and transparent, while applied research is more likely to need security protections (though this is not universally true, as some outcomes from basic research could be sensitive). However, it was suggested that a blurring may occur where applied research is funded with basic research money, creating additional tension related to research security.

Developing a clear strategy for what research DoD supports conducting at the open, unclassified level and what research problems must be conducted in a protected manner would help refine understanding of a majority of the talent management concerns listed in this report, and generally enable a more straightforward

dialogue across the research enterprise regarding potential solutions. The risk management strategy likely needs to be defined for each CTA (and for future emerging technologies), although there may be overarching guidelines that are cross-cutting. The OUSD(R&E) technology roadmaps may offer a framework upon which to build a research security strategy as well.

The risk management approach recommended here is distinct but aligned with the recommendation in the National Academies report for a coordinated risk management approach. That document recommends against identifying specific CTAs, given the interdependencies among them, and instead suggests "a comprehensive approach to managing the risks associated with strategically important classes of technology development or use." [2] Their recommendation further includes development of an interagency process to identify specific threats, and development of risk management strategies tailored to each threat.

Overarching Mechanisms

The preceding sub-sections include potential mechanisms for DoD to consider as ways to improve its identification and recruitment, screening, and vetting of basic and applied research talent, both within the CTAs and more broadly. There are two additional mechanisms that came up through the research that act as overarching mechanisms to consider.

Leverage Workforce Planning Tools to Enable Development of Talent Management Strategies

There appear to be opportunities for DoD to capitalize on data, analytics, and automated planning tools to better enable its talent management enterprise. Through interviews, the study team learned of a specific capability used by the Defense Civilian Personnel Advisory Service (DCPAS) to support workforce planning efforts. The DCPAS organization develops and oversees civilian HR efforts for DoD [36]. That office uses TalentNeuron™, a Gartner® product which provides "big data insights and tailored guidance," to support their workforce planning [37].

DCPAS personnel explained how they use the tool to understand the sizes of the pools of talent with relevant skillsets, which commercial organizations are hiring those skills, as well as insights into the educational background and diversity of the potential applicant pool. The data within the tool include job requisitions posted by other organizations, which can lend insight into what skills competitors

are looking for as well as offering language that DoD can use to better attract those same skillsets.

The analytics within the tool also show skillset maps and adjacencies, which can help workforce planners develop more holistic talent management strategies. For skillsets that are hard to attract or retain, the skillset maps provide suggestions for related skills that might substitute, or could be targeted for additional cross-skill training to transition into the needed role. Broadly, the data and analytics can help with determining a strategy for which skills to recruit and hire, and which to develop within the existing workforce.

In addition, HR personnel interviewed noted challenges working within the existing set of talent management tools they have. Software applications that make it easier to look across currently stove-piped data, or create searchable repositories of artifacts like candidate resumes, are seen as welcome additions to the HR toolkit. These tools are believed to exist in the broader HR world, but are not currently available to DoD HR personnel, based on the information provided for this study.

DoD can improve its talent management through better application of existing tools, including increasing awareness across the DoD research enterprise of DCPAS's workforce planning and support capabilities. An additional mechanism would be to provide HR software applications at DoD research institutions to enable more data-centric approaches to HR functions.

Develop Broad DoD Research Enterprise Talent Management Strategy, Linking Identifying, Vetting, and other Talent Management Aspects across the CTAs

At a more general level, the study team identified a potential gap regarding talent management in DoD's research enterprise. The research did not reveal any overarching guidance within OUSD(R&E) or elsewhere that brings together the various talent management challenges in a single, holistic strategy. The variety of potential challenges, along with differences among the CTA research workforce needs, suggest that there is not a one-size-fits-all solution, but the interdependencies and shared needs across CTAs also indicate that an integrated approach is necessary.

The study team did find specific workforce strategy documents, such as the QIST Workforce Development National Strategic Plan [26] and the Interagency Roadmap to Support Space-Related STEM Education and Workforce [25], which

attempt to address the broad talent management concerns for those specific fields. These types of documents could be replicated across the CTAs as a companion to the technology roadmaps, to provide CTA-specific guidance on workforce planning and development. Tailored CTA workforce strategy documents could serve as appendices to a centralized strategic approach for the DoD research enterprise.

An important piece of any talent management strategy would include gathering the necessary data to understand the scope and scale of the problems to address. This includes understanding the types of talent and the numbers of personnel required, as well as when and where in the research enterprise they are needed. This study looked across potential mechanisms to improve talent management aspects without a firm grounding in the specific problems DoD needs to overcome. Improving the understanding of the talent demand signal, within and across the CTAs, and within and across the layers of the DoD research enterprise, is critical for developing targeted and tailored mechanisms to address those areas. As highlighted in the QIST Workforce Strategy, the first critical action identified is to "[d]evelop and maintain an understanding of the workforce needs in the QIST ecosystem, with both short-term and long-term perspectives," and assessing "trends, forecasts and contingencies for both the supply (of) and demand for talent." [26]

Conclusion

This research effort addressed aspects of the congressionally mandated study of mechanisms for attracting and retaining high-quality talent within DoD, speci-fically focused on identifying and vetting that talent. This report provided an array of potential mechanisms for DoD to consider. Two mechanisms stand out as recommendations to pursue: developing talent management strategies, for each CTA individually and/or for the DoD research ecosystem as a whole, and pursuing a risk management approach to more clearly define the open, unclassified research within each technology area along with the research areas that DoD wants to keep protected. These two efforts would provide an improved foundation upon which further investigation into the identification and vetting of CTA-related research talent could build.

Lastly, the study team recommends revisiting some aspects of the problem space deemed out of scope for this effort. Specifically, multiple stakeholders high-lighted the need to develop and maintain the skilled workforce of technical pro-fessionals, supply chain analysts, cost accountants, and other fields that enable the

translation of basic research to operationalized capabilities. A deeper talent management study into those fields, and the interdependencies with the size and shape of the research talent pool, is warranted. This recommendation is in line with recommendations in the SERC report, which calls for better descriptions of the defense-related skilled technical workforce to improve engagement [21].

Appendix A. OUSD(R&E) Definitions of the Critical Technology Areas

The text included in this appendix is reproduced from Reference [5].

Seed Areas of Emerging Opportunity

Biotechnology

Biotechnology is an emerging engineering discipline that uses living systems to produce a wide range of technologies and capabilities. From fighting global pandemics and avoiding surprises to reducing logistics and sustainment costs and increasing energy efficiency, biotechnology can help change the way the Department conducts missions, performs in contested logistics environments, and adapts to major global changes.

Quantum Science

Quantum Science is the study of physical properties at small, even atomic, scales. Defense applications include atomic clocks, quantum sensors, quantum computing, and quantum networks. Quantum science promises to enable leap-ahead capabilities. Quantum computing can provide unprecedented computational speeds and help solve the Department's hardest analytical problems. Quantum sensors promise the ability to provide unprecedented accuracy in position, navigation, and timing. From more accurate information to faster decision making, to significantly stronger encryption capabilities, quantum science has the promise to deliver cutting-edge technology.

Future Generation Wireless Technology (FutureG)

FutureG is a suite of emerging wireless network technologies enabled by DoD and commercial industry cooperation to enable military operations and ensure a free and open internet. As Fifth Generation (5G) wireless technology is adopted and provides building blocks for capability, the DoD will also look to FutureG for leap-ahead technologies to lead in creating future standards. The Department will invest in FutureG technology development to lay the groundwork for continued United

States leadership in information technology, which is vital for maintaining our economic and national security.

Advanced Materials

Advanced materials explore innovative new materials and novel manufacturing techniques that can dramatically improve many of the Department's capabilities. Materials that have higher strength, lighter weight, higher efficiency, and can handle more extreme temperatures will have the potential to better protect our service members and enhance their ability to accomplish their missions.

Effective Adoption Areas

Trusted AI and Autonomy

Artificial Intelligence (Al) is the software engineering discipline of expanding capabilities of software applications to perform tasks that currently require human intelligence. Machine learning is an engineering subfield of AI that trains software models using example data, simulations, or real-world experiences rather than by direct programming or coding. Autonomy is the engineering discipline that expands robots' abilities to perform tasks while limiting the need for human interaction. AI holds tremendous promise to improve the ability and function of nearly all systems and operations. Trusted AI with trusted autonomous systems are imperative to dominate future conflicts. As AI, machine learning, and autonomous operations continue to mature, the DoD will focus on evidence-based AI-assurance and enabling operational effectiveness.

Integrated Network Systems-of-Systems

Integrated Network Systems-of-Systems technology encompasses the capa-bility to communicate, provide real-time dissemination of information across the Department, and effective command and control in a contested electromagnetic environment. Integrated Network Systems-of-Systems capability must enable engagements by any sensor and shooter, with the ability to integrate disparate systems. An interoperable network that leverages emerging capabilities across the electromagnetic spectrum such as 5G, software defined networking and radios, and modern information exchange techniques will allow the Department to better

integrate many diverse mission systems and provide fully networked command, control, and communication that is capable, resilient, and secure.

Microelectronics

Microelectronics are circuits and components that serve as the "brain" to human-made electronic functional systems. Virtually every military and commercial system relies on microelectronics. Diminishing microelectronics manufacturing in the United States and supply chain concerns have highlighted national economic and security risks. Working closely with industry, academia, and across the Government, the Department is addressing the need for secure microelectronics sources and will leverage state-of-the-art commercial development and production for defense microelectronic solutions.

Space Technology

Space technologies include space flight, Space communication and other technologies needed to maintain space operations. With rising threats and increasing dependence on space-based systems, the Department's space strategy must shift away from exquisite satellites to a more robust and proliferated architecture. Novel space technologies are necessary to enable resilient cross-domain operations. The space strategy must incorporate technologies that enhance the Department's adaptive and reconfigurable capabilities in space situational awareness, space control, communication path diversity, on-orbit processing, and autonomy.

Renewable Energy Generation and Storage

Renewable energy generation and storage includes solar wind, bio-based and geothermal technologies, advanced energy storage, electronic engines, and power grid integration. Renewable energy generation and storage promises to decrease warfighter vulnerability and deliver new operational capabilities for the Department. From more efficient batteries to diversifying energy sources and reduced fuel transportation risks, renewable energy generation and storage will add resilience and flexibility in a contested logistics environment.

Advanced Computing and Software

Advanced computing and software technologies include supercomputing, cloud computing, data storage, computing architectures, and data processing. Software is

ubiquitous throughout the Department, but the speed at which software develops outpaces the Department's ability to stay up to date. The Department must rapidly modernize its legacy software systems with resilient, affordable, and assured new software that has been designed, developed, and tested using processes that establish confidence in its performance. The Department must migrate to a Development-Security-Operations (DevSecOps) approach in its software development and evolve to a model of continuous development, continuous test, and continuous delivery. The Department must leverage modular open system architecture approaches to isolate hardware from software and enable rapid upgrades to secure processors.

Human-Machine Interfaces

Human-Machine Interface refers to technologies related to human-machine teaming and augmented and virtual reality. Rapid advancements in this technology will have a multitude of benefits for our service members. Highly immersive realistic training environments provide real-time feedback to enhance warfighter performance. Intuitive 5 interactive human-machine interfaces enable rapid mission planning and mission command by providing a common operational picture to geographically distributed operations.

Defense-Specific Areas

Directed Energy

Directed Energy Weapons utilize lasers, high power microwaves, and high energy particle beams to produce precision disruption, damage, or destruction of military targets at range. Directed energy systems will allow the Department to counter a wide variety of current and emerging threats with rapid responses and engagement at the speed of light. High-power lasers and high-power microwave technologies both offer new ways to counter diverse sets of threats.

Hypersonics

Hypersonic systems fly within the atmosphere for significant portions of their flight at or above 5 times the speed of sound, or approximately 3700 miles per hour. Hypersonics dramatically shorten the timeline to strike a target and increase unpredictability. While strategic competitors are pursuing and rapidly fielding advanced

hypersonic missiles, the DoD will develop leap-ahead and cost-effective technologies for our air, land, and sea operational forces.

Integrated Sensing and Cyber

To provide advantage for the joint force in highly contested environments, the Department must develop wideband sensors to operate at the intersection of cyber space, electronic warfare, radar, and communications. Sensors must be able to counter advanced threats and can no longer be stove-piped and single function.

Appendix B. FY21 NDAA Section 252

The text included in this appendix is reproduced from Section 252 of Reference [6].

SEC. 252. STUDY ON MECHANISMS FOR ATTRACTING AND RETAINING HIGH QUALITY TALENT IN THE DEPARTMENT OF DEFENSE.

(a) STUDY REQUIRED.—The Secretary of Defense shall enter into an agreement with an independent academic institution to conduct a study to develop policy options and recommendations for the establishment of a program to attract and retain covered individuals for employment in the Department of Defense.

(b) ELEMENTS.—The study required under subsection (a) shall include the following:

(1) An analysis of mechanisms the Department may use to engage public and private sector organizations to assist in the identification and recruitment of covered individuals for employment in the Department of Defense.

(2) Identification of statutory, regulatory, and organizational barriers to the development of the program described in subsection (a).

(3) An analysis of monetary and nonmonetary incentives that may be provided to retain covered individuals in positions in the Department.

(4) An analysis of methods that may be implemented to ensure appropriate vetting of covered individuals.

(5) An analysis of the size of a program required to advance the competitiveness of the research, development, test, and evaluation efforts of the Department in the critical technologies identified in the National Defense Strategy.

(6) The type and amount of resources required to implement the program described in subsection (a).

(c) REPORTS.

(1) INITIAL REPORT.—Not later than February 1, 2021, the Secretary shall submit to the congressional defense committees a report on the plan of the Secretary to execute the study required under subsection (a).

(2) FINAL REPORT.—Not later than February 1, 2022, the Secretary shall submit to the congressional defense committees a report on the results of the study conducted under subsection (a).

(d) COVERED INDIVIDUAL DEFINED.—In this section, the term "covered individual" means an individual who—

(1) is engaged in work to promote and protect the national security of the United States;

(2) is engaged in basic or applied research, funded by the Department of Defense; and

(3) possesses scientific or technical expertise that will advance the development of critical technologies identified in the National Defense Strategy or the National Defense Science and Technology Strategy, required by section 218 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Public Law 115–232; 132 Stat. 1679).

Appendix C. Job Requisition Analysis Methodology

This appendix provides additional detail on the methodology for the job requisition analysis, including the approach and parameters for inclusion in the dataset. This appendix also includes additional exploratory statistics of the collected data.

Data Collection Process

To conduct the data collection, the study team built and deployed a Python-based web scraping tool that automated the extraction of relevant data points from the webpages of CTA-relevant job requisitions. The reasoning for deploying a web scraper for this analysis was to expedite the collection of a large amount of information from a wide range of sources to avoid any bias in the dataset. While the variation in the HTML formatting of each source made it necessary to make adjustments to some of the parametric qualities of the web scraper (such as reference points), the explored sources were consistent in the general formatting and the type of information made available for each job requisition.

As such, the "Career Opportunities" websites of the explored institutions generally consisted of a list of the current open job opportunities that included its title, location of the position, a short description, and a hyperlink to the job requi-sition. Once the web scraper was modified for a specific web source, it would extract all of the listings and associated hyperlinks. Then, for each listed position, the web scraper would open the hyperlink in order to collect the following information from the job requisition webpage: (1) job title; (2) organization, department, and/or agency; (3) job description or summary; and (4) candidate requirements (minimum and desired).

After the desired text was extracted from each job requisition from a given institution, a filter was applied in order to eliminate datapoints that were irrelevant to this study. The following parameters were designed to ensure the dataset would only include CTA-relevant and research-focused job requisitions:

(1) The position was or could be categorized under professional work in a STEM field series as defined by the Office of Personnel Management (OPM) [7]: biological sciences, engineering, physical sciences, mathematics and statistics, and computer sciences.

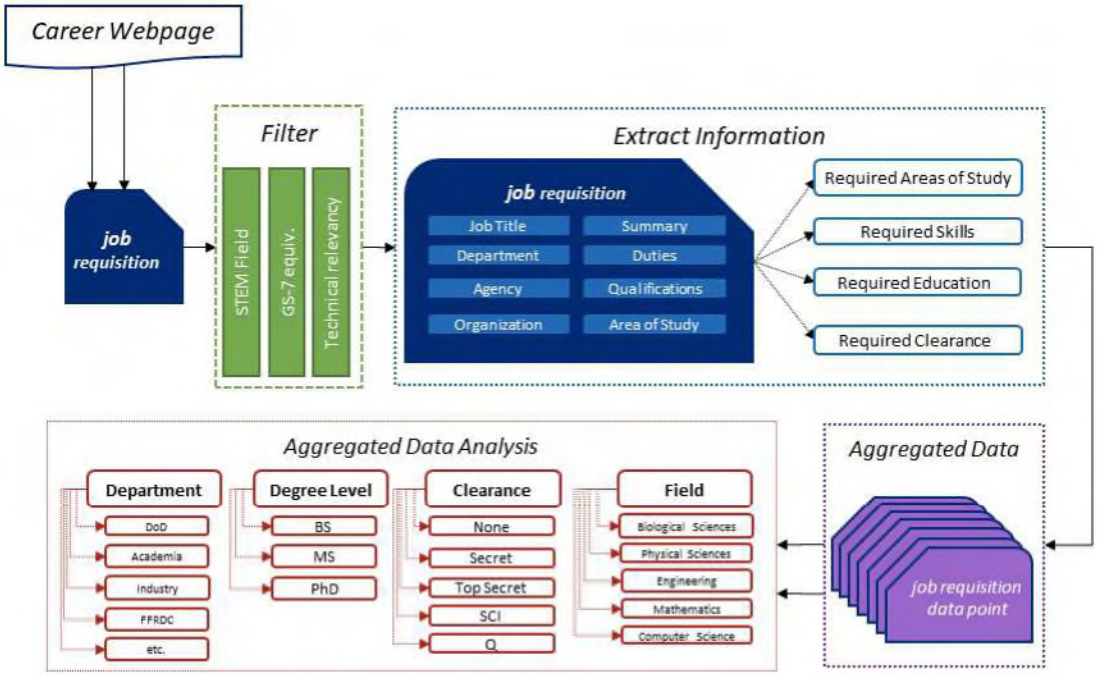
(2) The position requires a minimum of a bachelor's degree (or equivalent to a government GS-7 position [38]).

(3) The position is not classified as administrator, coordinator, or manager; licensed medical provider; technician, technologist, or IT specialist; or financial, budget, or actuary.

Finally, a Python-based post-processing tool was applied to the filtered subset of data to process the datapoints for the desired information. This was done by building a repository of keywords relevant to the desired information. For example, to search for information on security clearance requirements, the script would search for variations of keywords like *top secret, TS/SCI, active clearance, and DOE clearance*. If a keyword is identified in the data collected, the job requisition is then attributed to the given category.

Once this process was performed on all of the desired sources, a final analysis function was employed that searched for correlational properties across the various parameters of interest: institutional communities, degree levels, areas of study, etc.

Figure C-1 provides a visual depiction of the data extraction and aggregation process.



Acronyms not defined within the figure are included in the Abbreviations and Acronyms List.

Figure C-1. Job Requisition Analysis Overview

Scope of Analysis

In an attempt to provide an objective exploration of the various aspects of CTA-relevant online job requisitions, this analysis was conducted over three different scopes. For each scope, the methodology described above was applied with no differentiation to the parametric filter used to collect relevant job requisitions.

The first stage, *Federal Agencies and Research Centers*, examines CTA-relevant job requisitions made available by U.S. federal agencies, executive departments, and universities and research centers that receive federal funding. The purpose of this stage of the analysis was to provide a comprehensive investigation into federal or federally funded CTA research positions in an effort to extrapolate information on the current status or gaps of the U.S. government in acquiring highly skilled and educated CTA professionals. Job requisitions were collected from federal department career opportunity pages as well as official job websites used by multiple departments and agencies, such as USAJOBS.gov [38]. Figure C-2 shows a screenshot of the career webpage from USAJOBS.gov that provides a list of job requisitions with high-level information of each open position.

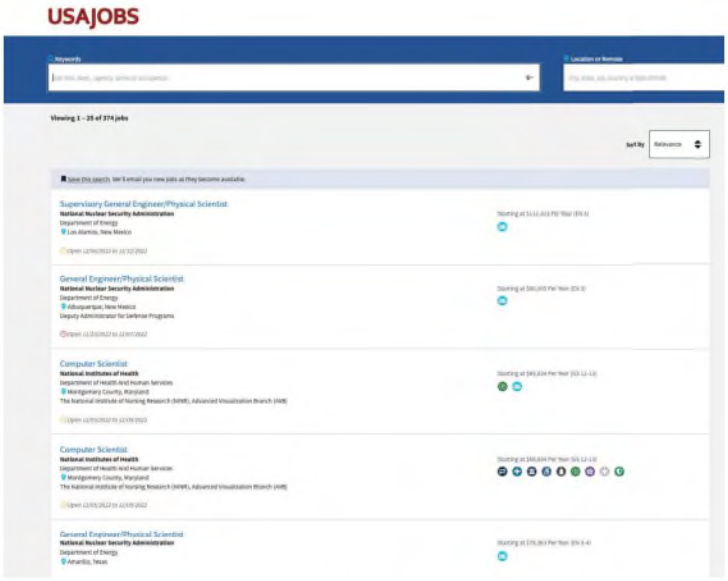


Figure C-2. USAJOBS.gov Career Page Screenshot

The sourced departments and facilities, given in the comprehensive list in Table C-1, were identified as part of the Defense Research Enterprise by the Directorate of Defense Research and Engineering for Research and Technology [40].

Table C-1. Sourced Departments and Facilities Used in Job Requisition Review

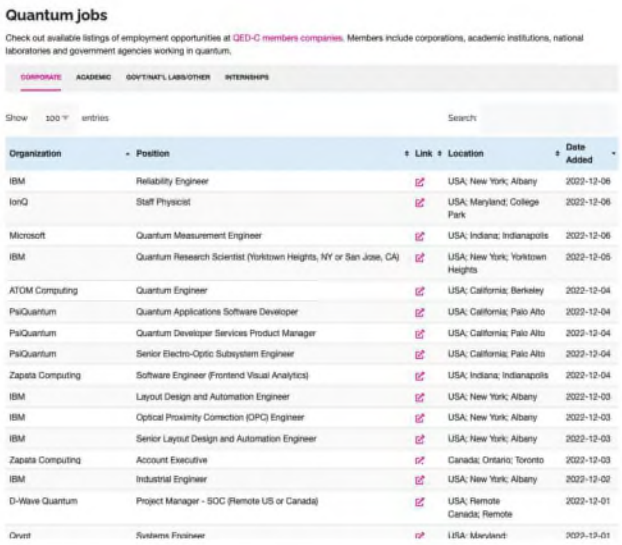
Entity	Organization	Webpage
Defense Microelectronics Activity	Department of Defense	https://www.usajobs.gov/Search/
Air Force Research Laboratory	Department of Defense	https://airforcestem.recsolu.com/job_boards/g193rQ-SUdupijEbTiPUvw
Army Research Institute	Department of Defense	https://www.usajobs.gov/Search/
Army Engineer Research & Development Center	Department of Defense	https://www.usajobs.gov/Search/
USAISR	Department of Defense	https://www.usajobs.gov/Search/
USAITCA	Department of Defense	https://www.usajobs.gov/Search/
Oakridge National Laboratory	Department of Energy	https://jobs.ornl.gov/
Argonne National Laboratory	Department of Energy	https://argonne.wd1.myworkdayjobs.com/Argonne_Careers
Brookhaven National Laboratory	Department of Energy	https://jobs.bnl.gov/search-jobs

Pacific Northwest National Laboratory	Department of Energy	https://careers.pnnl.gov/
Princeton Plasma Physics Lab	Department of Energy	https://www.pppl.gov/work-with-us
Fermilab	Department of Energy	https://fermilab.jobs
Thomas Jefferson National Accelerator Facility	Department of Energy	https://www.jlab.org/job-search
National Renewable Energy Laboratory	Department of Energy	https://nrel.wd5.myworkdayjobs.com
National Energy Technology Laboratory	Department of Energy	https://www.usajobs.gov/Search/Results?k=NETL
Savannah River National Laboratory	Department of Energy	https://sjobs.brassring.com/TGnewUI/Search/Home/HomeWithPreLoad?partnerid=25264&siteid=5259&PageType=searchResults&SearchType=linkquery&LinkID=1461033#keyWordSearch=&locationSearch=
Center for Naval Analysis	FFRDC	https://us63.dayforcehcm.com/CandidatePortal/en-US/CNA
Institute for Defense Analysis	FFRDC	https://phh.tbe.taleo.net/phh01/ats/careers/v2/searchResults?org=INSTITUTEDA&cws=39+E45
Carnegie Mellon University Software Engineering Institute	FFRDC	https://cmu.wd5.myworkdayjobs.com/SEI
Massachusetts Institute of Technology Lincoln Laboratory	FFRDC	https://careers.ll.mit.edu/search
RAND Corporation	FFRDC	https://rand.wd5.myworkdayjobs.com/External_Career_Site/
Naval Facilities Engineering and Expeditionary Warfare Center	Department of Defense	https://www.usajobs.gov/Search/
Naval Sea Systems Command	Department of Defense	https://www.usajobs.gov/Search/
Naval Air Warfare Center Aircraft Division	Department of Defense	https://www.usajobs.gov/Search/
Naval Air Warfare Center Training Systems Division	Department of Defense	https://www.usajobs.gov/Search/
National Health Research Center	Department of Defense	https://www.usajobs.gov/Search/
Naval Information Warfare Center	Department of Defense	https://www.usajobs.gov/Search/
Naval Medical Research Center	Department of Defense	https://www.usajobs.gov/Search/
NAVSEA Warfare Centers	Department of Defense	https://www.usajobs.gov/Search/
NAVSEA Undersea Warfare Centers	Department of Defense	https://www.usajobs.gov/Search/Results?a=NV14&k=ONR&p=1&s=startdate_desc
Office of Naval Research	Department of Defense	https://navair.recsolu.com/job_boards/mdxt8VG0qqvc7z8xHhZztg

Los Alamos National Laboratory	National Nuclear Security Administration (NNSA)	https://lanl.jobs/search/searchjobs
Lawrence Livermore National Laboratory	NNSA	https://www.llnl.gov/join-our-team/careers
Sandia National Laboratories	NNSA	http://sandia.jobs
Georgia Tech Research Institute	UARC	https://careers.gtri.gatech.edu/en-us/listing/
Johns Hopkins University Applied Physics Laboratory	UARC	https://careers.jhuapl.edu/jobs
Penn State University Applied Research Laboratory	UARC	https://psu.wd1.myworkdayjobs.com/PSU_Staff?q=ARL
Stevens Institute of Technology Systems Engineering Research Center	UARC	https://www.usajobs.gov/Search/
University of Maryland Applied Research Laboratory for Intelligence and Security	UARC	https://ejobs.umd.edu/postings/search?query_organizational_tier_3_id=1384
University of Southern California Institute for Creative Technologies	UARC	https://usccareers.usc.edu/search-jobs/ICT?orgIds=1728-1209&kt=1
Utah State University Space Dynamics Laboratory	UARC	https://www.sdl.usu.edu/employment/careers
University of Texas Applied Research Laboratory	UARC	https://utaustin.wd1.myworkdayjobs.com/UTstaff?company=a625047661120172b59fe0cc8f0ab342
University of Washington Applied Physics Laboratory	UARC	https://apl.uw.edu/jobs/job_postings.php
Department of Agriculture	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of Commerce	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of Defense	Department of Defense	https://www.usajobs.gov/Search/
Department of Energy	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of Homeland Security	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of Labor	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of the Air Force	Department of Defense	https://www.usajobs.gov/Search/
Department of the Army	Department of Defense	https://www.usajobs.gov/Search/
Department of the Interior	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of the Navy	Department of Defense	https://www.usajobs.gov/Search/

Department of the Treasury	U.S. Government, Other	https://www.usajobs.gov/Search/
Department of Transportation	U.S. Government, Other	https://www.usajobs.gov/Search/

The next stage performed the same analysis but focused on a single CTA: quantum sciences. This stage analyzed current career opportunities relevant to a single field across academia, industry, and the federal government to explore the variations in job types and requirements in each sector. Requisitions were identified and collected using the Quantum Science Consortium (QED-C), a consortium of academics, private businesses, and federal agencies in the quantum science field. QED-C was developed in response to the National Quantum Initiative Act in an effort to further develop the stance of the U.S. in quantum science research and development. QED-C provides the employment opportunities of most QED-C members,[4] a group that is made up of 166 corporations, 50 academic institutions, 10 FFRDCs, 40 government departments and agencies, and 8 affiliated science and technology societies. A screenshot of the Quantum Jobs page listing quantum sciences positions posted by members of the consortium is shown in Figure C-3.



Quantum jobs

Check out available listings of employment opportunities at QED-C members companies. Members include corporations, academic institutions, national laboratories and government agencies working in quantum.

CORPORATE | ACADEMIC | GOVT/NAT'L LABS/OTHER | INTERNSHIPS

Show 100 entries | Search

Organization	Position	Link	Location	Date Added
IBM	Reliability Engineer		USA; New York; Albany	2022-12-06
IonQ	Staff Physicist		USA; Maryland; College Park	2022-12-06
Microsoft	Quantum Measurement Engineer		USA; Indiana; Indianapolis	2022-12-06
IBM	Quantum Research Scientist (Yorktown Heights, NY or San Jose, CA)		USA; New York; Yorktown Heights	2022-12-05
ATOM Computing	Quantum Engineer		USA; California; Berkeley	2022-12-04
PsiQuantum	Quantum Applications Software Developer		USA; California; Palo Alto	2022-12-04
PsiQuantum	Quantum Developer Services Product Manager		USA; California; Palo Alto	2022-12-04
PsiQuantum	Senior Electro-Optic Subsystem Engineer		USA; California; Palo Alto	2022-12-04
Zapata Computing	Software Engineer (Frontend Visual Analytics)		USA; Indiana; Indianapolis	2022-12-04
IBM	Layout Design and Automation Engineer		USA; New York; Albany	2022-12-03
IBM	Optical Proximity Correction (OPC) Engineer		USA; New York; Albany	2022-12-03
IBM	Senior Layout Design and Automation Engineer		USA; New York; Albany	2022-12-03
Zapata Computing	Account Executive		Canada; Ontario; Toronto	2022-12-03
IBM	Industrial Engineer		USA; New York; Albany	2022-12-02
D-Wave Quantum	Project Manager - SOC (Remote US or Canada)		USA; Remote Canada; Remote	2022-12-01
Qrvst	Systems Engineer		USA; Maryland;	2022-12-01

Figure C-3. QED-C Job Listings

[4] See https://quantumconsortium.org/members/ for a list of QED-C members.

The final stage focuses on job requisitions posted in the field of hypersonics. Like the previous stage, its purpose is to explore career opportunities across aca-demia, industry, and government in a specific CTA. However, for this stage, a defense-focused CTA was selected in order to perform the analysis on a technically specialized and specific area. The sources for the hypersonics position were identified using the University Consortium for Applied Hypersonics (UCAH) [11], a collaborative network of academia, industry, and federal research centers, in an effort to advance research and development of hypersonic flight systems. UCAH was developed through funding awarded to Texas A&M University by the DoD for the advancement of hypersonics research.[5] Like the QED-C, UCAH advertises hypersonic-related employment opportunities from more than 140 corporations, 18 federal research centers, and 96 universities.[6]

The job requisitions collected for stages 2 and 3 include only those posted on their respective consortiums websites, resulting in a limited pool of data available for analysis. For future research, extensive data aggregation could be performed to eliminate the risk of bias in the data.

[5] An announcement and description of this collaboration can be found here: https://www.defense.gov/News/Releases/Release/Article/2394282/defense-department-awards-university-consortium-for-applied-hypersonics-contract/.

[6] A list of UCAH affiliates can be found here: https://hypersonics.tamu.edu/affiliate-members/.

Appendix D. DoD STEM Fellowship and Outreach Programs

The Department of Defense (DoD) and military services have spent consi-derable efforts fostering the development of a highly skilled science, technology, engineering, and mathematics (STEM) workforce that can conduct work to support national security [17]. The variety of available programs include internship and apprenticeship programs for high school, undergraduate (including cadets and midshipmen), and graduate students to gain practical work experience; scholarships and fellowships to support graduate and postdoctoral students conducting research that aligns with DoD priorities; as well as educational outreach programs for instructors and K-12 students to raise awareness of STEM disciplines and their application to the DoD. A non-comprehensive list of available programs, organized by affiliation, is presented in Table D-1.

Table D-1. DoD STEM Fellowship and Outreach Programs

	Type	Education level	Program	Description	Objectives	Affiliate
1	Fellowship	Graduate	National Defense Science and Engineering Graduate (NDSEG) Fellowship[7]	Graduate fellowship that is awarded to U.S. citizens, U.S. nationals, and U.S. dual citizens who intend to pursue a doctoral degree aligned to the DoD services Broad Agency Announcements (BAAs) in research and development at a U.S. institution of their choice. The fellowship lasts for 3 years and pays full tuition and fees, a monthly stipend, a travel budget, and an allotment toward health insurance.	• Increase the number of U.S. citizens or nationals trained in disciplines of science and engineering of military importance. • Develop continuing relationships with recipients and the sponsoring military services; each service is responsible for mentoring and interacting with its selected awardees. • Attract science and engineering baccalaureate graduates to pursue doctorates in DoD-mission-related research areas from U.S. institutions.	Air Force Office of Scientific Research (AFOSR), Army Research Office, Office of Naval Research (ONR)
2	Scholarship	Undergraduate, Graduate	Science, Mathematics, and Research for Transformation (SMART)	Combined educational and workforce development scholarship program for undergraduate, master's, and doctoral students currently pursuing a degree in one of	• Enhance the DoD civilian workforce with innovative scientists, engineers, and researchers across the U.S. • Create a highly skilled DoD STEM workforce that	DoD

[7] https://ndseg.sysplus.com/

			Scholarship Program[8]	the 21 designated STEM disciplines. The scholarship provides full tuition, an annual stipend, internships, a book and health allowance, and guaranteed employment with the DoD after graduation to participants.	competes with the dynamic trends in technology and innovation to protect national security.	
Army						
3	Internship, Apprenticeship	Undergraduate	Army Educational Outreach Program (AEOP) Undergraduate Research Apprenticeship Program (URAP)[9]	Science and engineering research experience for undergraduate students alongside university students in a university lab setting nationwide.	Learn about the variety of paths in their STEM field of interest and develop the tools needed to get there	Army Research Laboratory (ARL)
4	Fellowship	Graduate, Post-Graduate	AEOP Fellowship[10]	Professional research opportunities for graduate and post-graduate students in U.S. Army Research laboratories and centers focused on the most current and cutting-edge future modernization priorities of DoD.	• Provide graduate and post-graduate students with real-world applications of their STEM skills. • Develop professional and research skills. • Gain access to career development resources.	ARL

[8] https://www.smartscholarship.org/smart

[9] https://www.usaeop.com/program/undergraduate-apprenticeships/

[10] https://www.usaeop.com/program/fellowships/

					• Foster relationships with ARL researchers and expand professional networks.	
5	Educational Program, Fellowship	Undergraduate, Graduate	U.S. Army Combat Capabilities Development Command (DEVCOM) ARL Research Associateship Program Summer Student Experience[11]	Summer educational program for students and recent graduates to participate in paid research at a U.S. DoD laboratory nationwide.	Introduce students to ARL science and engineering research that will help shape and execute the Army's program for meeting the challenge of developing technologies that will support Army forces in meeting future operational needs.	DEVCOM ARL
Navy/Marine Corps						
6	Program, Contest	Undergraduate, Graduate	Naval Horizons[12]	Contest for undergraduate and graduate students where they can watch videos to learn about U.S. Navy and Marine Corps STEM research, choose a STEM topic to conduct research on, and write and submit an essay on how the research and people inspire them. Submitters compete for a cash prize, and being designated Naval Horizons Highest Honors.	Introduce students to cutting-edge STEM topics and challenges that impact the U.S. Navy and Marine Corps.	Naval STEM (Department of the Navy)

[11] https://www.orau.org/arlfellowship/applicants/default.htm

[12] https://navalhorizons.us/

7	Internship, Apprenticeship	Undergraduate	Naval Intelligence Activity Internship[13]	Program where students can participate in Operational Familiarization trips to Norfolk, Virginia; Office of Naval Intelligence's (ONI's) operational customers onboard ships; aviation squadrons; and other U.S. Navy commands. The program also includes field trips to Washington, D.C. area commands, agencies, and relevant landmarks while conducting work important to national security.	Provide pre-professional work experience relevant to academic and career-related goals, and enable students to delve into the world of intelligence.	ONI
8	Fellowship	Postdoctoral	Naval Research Laboratory (NRL) Postdoctoral Fellowship Program[14]	Program for postdoctoral fellows to conduct research in a Navy laboratory environment while interacting with senior laboratory scientists and engineers.	Increase the involvement of creative and highly trained scientists and engineers from academia and industry to scientific and technical areas of interest and relevance to the Navy.	NRL
9	Internship, Apprenticeship	Undergraduate, Graduate	Shipyard's Apprentice Program[15]	Four-year program that provides paid academic, trade, and on-the-job training. Graduates receive journey worker certificates	Develop skilled journeyworkers and future leaders.	Naval Sea Systems Command (NAVSEA)

[13] https://www.oni.navy.mil/Careers/Intern-Programs/

[14] https://nrl.asee.org/about

[15] https://www.navsea.navy.mil/Home/Shipyards/PHNS-IMF/Careers/Apprenticeship/

				from both the U.S. Department of Labor and U.S. Department of the Navy, as well as college credit toward an associate's degree.		
10	Internship	Undergraduate, Graduate	Naval Research Enterprise Internship Program (NREIP)[16]	10-week summer undergraduate and graduate internship program hosted at one of 41 Naval laboratories or warfare centers nationwide. Provides an opportunity for STEM students to learn about and participate in Naval research and technology while being mentored by Naval scientists and engineers. Students receive a stipend, the level of which is determined by the student's years of participation in the NREIP program.	Introduce academically talented college and graduate students with interest and ability in science and engineering to real Naval research.	ONR
11	Internship	High school (grades 9-12)	Science and Engineering Apprenticeship Program (SEAP)[17]	8-week summer internship program for high school sophomores, juniors, and seniors interested in STEM to learn about and participate in Naval research and technology at one of 30 Naval	Introduce academically talented high school students with interest and ability in STEM to real Naval research.	ONR

[16] https://navalsteminterns.us/nreip/

[17] https://navalsteminterns.us/seap/

				laboratories nationwide. Students receive a stipend, the level of which is determined by the student's years of participation in the SEAP program.		
Air Force/Space Force						
12	Internship	Undergraduate, Graduate	Griffis Institute Summer Internship Program[18]	Paid summer internship opportunity for students to work on-site (Rome, NY-based) with Air Force Research Laboratory (AFRL) researchers on a wide variety of research projects.	Develop the next generation of STEM talent and defense technologies that will strengthen U.S. national security and create economic opportunity for Rome, NY, New York State, and the nation.	Information Directorate of the AFRL
13	Fellowship	Graduate, Academic Faculty	Summer Faculty Fellowship Program[19]	Program that offers hands-on exposure to Air Force research challenges through 8- to 12-week research residencies at participating Air Force research facilities (AFRL Directorate, Air Force Test Center, the U.S. Air Force (USAF) Academy, or the Air Force Institute of Technology) for full-time science, mathematics, and engineering faculty and their	• Stimulate professional relationships among AFRL Summer Faculty Fellowship Program participants and the scientists and engineers at Air Force research facilities. • Enhance the research interests and capabilities of faculty (both new and experienced researchers)	AFOSR

[18] https://www.griffissinstitute.org/who-we-work-with/afrl/summer-internship

[19] http://afsffp.sysplus.com/

				graduate students at U.S. colleges and universities.	in the U.S. academic community. • Elevate awareness in the U.S. academic community of Air Force research needs and foster continued research at AFRL Summer Faculty Fellowship Program fellows' institutions. • Provide the U.S. AFRL Summer Faculty Fellowship Program participants opportunities to perform high-quality and meaningful research at AFRL Directorates, Air Force Test Center, the United States Air Force Academy, or the Air Force Institute of Technology. • Provide nationally accredited mentoring of academic researchers at technical directorates of the AFRL, Air Force Test Center, the United States Air Force Academy, and the Air Force Institute of Technology.	

14	Internship, Apprenticeship	High School (grades 9-12), Undergraduate, Graduate	AFRL Scholars Program[20]	Paid internship opportunity for students pursuing STEM degrees. Involves working directly with AFRL scientists and engineers on cutting-edge research and technology, and graduate interns can collaborate with AFRL on current research and incorporate it into their graduate work.	Gain valuable hands-on experience working with full-time AFRL scientists and engineers on cutting-edge research and technology and contribute to research-based projects.	AFRL
15	Training Program	Undergraduate, Graduate	PALACE Acquire[21]	2- to 3-year training program where students work with Air Force Civilian Service (AFCS) scientists and engineers around the globe on challenging projects. Students work on real-world projects and missions, and gain on-the-job training and mentoring from civilian and military scientists and engineers. Successful completion of the program may lead to a permanent AFCS position as a scientist or engineer.	Provide on-the-job training and mentoring to develop the next generation AFCS leaders and contributors.	AFCS

[20] https://afrlscholars.usra.edu/

[21] https://afciviliancareers.com/paq-scienceengineering/

16	Fellowship	Postdoctoral	Air Force Science and Technology Fellowship Program[22]	Fellowship for postdoctoral scholars to perform collaborative research at USAF research facilities (AFRL, Air Force Institute of Technology (AFIT), and USAF Academy) across the country.	Provide high-quality research opportunities with Air Force scientists at AFRL, Air Force Institute of Technology, and USAF Academy.	AFRL, AFIT, and USAF Academy
17	Program	Undergraduate, Graduate	Autonomy Technology Research Center[23]	14-week collaborative research experience for university students, professors, industry, and the government to work together to solve challenging Air Force problems in sensing and autonomy challenges.	Enhance students' education and provide relevant technical experience for future work.	AFRL, Wright State University
18	Program	Grades K-12	STEMtoSpace[24]	Program that pairs U.S. Space Force (USSF) Guardians with classrooms to share the importance of STEM in space, possible STEM career opportunities, and how the Space Force contributes to daily life around the U.S.	Facilitate virtual connections between Space Force Guardians and K-12 classrooms to share the importance of STEM careers related to space, and how Space Force contributes to national security and daily life.	USSF

[22] https://sites.nationalacademies.org/PGA/Fellowships/AFRL/index.htm

[23] https://www.wright.edu/autonomy-technology-research-center

[24] https://sites.google.com/afk12stem.org/stemtospace/home

Defense Threat Reduction Agency (DTRA)						
19	Program	Educators, grades 6-12	Joint Science and Technology Institute[25]	1-2 week residential STEM research program for middle and high school students and teachers in DoD schools around the world. Students participate in research projects mentored by DoD research scientists.	• Inspire and encourage students to pursue careers in STEM fields. • Increase STEM literacy. • Expose students to the importance of STEM through hands-on, relevant research.	DTRA, Oak Ridge Institute for Science and Education.
20	Program	Educators, Undergraduate	Faculty-Student Team Defense Lab Research Activity[26]	Program that provides faculty and student research teams from underserved academic communities with the opportunity to conduct research associated with real-world DoD science and technology requirements at a DoD laboratory nationwide.	• Better understand the mission and research needs of DoD. • Make advances in DoD research areas. • Strengthen the talent pool of scientists and engineers. • Conduct collaborative research of mutual interest to the team and the DoD laboratory.	DTRA, Oak Ridge Institute for Science and Education
Missile Defense Agency (MDA)						
21	Internship, Apprenticeship	Undergraduate	Military Academy Internship[27]	Month-long internship for military academy cadets, USAF Academy cadets, and U.S. Naval Academy	Develop new technical skills while working with top-notch professionals and being put at the cutting edge of some	MDA

[25] https://orise.orau.gov/jsti/

[26] https://orise.orau.gov/FSRP/

[27] https://www.mda.mil/about/STEM_initiatives.html

				midshipmen to participate in real-world projects with the MDA Advanced Research and Architecture and Concepts Division.	of the most critical aspects of national security affairs.	
22	Program	Undergraduate	Missile Defense Career Development Program[28]	Three-year program for recent college graduates and those about to graduate college where they participate in rotational assignments including seminars, formal classroom training, and on-the-job training.	Acquire valuable technical and work-related skills by working hand-in-hand with industry partners developing MDA technology.	MDA
23	Program	K-12	MDA Classroom Speakers[29]	Program aimed at raising awareness of STEM disciplines and their application to missile defense in K-12 classrooms and STEM events geographically located near MDA locations.	Raise awareness of STEM disciplines and their application to missile defense.	MDA
Department of Defense (DoD)						
24	Internship, Apprenticeship	Undergraduate, Graduate	DoD Historically Black Colleges and Universities and Minority-Serving Institutions	Program that provides undergraduate and graduate student participants with a unique developmental experience to broaden their	Increase the number of minority scientists and engineers throughout DoD.	DoD, Office of the Under Secretary of Defense for Research and

[28] https://www.mda.mil/careers/jobs_entry_level.html

[29] https://www.mda.mil/about/STEM_initiatives.html

			(HBCU/MI) Summer Research Program[30]	perspectives and practical advanced education related to their academic field. Includes an 11-week research experience at DoD facilities across the nation under the supervision of DoD scientists and engineers.		Engineering (OUSD[R&E])
25	Internship, Apprenticeship	Undergraduate	DoD College Acquisition Internship Program[31]	10- to 12-week paid internship for college sophomores and juniors within DoD components participating in the program nationwide. Interns gain experience in career fields available within the acquisition workforce, and receive hands-on experience in analysis, research, report writing, oral briefings, policy development, program analysis, and computer applications.	Provide students with real-world exposure to DoD acquisition workforce career opportunities.	DoD, Office of the Undersecretary of Defense for Acquisition and Sustainment (OUSD{[A&S])
External DoD STEM Partner						
26	Program	High School (grades 9-12)	Center for Excellence in Education (CEE)	Summer science and engineering program that combines on-campus coursework at the	Nurture high school students to careers of excellence and leadership in STEM.	CEE

[30] https://www.dodhbcumiinternship.com/participating-research-labs

[31] https://www.hci.mil/dodcareers/internship.html

			Research Science Institute[32]	Massachusetts Institute of Technology with off-campus experience in science and technology research.		
27	Program	High School (grades 9-12), Undergraduate	Emerging Leaders in Biotechnology[33]	Hybrid program that introduces high school and college-age women to biotechnology jobs by connecting them with near-peer mentors and providing a hands-on laboratory experience.	Connect young women with biotech, cyber, and other in-demand STEM content and inspire them toward high-demand careers.	Learning Undefeated, Defense STEM Education Consortium
28	Competition	Grades 6-12	SeaPerch[34]	Underwater remotely operated vehicle competition for students and teachers nationwide.	Equip students and teachers with the resources needed to learn basic science and engineering concepts.	RoboNation
29	Fellowship	Graduate	John S. McCain Strategic Defense Fellows Program[35]	1-year civilian fellowship program designed to provide leadership development for the commencement of a career track toward senior leadership at DoD. Includes rotations in the Office of the Secretary of Defense or the	Program where participants can gain DoD experience and leadership capabilities through challenging opportunities to flourish into problem solvers, strategic thinkers, and future leaders.	Washington Headquarters Services

[32] https://www.cee.org/programs/research-science-institute

[33] https://www.learningundefeated.org/emerging-leaders-in-biotechnology/

[34] https://seaperch.org/about/

[35] https://www.whs.mil/McCain-Fellows-Program/

				Office of the Secretary of a military department.		
30	Internship, Apprenticeship	Undergraduate	Photonics Certificate Program[36]	12-month, hands-on training program that prepares students with minimal prior technical background to work as technicians in the optics, photonics, and robotics industries.	Equip participants with the skills and experience needed to thrive in the optics, photonics, and robotics market.	ONR, Stonehill College

[36] https://www.stonehill.edu/programs/photonics-certificate/

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Abbreviations and Acronyms

5G	Fifth Generation
AEOP	Army Educational Outreach Program
AFCS	Air Force Civilian Service
AFIT	Air Force Institute of Technology
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AI	Artificial Intelligence
ARL	Army Research Laboratory
BAA	Broad Agency Announcements (DoD Services)
CMU	Carnegie Mellon University
CTA	Critical Technology Area
CUI	Controlled Unclassified Information
DCPAS	Defense Civilian Personnel Advisory Service
DEVCOM	Development Command
DoD	Department of Defense
DOE	Department of Energy
DTRA	Defense Threat Reduction Agency
FFRDC	Federally Funded Research and Development Center
FutureG	Future Generation
FY	Fiscal Year
GS	General Schedule
HBCU	Historically Black Colleges and Universities
HBCU/MI	Historically Black Colleges and Universities and Minority-Serving Institutions
HR	Human Resources
JHU/APL	Johns Hopkins University Applied Physics Laboratory
MDA	Missile Defense Agency
National Academies	National Academies of Sciences, Engineering, and Medicine
NDAA	National Defense Authorization Act

NDSEG	National Defense Science and Engineering Graduate
NNSA	National Nuclear Security Administration
NREIP	Naval Research Enterprise Internship Program
NRL	Naval Research Laboratory
ONR	Office of Naval Research
OPM	Office of Personnel Management
OUSD(R&E)	Office of the Undersecretary of Defense for Research and Engineering
QED-C	Quantum Science Consortium
QIST	Quantum Information Science and Technology
SCALE	Scalable Asymmetric Lifecycle Engagement
SEAP	Science and Engineering Apprenticeship Program
SERC	Systems Engineering and Research Center
SMART	Science, Mathematics, and Research for Transformation
STEM	Science, Technology, Engineering, and Mathematics
STRL	Science and Technology Reinvention Laboratory
UARC	University Affiliated Research Center
UCAH	University Consortium for Applied Hypersonics
URAP	Undergraduate Research Apprenticeship Program
USD(R&E)	Under Secretary of Defense for Research and Engineering
USAF	U.S. Air Force
USSF	U.S. Space Force

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About the Authors

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