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Report to Congressional Committees

December 2023

QUANTUM TECHNOLOGIES

Defense Laboratories Should Take Steps to Improve Workforce Planning

GAO-24-106284

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GAO Highlights

Highlights of GAO-24-106284, a report to congressional committees

Why GAO Did This Study

DOD considers quantum technologies as critical to protecting national security. Nations that lead in quantum technologies can gain a competitive edge in areas such as cryptography, sensing, and computing. To remain competitive, DOD is developing its quantum workforce.

A Senate report included a provision for GAO to review DOD's quantum workforce planning and workforce development activities. This report examines (1) the size and composition of the quantum workforce at defense laboratories that conduct quantum research and development, (2) the extent to which the primary defense laboratories conducting this research and development followed leading practices for strategic workforce planning, and (3) how DOD's STEM education programs have contributed to quantum workforce development and the extent to which DOD has monitored these contributions.

GAO analyzed defense laboratories' workforce data and workforce planning activities, compared workforce planning activities to GAO leading practices for strategic workforce planning, and administered a questionnaire to 86 DOD STEM education programs. GAO received responses from 59 programs.

What GAO Recommends

This report includes four recommendations for the defense laboratories to fully adopt leading practices for strategic workforce planning. DOD concurred with all four recommendations.

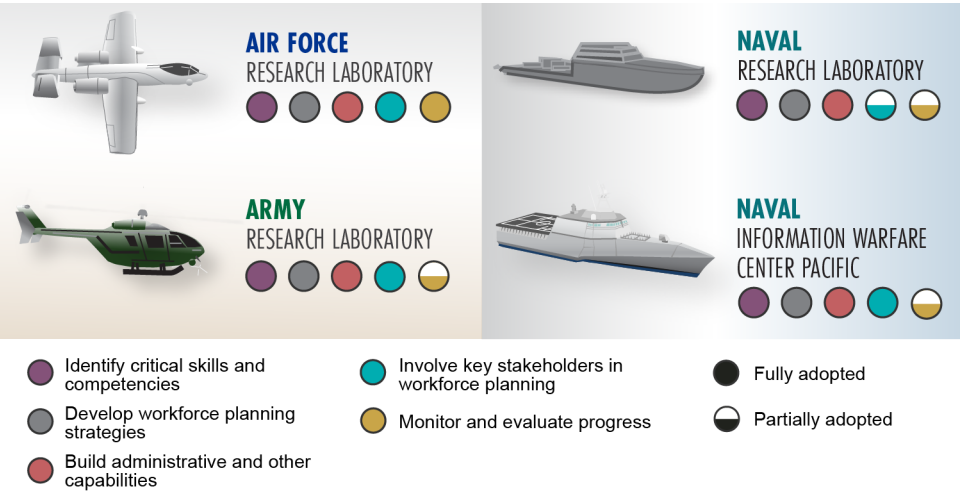
View GAO-24-106284. For more information, contact Candice N. Wright at 202-512-6888 or WrightC@GAO.gov.

What GAO Found

In fiscal year 2023, seven defense laboratories reported 255 staff working all or part of their time on quantum projects. Most of these quantum workers had PhDs, were either physicists or engineers, and were a mix of mostly federal civilian employees and some contractors. Consistent with DOD's priority to expand the quantum workforce beyond the field of physics, these laboratories also had specialists from fields such as chemistry, computer science, and mathematics.

The four defense laboratories conducting most of DOD's quantum work included quantum information science as part of their broader strategic workforce planning but varied in their adoption of five leading practices (see figure). One laboratory fully adopted all five, while three laboratories conducted workforce planning that was aligned with most but not all leading practices. Three laboratories did not fully adopt the leading practice of monitoring and evaluating progress because their strategic workforce plans either did not have performance measures or inconsistently applied them. One laboratory also did not fully adopt the leading practice of involving key stakeholders in workforce planning because it did not have a means to communicate its workforce goals, initiatives, and metrics for success. Better workforce planning could help these laboratories build and retain the workforce needed to maintain global leadership in quantum technologies.

Defense Laboratories' Adoption of Leading Practices for Strategic Workforce Planning



Source: GAO analysis of Department of Defense documents and interviews; GAO (icons). | GAO-24-106284

According to GAO's questionnaire results, 41 DOD science, technology, engineering, and mathematics (STEM) education programs contributed to quantum workforce development from fiscal years 2019 through 2023. Through these programs, at least 423 students and postdoctoral researchers gained quantum work experience at defense laboratories. These programs also reported developing students through exposure to DOD quantum research, postdoctoral research funding, and training in a variety of STEM disciplines that can feed into the quantum workforce, such as physics, engineering, and computer science.

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Abbreviations

AFRL	Air Force Research Laboratory
ARL	Army Research Laboratory
DOD	Department of Defense
NIWC Pacific	Naval Information Warfare Center Pacific
NRL	Naval Research Laboratory
NSA	National Security Agency
OUSD (R&E)	Office of the Under Secretary of Defense for Research and Engineering
SCQIS	Subcommittee on Quantum Information Science
STEM	Science, Technology, Engineering, and Mathematics

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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December 5, 2023

The Honorable Jack Reed
Chairman
The Honorable Roger Wicker
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

Quantum technologies, which are developed around the principles of quantum physics, have the potential to address national security needs but also create challenges. Nations that lead in quantum research and development can gain a competitive advantage in areas such as cryptography, sensing, and computing. For example, quantum sensors may offer significant improvements to the warfighter's intelligence, surveillance, and reconnaissance capabilities. Additionally, quantum computing may enable advances in machine learning and artificial intelligence, improving pattern recognition for more accurate targeting and more lethal autonomous weapon systems.

The Department of Defense (DOD) has identified quantum science as one of 14 critical technology areas vital to maintaining U.S. national security.[1] However, DOD faces challenges building its quantum workforce, such as difficulties recruiting highly specialized staff. To foster growth in this field, as well as other technology areas, DOD seeks to develop current and future science, technology, engineering, and

[1]Department of Defense, *National Defense Science & Technology Strategy 2023* (May 2023). DOD defines quantum science as the study of physical properties at small, even atomic, scales. First-generation quantum technologies, such as atomic clocks, apply an understanding of quantum mechanics. In contrast, second-generation quantum technologies—such as quantum computing, communications, and sensing—manipulate quantum mechanics. In this report, "quantum science" refers to the DOD critical technology area and "quantum information science" refers to second-generation quantum research and development.

mathematics (STEM) talent by cultivating multiple pathways to DOD employment through STEM education programs.[2]

We previously reported that strategic workforce planning can help agencies keep pace with advances in science and technology in challenging environments.[3] In 2003, we identified five leading practices that all effective strategic workforce planning should address regardless of context: (1) determine the critical skills and competencies needed, (2) develop workforce planning strategies, (3) build administrative and other capabilities, (4) involve key stakeholders in workforce planning, and (5) monitor and evaluate progress.

By applying these practices, agencies identify current and future workforce needs and develop effective strategies to fill identified workforce gaps.[4] Our previous work suggests that agencies could use workforce planning as well as new and existing STEM education programs to build the necessary workforce to maintain global leadership in quantum technologies.[5]

In July 2022, a Senate report accompanying the National Defense Authorization Act for fiscal year (FY) 2023 included a provision for GAO to examine DOD's planning for quantum workforce needs over the next 10 years, including the use of STEM scholarships and fellowships to support the department's planning.[6] This report assesses (1) the size and composition of the quantum workforce at defense laboratories that conduct quantum research and development; (2) the extent to which the primary defense laboratories conducting this research and development followed leading practices for strategic workforce planning; and (3) how DOD's STEM education programs have contributed to quantum workforce

[2]Department of Defense, *The Department of Defense STEM Strategic Plan FY2021-FY2025.*

[3]GAO, *Science and Technology: Strengthening and Sustaining the Federal Science and Technology Workforce,* GAO-21-461T (Washington, D.C.: Mar. 17, 2021).

[4]GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning,* GAO-04-39 (Washington, D.C.: Dec. 11, 2003).

[5]GAO, *Technology Assessment: Quantum Computing and Communications Status and Prospects*, GAO-22-104422 (Washington, D.C.: Oct. 19, 2021).

[6]S. Rep. No. 117-130, at 77 (2022).

development and the extent to which the department has monitored these contributions.

The scope of our review included defense laboratories with quantum projects—Air Force Research Laboratory (AFRL), Army Research Laboratory (ARL), Naval Research Laboratory (NRL), and four naval warfare centers—and the DOD STEM office.[7] We reviewed relevant federal guidance and interviewed knowledgeable agency officials. We collected and analyzed workforce data on the size and composition of the quantum workforce at the defense laboratories in our scope. We also collected and analyzed information on current strategic workforce planning at the four defense laboratories that conduct most of the department's quantum research and development and compared it to GAO's five leading practices for strategic workforce planning.[8] We used a questionnaire to collect data from 86 DOD STEM education programs on their contributions to quantum workforce development and received responses from 59 of these programs. Lastly, we reviewed agency STEM education strategies, progress reports, and data collection instruments, and discussed these with agency officials. (See app. I for more information on our objectives, scope, and methodology.)

We conducted this performance audit from October 2022 to December 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[7]The naval warfare centers in our review include the Naval Information Warfare Center Atlantic, Naval Information Warfare Center Pacific (NIWC Pacific), Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division.

[8]We analyzed workforce planning information from AFRL, ARL, NRL, and NIWC Pacific because the military departments identified each of these organizations as the defense laboratories conducting most of their department's quantum research and development. We did not analyze workforce planning information for three of the four naval warfare centers in our review—Naval Information Warfare Center Atlantic, Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division—because Navy officials told us these warfare centers conduct a small amount of quantum research and development.

Background

Quantum Technologies

Defense applications of quantum technologies include quantum computing, quantum communication, and quantum sensing. Quantum sensing technologies are the most mature, while quantum computing and communications technologies are available for limited uses and require extensive development.

DOD uses some first-generation quantum sensing technologies, such as the atomic clocks used in the global positioning system. Future defense applications could include more precise sensors capable of maintaining timing and position accuracy where the global positioning system is degraded or denied. For example, handheld battery-powered atomic clocks could enable communications systems to operate in environments where radio frequencies are jammed.

Quantum computing and communications technologies are in the early stages of development.[9] Future quantum computers may be able to quickly complete tasks that are inefficient for traditional computers, such as breaking the methods used to encrypt sensitive national security information.[10] Future quantum communications technologies could connect quantum devices, such as quantum computers, and enhance network security.

National Quantum Initiative

In 2018, Congress passed the National Quantum Initiative Act to establish a whole-of-government approach to quantum information science and technology. The act established a 10-year national quantum initiative to invest in quantum workforce development, among other things.[11] Certain federal agencies, including DOD, carry out the national quantum initiative, in part, through the National Science and Technology Council's Subcommittee on Quantum Information Science (SCQIS).

In 2022, SCQIS issued a national quantum workforce development plan that identified several actions government, academia, and industry should

[9]GAO-22-104422.

[10]GAO, *Science & Tech Spotlight: Securing Data for a Post-Quantum World*, GAO-23-106559 (Washington, D.C.: Mar. 8, 2023).

[11]National Quantum Initiative Act, Pub. L. No. 115-368, 132 Stat. 5092, 5094 (2018).

take to identify and fill national quantum workforce needs.[12] Among other things, SCQIS recommended that agencies should develop an understanding of their quantum workforce needs and leverage existing programs to expand the on-ramps to quantum-focused careers.

DOD's Science and Technology Mission

Part of DOD's science and technology mission is to accelerate quantum technology development. The 2019 National Defense Authorization Act authorized DOD's quantum information science research and development program, and an amendment to the program authorized the establishment of quantum information science research centers.[13] Between FY 2019 and 2023, Air Force, Army, and Navy designated their own quantum information science research centers, located at AFRL, ARL, and NRL.[14] Four naval warfare centers—Naval Information Warfare Center Atlantic, Naval Information Warfare Center Pacific (NIWC Pacific), Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division—also conduct quantum information science research and development.

DOD's quantum information science research and development program draws support from the department's FY 2021–2025 STEM strategic plan, which aims to inspire, cultivate, and develop the department's STEM workforce. As part of this effort, the Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E)), through the DOD STEM office, evaluates and assesses the department's STEM education program portfolio, which is composed of a variety of education and outreach activities offered by various DOD offices and components.[15]

[12]National Science and Technology Council, Subcommittee on Quantum Information Science, *Quantum Information Science and Technology Workforce Development National Strategic Plan* (Feb. 2022).

[13]John S. McCain National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, div. A, tit. II, § 234, 132 Stat. 1636, 1692-93 (2018), as amended by Pub. L. No. 116-92 div. A., tit. II, § 220, 133 Stat. 1198, 1260-61 (2019).

[14]The National Security Agency (NSA) also designated its Laboratory for Physical Sciences Qubit Collaboratory as a quantum information science research center.

[15]Department of Defense, *The Department of Defense STEM Strategic Plan FY2021-FY2025.*

Defense Laboratories Reported 255 Staff Spending All or Part of Their Time on Quantum Projects

Officials from the defense laboratories in our review—AFRL, ARL, NRL, and four naval warfare centers—told us they consider personnel assigned to quantum projects to be part of their quantum workforce. As of FY 2023, officials from the defense laboratories reported having 255 personnel working all or part of their time on quantum projects, with the amount of time these personnel worked on quantum projects ranging from 10 percent to 100 percent (see table 1). Defense laboratory officials told us they are developing the department's quantum workforce to support additional quantum information science research and development efforts.

Table 1: Number of Personnel at Selected Defense Laboratories Working Full or Part Time on Quantum Projects, Fiscal Year 2023

Defense laboratory	Personnel	Description of quantum workforce data
Air Force Research Laboratory (AFRL)	116	AFRL workforce data included personnel that worked any amount of time on quantum projects (the amounts ranged from 10 to 100 percent).
Army Research Laboratory (ARL)	31	ARL workforce data included only personnel who worked 100 percent of their time on quantum projects.
Naval Research Laboratory (NRL)	23	NRL workforce data included personnel who worked at least 20 percent of their time on quantum projects.
Naval warfare centers[a]	85	Naval warfare center workforce data included personnel who worked at least 20 percent of their time on quantum projects.

Source: GAO analysis of Department of Defense quantum workforce data. | GAO-24-106284

Note: Defense laboratories included personnel working on quantum information science research and development projects and did not include personnel working in quantum adjacent fields, such as computer science, materials, or optical physics.

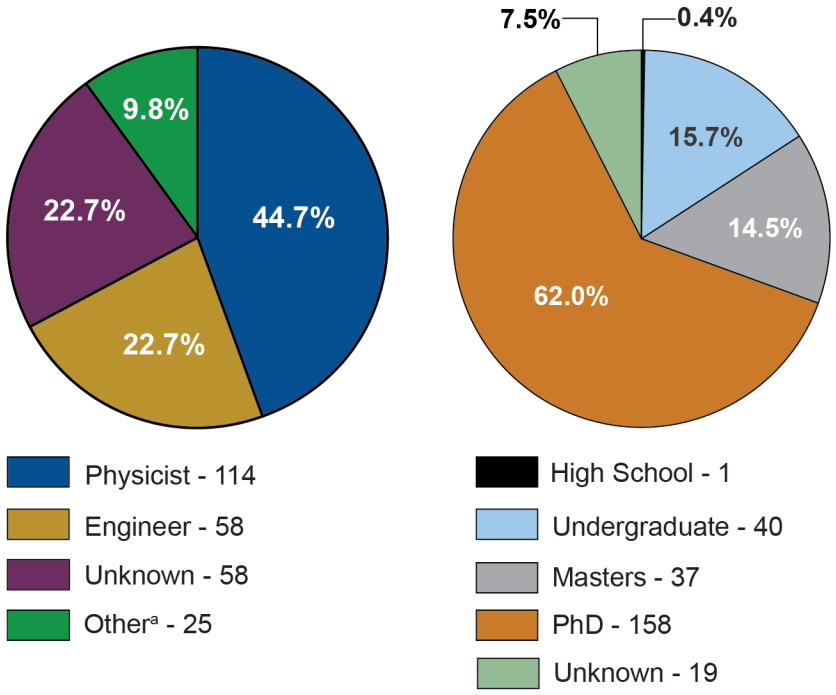
[a]Workforce data for the naval warfare centers include personnel at Naval Information Warfare Center Atlantic, Naval Information Warfare Center Pacific, Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division.

According to data provided by the defense laboratories, most personnel working all or part of their time on quantum projects have PhDs and are either physicists or engineers (see fig. 1). PhDs constitute 62 percent of the workforce and another 30 percent hold bachelor's or master's degrees. The high proportion of PhDs is consistent with DOD's current focus on fundamental quantum research, which often requires quantum expertise at the PhD level.[16] In addition to physicists and engineers, the defense laboratories also employ a broad group of specialists from various fields such as chemistry, computer science, and mathematics.

[16]Department of Defense, *Quantum Science Roadmap 2023* (document presented internally, 2023); National Science and Technology Council, Subcommittee on Quantum Information Science, *Quantum Information Science and Technology Workforce Development National Strategic Plan* (Feb. 2022)

This workforce composition is consistent with DOD's quantum workforce development priorities, which call for expanding the workforce beyond the field of physics.[17]

Figure 1: Occupation and Education Level for Personnel Working All or Part of Their Time on Quantum Projects at Selected Defense Laboratories, Fiscal Year 2023



Source: GAO analysis of Department of Defense quantum workforce data. | GAO-24-106284

Note: Figure includes workforce data from the Air Force Research Laboratory, Army Research Laboratory, Naval Research Laboratory, and four naval warfare centers. The defense laboratories were unable to identify demographic data for some quantum workers. For example, Air Force Research Laboratory did not collect information on profession and education level from all of its contractors.

[a]Other professions include computer scientists, chemists, mathematicians, optical scientists, management, and support staff, including students and postdoctoral researchers.

In FY 2023, most personnel working all or part of their time on quantum projects were federal civilian employees and contractors, who respectively made up 69 percent and 27 percent of the workforce. Military personnel, students, and postdoctoral researchers made up the remaining 5 percent. Workforce staffing strategies vary across defense

[17]Department of Defense, *Quantum Science Roadmap 2023.*

laboratories. NRL and the naval warfare centers are composed almost entirely of federal civilian employees. In contrast, AFRL and ARL officials told us they use contracting as a mechanism to augment the federal hiring process. For example, ARL officials told us they utilize postdoctoral researchers on contracts through the Oak Ridge Associated Universities and National Research Council Research Associateship Program, and that these postdoctoral researchers are often converted to civilian federal employees upon program completion. AFRL officials also told us they use on-site contractors to conduct work alongside their civilian staff on in-house research projects.

All of the defense laboratories assigned personnel to projects focused on quantum computing, communications, and sensing. These include:

- A project in AFRL to reduce the size and complexity of advanced quantum clocks, which are currently too large and consume too much energy for operational environments.
- A project in ARL to develop quantum sensors that can supplement and secure the global positioning system in hostile environments.
- A project in NRL that could increase the capacity and scalability of quantum networks and enable new forms of metrology—the study of measurement.
- A project in NIWC Pacific to develop quantum computing hardware that could be used as a platform for future research and reduce reliance on private sector platforms.

In 2023, OUSD (R&E) began including information on the department's quantum workforce in its quantum science research and development strategy. DOD officials told us that the department's personnel system places quantum workers into various occupational series, such as physics and engineering, because the Office of Personnel Management has not established a quantum-specific occupational series.[18] DOD officials added that the Office of Personnel Management was unlikely to establish one in the near future because the field is still nascent. Moreover, DOD officials told us that, because quantum science is a multidisciplinary field,

[18]The Office of Personnel Management defines an occupational series as a subdivision of an occupational group or job family consisting of positions similar as to specialized line of work and qualification requirements. U.S. Office of Personnel Management, *Handbook of Occupational Groups and Families* (Dec. 2018).

limiting it to a single occupational series would reduce their flexibility to hire personnel that meet mission needs.

Defense Laboratories Vary in Adoption of Leading Practices for Strategic Workforce Planning

The four defense laboratories conducting most of the department's quantum research and development—AFRL, ARL, NIWC Pacific, and NRL—each address workforce planning for their quantum projects through their broader strategic workforce planning processes but varied in their adoption of leading practices (see table 2).[19] AFRL fully adopted all five of the leading practices, while the other defense laboratories fully adopted three or four of the practices. These leading practices can apply to strategic workforce planning more generally and also to emerging mission and programmatic goals, such as DOD's mission to accelerate the development of quantum technologies.

Table 2: Defense Laboratories' Adoption of Leading Practices for Strategic Workforce Planning

Strategic workforce planning leading practice	Air Force Research Laboratory	Army Research Laboratory	Naval Information Warfare Center Pacific	Naval Research Laboratory
Determine critical skills and competencies needed to achieve current and future programmatic results	●	●	●	●
Develop workforce planning strategies designed to address gaps in critical skills and competencies	●	●	●	●
Build administrative and other capabilities to support workforce planning strategies	●	●	●	●
Involve top management, employees, and other stakeholders in strategic workforce planning	●	●	●	◒
Monitor and evaluate progress toward human capital goals and programmatic results	●	◒	◒	◒

Legend: ● Fully Adopted; ◒ Partially Adopted; ◯ Not Adopted

Source: GAO analysis of Department of Defense documents and interviews. | GAO-24-106284

Note: "Fully adopted" indicates that a defense laboratory adopted every aspect of the practice. "Partially adopted" indicates that a defense laboratory partially addressed the supporting actions for adoption of a leading practice or had a plan in development, that if implemented, would lead to partial or full adoption of a leading practice.

[19]We did not analyze workforce planning information for three of the four naval warfare centers in our review—Naval Information Warfare Center Atlantic, Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division—because Navy officials told us they conduct a small amount of quantum research and development.

Defense Laboratories Fully Adopted Three Leading Practices

Based on our analysis of information provided by the defense laboratories, we found that each defense laboratory fully adopted three of the leading practices: (1) determining the critical skills and competencies needed to achieve their programmatic results; (2) developing strategies to address human capital gaps in critical skills and competencies; and (3) building administrative capabilities to support workforce planning. Specifically

- *Determine critical skills and competencies.* AFRL and ARL directorates focusing on specific research areas identify the critical skills and competencies needed to staff research projects aligned with quantum information science and other research priorities. For example, ARL's directorates conduct an annual workforce gap analysis for 11 foundational research competencies established in 2021, two of which are related to quantum information science. NIWC Pacific and NRL receive funds from multiple customers to execute research projects aligned with strategic priorities. After receiving funding for a project, NIWC Pacific and NRL identify the critical skills and competencies needed to staff them. NRL also has a long-term plan to double the size of its quantum workforce over the next 10 years to address its strategic priority to field quantum technologies.
- *Develop strategies to address gaps in critical skills and competencies.* Each defense laboratory uses multiple recruiting and retention strategies for filling workforce gaps in quantum information science and other high-priority areas. The defense laboratories align their use of these strategies with their strategic goals. For example, AFRL and ARL directorates have established strategies to fill gaps in critical STEM fields, such as quantum information science, through succession planning, staff development, direct hiring, and STEM education programs. Similarly, NIWC Pacific and NRL have processes to identify appropriate hiring authorities to staff research projects. For example, NRL officials told us that using direct hire authority to offer permanent positions to postdoctoral researchers already in temporary positions within the lab is one of their main methods for recruiting new federal civilian employees.[20]
- *Build administrative and other capabilities to support workforce planning strategies.* Each defense laboratory established a process for streamlining and improving how they use their recruiting and retention strategies, such as by sharing best practices with other

[20]Direct hire authority enables an agency to hire any qualified applicant without regard to certain federal hiring requirements, such as competitive rating and ranking and veterans' preference.

defense laboratories or establishing a committee to regularly review their effectiveness. These processes aim to improve the use of these strategies for workforce development in quantum information science and other technology areas. The laboratories also train managers and educate employees on the use of these strategies. For example, NRL trains managers on how to use merit-based pay increases, direct hire authority, and recruitment bonuses. Lastly, each laboratory promotes transparency by communicating how they use these strategies in guidance documents, notices, or internal human resources websites.

Defense Laboratories Varied in Their Adoption of Two Leading Practices

We found that the defense laboratories varied in their adoption of the two remaining leading practices: (1) involving top management, employees, and other stakeholders in strategic workforce planning and (2) monitoring and evaluating progress toward human capital goals and programmatic results. Specifically:

- *AFRL fully adopted both leading practices.* AFRL involved top management and employees in developing its human capital strategy, which communicates the overall direction and goals for workforce planning. The strategy's annual action plans describe initiatives aligned to these goals, and AFRL uses employee and supervisor input collected through surveys to inform the development of these initiatives. AFRL's action plans track progress toward completing its initiatives. Each of the 11 initiatives in the most recent action plan have defined deliverables, metrics, and a timeline for completion. According to AFRL officials, these initiatives contribute to workforce development in all AFRL technology areas, including quantum information science.
- *ARL fully adopted one of two leading practices and partially adopted the other.* ARL fully adopted the leading practice of involving top management, employees, and other stakeholders in strategic workforce planning. Top management communicates ARL's overall direction and goals for workforce planning through ARL's talent management strategy. Additionally, ARL incorporates employee feedback, collected through surveys and panels, into its workforce planning.

  In contrast, ARL partially adopted the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results. Specifically, ARL has established high-level priorities aligned with its strategic goals, but it has not established performance measures for monitoring and evaluating progress toward achieving them. ARL officials told us they transitioned away from using such performance measures after its reorganization in FY 2023

because the measures were inflexible. However, practical and meaningful performance measures can be tailored to mission needs and could help ARL better assess progress toward its human capital and programmatic goals.

- *NIWC Pacific fully adopted one of two leading practices and partially adopted the other.* NIWC Pacific fully adopted the leading practice of involving top management, employees, and other stakeholders in strategic workforce planning. Top management communicates the overall direction and goals for workforce planning through the center's strategic pillars. The center communicates initiatives aligned to these pillars through strategic planning meetings and department reviews, which are led by management and solicit input from employees through direct participation and surveys. These initiatives contribute to workforce development in all NIWC Pacific technology areas, including quantum information science. For example, an initiative to reduce hiring time is intended to help the center staff its projects more quickly.

  In contrast, NIWC Pacific partially adopted the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results. In particular, NIWC Pacific's strategic management process requires developing performance measures for monitoring and evaluating progress, but the center has not consistently done this for all of its human capital initiatives. Specifically, the center's department reviews do not have performance measures for monitoring and evaluating progress toward workforce development initiatives.[21] Department reviews lack such measures because NIWC Pacific guidance does not instruct departments to develop them.

- *NRL partially adopted both leading practices.* NRL officials described how management and employees contribute to the laboratory's workforce planning activities and how these activities align with its human capital goals. The activities contribute to workforce development in quantum information science and other NRL technology areas. Moreover, NRL involves employees in workforce planning through its Inclusion and Diversity Council, which solicits input on recruitment and employee development.

  NRL has not fully adopted these leading practices because it does not have a written strategic workforce plan or other means of communicating its workforce goals, initiatives, and metrics for

[21]NIWC Pacific's departments conduct periodic reviews that analyze, among other things, the status of workforce development initiatives and workforce needs to staff new projects.

evaluating success throughout the laboratory. Additionally, NRL has not established performance measures for monitoring and evaluating progress toward achieving its human capital goals. NRL officials told us such long-term workforce planning is challenging because it needs to receive funding from its customers before research can be initiated and, as a result, its future workforce needs are unpredictable. However, long-term workforce planning could help NRL better position itself to close workforce gaps in quantum information science and other technology areas when funding becomes available. For example, a formalized strategic workforce plan could help NRL better communicate its hiring priorities and strategies throughout the laboratory, ensuring that resources are allocated to NRL's most critical needs.

Our prior work stressed the importance of agencies developing strategic workforce planning processes tailored to their unique needs.[22] Fully adopting the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results could help ARL, NIWC Pacific, and NRL better assess the effectiveness of their workforce planning and human capital goals. Additionally, fully adopting the leading practice of involving top management, employees, and other stakeholders in workforce planning could help NRL better communicate its workforce goals, initiatives, and metrics for evaluating success throughout the laboratory. Better workforce planning could help these laboratories build and retain the workforce needed to maintain global leadership in quantum technologies.

DOD Has a Mix of Programs to Develop Its Quantum Workforce

DOD STEM education programs support quantum workforce development through a mix of activities. We found that DOD monitors these programs' contributions to quantum workforce development and has taken several steps to validate how programs report this information.

DOD Uses a Mix of Existing STEM Education Programs to Develop Its Quantum Workforce

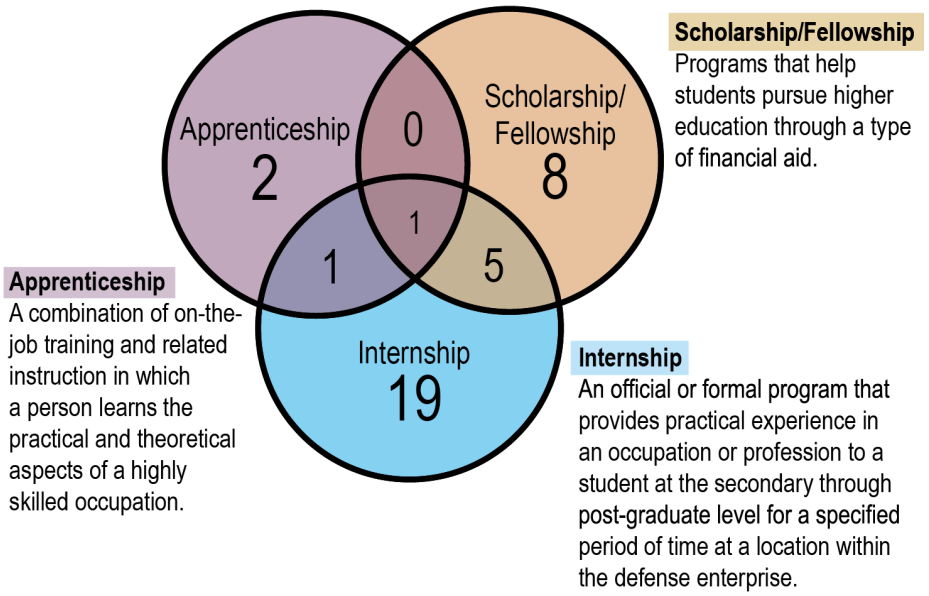
According to our survey respondents, DOD used at least 41 existing STEM education programs to support quantum workforce development from FY 2019 to 2023 (see fig. 2). These programs are part of the department's FY 2021–2025 STEM strategic plan to attract talent through

[22]GAO-04-39.

multiple pathways.[23] These programs also address, in part, a recommendation from SCQIS that agencies should use STEM education programs to expand on-ramps to quantum-related professions. For example, one Navy program open to undergraduate and graduate students provides 10-week internships where students work on naval research at NRL and the naval warfare centers, with some students supporting quantum projects. Another program supported by the Army and the National Security Agency (NSA) provides fellowships to graduate students and postdoctoral researchers working on quantum information processing and quantum sensing. (See app. II for a complete list of the 41 DOD STEM education programs that reported contributing to quantum workforce development.)

[23]DOD also carried out other activities—such as teacher training and competitions that result in awards or recognition—that develop the STEM workforce. These activities did not fall within the scope of our review, which focused on programs that have both work experience and educational components.

Figure 2: Types of Workforce Development Activities Offered by 41 DOD STEM Education Programs Contributing to Quantum Workforce Development, Fiscal Years 2019–2023



Source: GAO analysis of questionnaire responses by agency officials on Department of Defense (DOD) science, technology, engineering, and mathematics (STEM) education programs and DOD documentation. | GAO-24-106284

Note: The figure does not include five programs that reported offering opportunities other than internships, apprenticeships, scholarships, or fellowships as defined by our survey. For example, one program reported placing interns brought on as contractors through a non-profit partner into a defense laboratory.

According to our survey, most of the 41 DOD STEM education programs contributing to quantum workforce development are broadly focused on STEM rather than on quantum science specifically. Survey respondents from 29 programs reported that they indirectly support quantum workforce development by training participants across a spectrum of STEM disciplines that can feed into the quantum workforce. For example, DOD's Science, Mathematics, and Research for Transformation program offers undergraduate and graduate students full tuition, annual stipends, internships, and guaranteed employment with the department if they pursue STEM degrees in fields such as physics, engineering, and computer science. DOD officials told us that all of these disciplines support DOD's quantum research and development efforts.

In contrast, survey respondents from 12 programs reported direct contributions to quantum workforce development through a variety of efforts such as exposing undergraduate and graduate students to DOD

quantum research, funding postdoctoral researchers to conduct quantum research, and providing quantum work experience at defense laboratories. For example, a program supported by OUSD (R&E) and the Army provides quantum work experience to select university students and facilitates networking with defense laboratories such as ARL.

Survey respondents for 20 of the 41 programs contributing to quantum workforce development reported placing 423 participants on quantum projects at the defense laboratories from FY 2019 to 2023. In contrast, 21 programs reported not tracking how many participants are assigned to quantum projects.

As shown in table 3, almost all of the 423 participants were placed in AFRL, ARL, or NRL with a small number also being placed in other DOD organizations. However, our survey did not show how many participants joined the DOD quantum workforce after program completion because 14 of the 20 survey respondents did not report tracking this information. One program official told us it is difficult to collect this information because participants have no obligation to respond to DOD information requests after they finish the program.

Table 3: DOD STEM Education Program Participants Placed on Quantum Projects, by DOD Organization, Fiscal Years 2019–2023

Defense Laboratory	FY19	FY20	FY21	FY22	FY23
Air Force Research Laboratory	60	30	46	67	68
Army Research Laboratory	8	7	21	31	23
Naval Research Laboratory	2	4	9	13	10
Other[a]	4	3	5	5	7
Total	**74**	**44**	**81**	**116**	**108**

Source: GAO analysis of questionnaire responses by agency officials on Department of Defense (DOD) science, technology, engineering, and mathematics (STEM) education programs. | GAO-24-106284

[a]Other DOD organizations include the Air Force Institute of Technology, Air Force Test Center, Naval Air Warfare Center, U.S. Army Engineer Research and Development Center, and U.S. Air Force Academy.

DOD Monitors STEM Education Contributions to Quantum Workforce Development

In FY 2017, the DOD STEM office established a process for evaluating and assessing progress toward achieving its STEM education strategic goals and increasing access to program-level data to support decision-

making.[24] These goals include inspiring community engagement in STEM education, attracting the current and future workforce through multiple pathways, increasing participation of underserved and underrepresented groups, and advancing the efficiency and effectiveness of existing STEM education programs.[25] To assess progress toward these goals, the DOD STEM office has an annual data call to the department's STEM education program managers to collect common metrics, such as which underserved and underrepresented group they serve. The program office uses the results of these data calls in yearly reports that track progress toward DOD's STEM education strategic goals and objectives.

Beginning in FY 2020, the DOD STEM office asked STEM education programs to self-report whether the programs directly or indirectly contribute to workforce development in quantum science and other DOD critical technology areas.[26] DOD officials told us they developed this metric to track how the overall STEM education program portfolio contributes to workforce development in critical technology areas such as quantum science. The DOD STEM office considers a STEM education program to directly contribute to quantum workforce development if its program goals, objectives, or intended outcomes are specific to quantum science. In contrast, a program contributes indirectly to quantum workforce development if it is tangentially related to quantum science. For example, a program's contributions are considered indirect if its focus is on STEM disciplines that could eventually produce quantum workers (such as physics) rather than on quantum science specifically.

[24]OUSD (R&E), through the DOD STEM office, evaluates and assesses the department's STEM education program portfolio by facilitating a coordinated approach to data collection and analysis, helping to develop common metrics, and helping to create an environment for continued learning and program improvement. DOD components typically evaluate and assess STEM education programs and then provide information to the DOD STEM office for its portfolio reviews.

[25]DOD defines underserved and underrepresented populations as including military children; military-connected children; low-income students; racial and ethnic minorities that are underrepresented in STEM; individuals with disabilities; individuals with English as a second language or English language learners; first-generation college students; students in rural, frontier, or other federally targeted schools; and females in STEM fields where they remain underrepresented.

[26]DOD STEM asks STEM education programs to report whether their programs are directly or indirectly aligned with DOD's critical technology areas, including quantum science. For the purposes of our report, we consider a STEM education program to contribute to quantum workforce development if it is directly or indirectly aligned to quantum science.

Officials in the DOD STEM office told us they take several steps to validate each STEM education programs' self-reported data on contributions to quantum workforce development. This is consistent with Standards for Internal Control in the Federal Government, which calls for management to use and internally communicate the quality information necessary to achieve the entity's objectives.[27] In particular, DOD officials said that they cross-reference responses with program descriptions, have components review how their programs are portrayed in data call reports, and solicit feedback from components on the instructions in annual data calls. For example, the DOD STEM office included its definitions for direct and indirect contributions to quantum workforce development in its most recent annual data call in response to feedback; specifically, components told the DOD STEM office the instructions on how to report contributions to workforce development in critical technology areas such as quantum science were unclear.

Conclusions

DOD faces challenges building its quantum workforce, such as difficulties recruiting highly specialized staff. DOD has made an effort to address these challenges by conducting strategic workforce planning and by offering multiple pathways for future quantum talent to enter its workforce. For example, all four of the defense laboratories performing most of the department's quantum research and development fully adopted three of GAO's five leading practices for strategic workforce planning, including for its quantum projects, and one defense laboratory—AFRL—fully adopted all five.

However, three of the four defense laboratories conducted workforce planning that was not in line with all leading practices. Specifically, ARL, NIWC Pacific, and NRL did not fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results, because their strategic workforce plans did not have performance measures for monitoring and evaluating progress or were inconsistently applied. Additionally, NRL did not fully adopt the leading practice of involving top management, employees, and other stakeholders in workforce planning, because it did not have a written strategic workforce plan or other means of communicating its workforce goals, initiatives, and metrics for evaluating success throughout the laboratory. Better workforce planning could help these laboratories build

[27]GAO, *Standards for Internal Control in the Federal Government,* GAO-14-704G (Washington, D.C.: Sept. 2014).

and retain the workforce needed to maintain global leadership in quantum technologies.

Recommendations for Executive Action

We are making four recommendations to Army and Navy. Specifically:

The Secretary of the Army should direct the Commander of ARL to fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures tailored to its mission needs. (Recommendation 1)

The Secretary of the Navy should direct the Commander of NIWC Pacific to fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures for evaluating success across the center. (Recommendation 2)

The Secretary of the Navy should direct the Commander of NRL to fully adopt the leading practice of involving top management, employees, and other stakeholders in workforce planning by developing and implementing an enterprise-wide strategic workforce plan or otherwise communicating its workforce goals, initiatives, and metrics for evaluating success throughout the laboratory. (Recommendation 3)

The Secretary of the Navy should direct the Commander of NRL to fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures for evaluating success. (Recommendation 4)

Agency Comments

We provided a draft of this report to DOD for review and comment. In its written comments, reproduced in appendix III, DOD concurred with all four of our recommendations. DOD also provided technical comments, which we incorporated as appropriate. For several of our recommendations, DOD stated that it had already taken actions to address our recommendations.

- In response to our first recommendation that ARL should develop performance measures, DOD stated that ARL had already done so by establishing high-level priorities aligned with its strategic goals and would continue to evaluate current practices and identify opportunities for improvement. We determined ARL partially adopted the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results

because the laboratory established these high-level priorities. However, ARL has not established performance measures in that these high-level priorities do not have desired outcomes, metrics, and timelines for completion. To fully adopt this leading practice, ARL should develop such performance measures.

- In response to our recommendation that NRL should communicate its strategic workforce plan, DOD stated that NRL's existing policies and procedures already do this. We determined NRL partially adopted the leading practice of involving top management, employees, and other stakeholders in workforce planning because of the activities described in DOD's response. However, these activities do not include an ongoing means for communicating the laboratory's strategic workforce plan. To fully adopt this leading practice, NRL should implement our recommendation to establish a workforce plan or other mechanism for communicating its workforce goals, initiatives, and metrics for evaluating success throughout the laboratory.

- In response to our recommendation that NRL should develop performance measures, DOD stated that NRL had already done so. We determined NRL partially adopted the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results because the laboratory uses workforce data, surveys, and other methods to track progress toward achieving its human capital goals. However, NRL has not established performance measures that link these monitoring activities to desired outcomes, metrics, and timelines for completion. To fully adopt this leading practice, NRL should implement our recommendation to develop such performance measures.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, the Secretary of the Air Force, the Secretary of the Army, the Secretary of the Navy, the Director of the NSA, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact us at (202) 512-6888 or wrightc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

Candice N. Wright
Director, Science, Technology Assessment, and Analytics

Appendix I: Scope and Methodology

This report assesses (1) the size and composition of the quantum workforce at defense laboratories that conduct quantum research and development; (2) the extent to which the primary defense laboratories conducting this research and development followed leading practices for strategic workforce planning; and (3) how the department's science, technology, engineering, and mathematics (STEM) education programs have contributed to quantum workforce development and the extent to which the Department of Defense (DOD) has monitored these contributions.

To determine the size and composition of the quantum workforce at select defense laboratories, we requested workforce data from the defense laboratories that the Air Force, Army, and Navy identified as having quantum information science research and development programs from FY 2019 to 2023—Air Force Research Laboratory (AFRL), Army Research Laboratory (ARL), Naval Research Laboratory (NRL), and four naval warfare centers.[1] The defense laboratories consider personnel assigned to quantum projects to be part of their quantum workforce. Accordingly, we asked each defense laboratory to provide a list of its quantum research and development projects, including project descriptions and the number of personnel assigned for FY 2019 to 2023. For each assigned person we requested demographic data on employee type (such as civilian, military, and contractor), occupational series or job title, education level, and location.[2] We also asked each defense laboratory to describe challenges in collecting this information and to identify any limitations.

The defense laboratories provided data on their quantum workforce as follows:

- AFRL's workforce data included personnel that worked any amount of time on quantum projects (the amounts ranged from 10 to 100 percent). AFRL excluded personnel working on quantum adjacent

[1]Four naval warfare centers have quantum research and development programs—Naval Information Warfare Center Atlantic, Naval Information Warfare Center Pacific (NIWC Pacific), Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division. The National Security Agency (NSA) also has quantum research and development programs, but we excluded NSA because its workforce data are classified, and the results of our analysis could not have been included in this report.

[2] We also requested that each defense laboratory provide similar information for their sponsored federally funded research and development centers and university affiliated research centers, but all defense laboratories told us no quantum work is conducted at these organizations.

projects. AFRL was unable to provide all demographic data for its contractors. AFRL officials told us they do not usually collect demographic information from contractors and that doing so would require writing it into AFRL's contracts.

- ARL's quantum workforce data only included personnel who worked 100 percent of their time on quantum projects. ARL excluded students and personnel working in quantum-adjacent fields.
- NRL and naval warfare center workforce data included personnel who worked at least 20 percent of their time on quantum projects. NRL and the naval warfare centers excluded personnel working in quantum adjacent fields.

To assess the extent to which selected defense laboratories—AFRL, ARL, NIWC Pacific, and NRL—have followed leading practices for strategic workforce planning, we reviewed the defense laboratories' workforce planning documents and interviewed agency officials. We selected these four defense laboratories because the military departments identified them as conducting most of their department's quantum research and development.[3] We compared this information to five leading practices for strategic workforce planning previously identified by GAO.[4] These practices are: (1) determining critical skills and competencies needed, (2) developing workforce planning strategies, (3) building administrative and other capabilities, (4) involving management in workforce planning, and (5) monitoring and evaluating progress. For each leading practice, we assessed defense laboratories' implementation of key supporting actions that make up the leading practice.

Based on our analysis and review, we determined whether the select defense laboratories had fully adopted, partially adopted, or had not adopted each of the strategic workforce planning leading practices. If a defense laboratory provided sufficient evidence demonstrating that it carried out all supporting actions of a leading practice, then we considered the practice fully adopted. If it showed evidence

[3]We did not analyze workforce planning information for three of the four naval warfare centers in our review—Naval Information Warfare Center Atlantic, Naval Sea Systems Command, and Naval Air Warfare Center Aircraft Division—because Navy officials told us these warfare centers conduct a small amount of quantum research and development. Additionally, NSA was excluded from this analysis because its strategic workforce planning documents are classified, and the results of our analysis could not have been included in this report.

[4]GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning,* GAO-04-39 (Washington, D.C.: Dec. 11, 2003).

demonstrating that it carried out some, but not all, supporting actions for a leading practice, then we considered the practice to be partially adopted. If it had documented plans to adopt a leading practice in the future, we considered the laboratory to have partially adopted that leading practice. If it showed no evidence or insufficient evidence of following the leading practice or any of its supporting actions, and had no documented plans to correct this, then we considered the practice to not be adopted.

To assess how DOD STEM education programs have contributed to quantum workforce development we sent a web-based questionnaire to 86 DOD STEM education programs that we identified as potentially making direct or indirect contributions to quantum workforce development. We received responses from 59 of these programs. We invited respondents to complete the web-based questionnaire starting in May 2023 and collected responses online through August 2023. To encourage program managers to respond, we sent multiple reminders by email and made follow-up phone calls where possible to non-responding programs. In developing the survey questions, we reviewed prior GAO research that used a questionnaire for STEM education programs and consulted with officials from the DOD STEM office. The questionnaire covered topics such as the STEM education programs' objectives, intended groups served, and contributions to quantum workforce development.

To identify the programs that should receive our questionnaire, we used DOD and other federal government websites and reports, as well as input from DOD officials, to build an inventory of 184 STEM education programs. Therefore, the scope of this objective was broader than our other objectives, which were focused on selected defense laboratories. We narrowed down this inventory to only include programs with a workforce development component, which we defined as programs offering internships, apprenticeships, scholarships, or fellowships that target high school students, undergraduates, graduates, or postdoctoral researchers. In addition, we excluded programs that reported to DOD in FY 2020 that they did not contribute to quantum workforce development or that were no longer active. Of the 86 programs that met our selection criteria for receiving a questionnaire, we identified 79 before questionnaire launch and seven afterward through information requests to DOD officials or further analysis of DOD websites (see table 4).

Table 4: Summary of Steps Taken to Select DOD STEM Education Programs to Receive GAO's Questionnaire

Program selection step	Number of programs
Number of programs identified before questionnaire launch	176
Programs excluded for reporting no contributions to quantum workforce development in fiscal year 2020	(48)
Programs excluded for not having a workforce development component	(48)
Programs excluded for being inactive	(1)
Number of programs identified after questionnaire launch	8
Programs excluded for not having a workforce development component	(1)
Selected to receive GAO's questionnaire	86

Source: GAO analysis of Department of Defense (DOD) and federal science, technology, engineering, and mathematics (STEM) education websites and reports and DOD submissions on their STEM education programs. | GAO-24-106284

Because this was not a sample survey, it has no sampling errors. However, the practical difficulties of conducting any survey may introduce errors, commonly referred to as non-sampling errors. For example, difficulties in interpreting a particular question, sources of information available to respondents, or different estimating methods can introduce unwanted variability into the survey results. To minimize non-sampling errors, we took steps to improve the quality of information gathered. For example, we conducted pretests with representatives of three DOD STEM education programs selected based on characteristics expected to resemble other DOD STEM education programs that we planned to survey. Specifically, we conducted pretests with programs that appeared to support quantum workforce development to varying degrees or managed a single workforce development activity versus multiple workforce development activities.

We conducted the pretests by videoconference to check that (1) the questions were clear, (2) the questionnaire did not place an undue burden on agency officials, and (3) agency officials could obtain the information and data we requested. We made revisions based on results from these pretests, and also included space in the final questionnaire for respondents to describe any additional information that may help us accurately interpret their reported information.

Of the 86 DOD STEM education programs we contacted, we received responses from 59 programs. Of these, 18 programs reported that they do not contribute to quantum workforce development or otherwise did not fall within the scope of our review (see table 5). The other 41 DOD STEM education programs reported supporting quantum workforce development. We did not receive information from the remaining 27

programs we contacted and could not confirm whether these programs would describe themselves as supporting quantum science.

Table 5: Programs Excluded from Our DOD STEM Education Program Inventory

Reason	Number of programs
Program was excluded for reporting no contributions to quantum workforce development	11
Program was excluded for not being managed, administered, or funded by DOD	3
Program was excluded for being inactive	1
Program was part of another STEM education program in our inventory	2
Program excluded for not having a workforce development component	1
Total	**18**

Source: GAO analysis of Department of Defense (DOD) submissions on their science, technology, engineering, and mathematics (STEM) education programs. | GAO-24-106284

While we did not independently verify information that program officials reported in our survey, we took steps to ensure that the information was sufficiently reliable for the purposes of this report. For example, we performed manual checks to review the data reported to us and reviewed survey answers for obvious errors as well as missing or ambiguous responses. On the basis of our survey testing, review process, and data quality procedures, we determined that the data gathered through our questionnaires were sufficiently reliable for describing DOD STEM education program contributions to quantum workforce development.

To determine to what extent DOD has monitored the contributions of its STEM education programs to quantum workforce development, we reviewed agency STEM education strategies, progress reports, and data collection instruments, and we discussed these with agency officials. We compared this information against Standards for Internal Control in the Federal Government, which states that management should use and communicate the necessary quality information to achieve the entity's objectives.[5]

We conducted this performance audit from October 2022 to December 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe

[5]GAO, *Standards for Internal Control in the Federal Government,* GAO-14-704G (Washington, D.C.: Sept. 2014).

that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: DOD STEM Education Programs Contributing to Quantum Workforce Development

Table 6: Information on DOD STEM Education Programs Contributing to Quantum Workforce Development, Fiscal Years 2019–2023

Program	DOD offices and components involved	Contribution type[a]	Type of workforce development activities	Populations served
3-Step Approach Providing a Pipeline of Skilled Minority STEM Professionals for the DOD Future Workforce Initiative	Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E))	Indirect	Internship	High school, undergraduate, graduate
Advanced Course in Engineering	Air Force	Indirect	Other[b]	Undergraduate
Advanced Quantum Sensing Center of Excellence	OUSD (R&E), Army	Direct	Internship, scholarship/fellowship, other	Undergraduate, graduate, postdoctoral researchers
Air and Space Force Leadership Experience Growing Apprenticeships Committed to Youth Program	Air Force	Indirect	Internship, apprenticeship	High school, undergraduate
Air Force Research Laboratory - Rome STEM Outreach Program	Air Force	Direct	Internship, apprenticeship, scholarship/fellowship	High school
Air Force Science and Technology Fellowship Program	Air Force	Indirect	Scholarship/fellowship	Postdoctoral researchers
Applied Research Laboratory for Intelligence and Security –Research for Intelligence and Security Challenges Initiative Internship Program	National Geospatial-Intelligence Agency	Indirect	Internship	Undergraduate, graduate
Army Educational Outreach Program	Army	Indirect	Internship	High school, undergraduate, graduate, postdoctoral researchers
Army Research Laboratory (ARL) Distinguished Postdoctoral Fellowship Program	Army	Direct	Other	Postdoctoral researchers
U.S. Army Combat Capabilities Development Command ARL Fellowship Program	Army	Direct	Other	Undergraduate, graduate, postdoctoral researchers
Awards to Stimulate and Support Undergraduate Research Experiences Program	Office of the Secretary of Defense, Air Force, Army, Navy	Direct	Apprenticeship	Undergraduate
Cadet Summer Research Program	Defense Threat Reduction Agency	Direct	Internship	Undergraduate
Center for Quantum Engineering – Laboratory for Physical Sciences Doc Bedard Fellowship	National Security Agency (NSA)	Direct	Scholarship/fellowship	Graduate

Program	DOD offices and components involved	Contribution type[a]	Type of workforce development activities	Populations served
Cooperative Education Program	NSA	Indirect	Internship	Undergraduate
DOD Historically Black Colleges and Universities and Minority-Serving Institutions Summer Research Program	Army	Direct	Internship, scholarship/fellowship, other	High school, undergraduate, graduate, postdoctoral researchers
Graduate Fellowships for STEM Diversity	NSA	Indirect	Scholarship/fellowship	Graduate
Griffiss Institute Summer Internship Program	Air Force	Indirect	Internship	Undergraduate, graduate, postdoctoral researchers
High Performance Computing Internship Program	Army	Indirect	Internship	Undergraduate, graduate, postdoctoral researchers
Innovation Driven Research/Education Ecosystem for Advanced Manufacturing For the Defense	Army	Direct	Internship	High school, undergraduate, graduate
Laboratory for Physical Sciences National Research Council Postdoctoral Fellowship	NSA	Indirect	Scholarship/fellowship	Postdoctoral researchers
Laboratory for Physical Sciences Qubit Collaboratory – University of Maryland Graduate Fellowship	NSA	Direct	Scholarship/fellowship	Graduate
Military Academy Internship	Missile Defense Agency	Indirect	Internship	Undergraduate
Minority Leaders Research Collaboration Program II	Air Force, OUSD (R&E)	Indirect	Internship	Undergraduate, graduate
National Centers of Academic Excellence in Cybersecurity	NSA	Indirect	Internship	Undergraduate, graduate
National Defense Science and Engineering Graduate Fellowship	Air Force, Army, Navy	Indirect	Internship, scholarship/fellowship	Undergraduate, graduate
National Research Council Research Associateship Programs	Air Force, Army, Navy, NSA	Indirect	Scholarship/fellowship	Postdoctoral researchers
Naval Air Systems Command Historically Black Colleges and Universities/Minority Institutions Internship Program	Navy	Indirect	Internship	Undergraduate, graduate
Naval Engineering Education Consortium	Navy	Indirect	Other	Undergraduate, graduate
Naval Research Enterprise Internship Program	Navy	Indirect	Internship	Undergraduate, graduate

Program	DOD offices and components involved	Contribution type[a]	Type of workforce development activities	Populations served
Naval Research Laboratory Postdoctoral Fellowship Program	Navy[c]	Indirect	Other	Postdoctoral researchers
Oak Ridge Institute for Science and Education	DOD[d]	Indirect	Internship, scholarship/fellowship, other	High school, undergraduate, graduate, postdoctoral researchers
Problem-Based Initiatives for Powerful Engagement and Learning in Naval Engineering and Science	Navy	Indirect	Internship	Undergraduate
Quantum Computing Graduate Research Fellowship	Army, NSA	Direct	Scholarship/fellowship	Graduate, postdoctoral researchers
Science, Mathematics, and Research for Transformation Program	OUSD (R&E), Air Force, Army, Navy[c]	Indirect	Internship, scholarship/fellowship	Undergraduate, graduate
Signals Intelligence Collection Program	NSA	Indirect	Internship	Undergraduate, graduate
Summer Faculty Fellowship Program	Air Force	Indirect	Apprenticeship	Graduate
Summer Intern Program for Information Assurance	NSA	Indirect	Internship	Undergraduate, graduate
Summer Intern Program for Science and Technology	NSA	Indirect	Internship	Undergraduate, graduate
U.S. Military Service Academies' Engagement Program	National Geospatial-Intelligence Agency	Indirect	Internship	Undergraduate
University of Maryland Laboratory for Physical Sciences – Joint Quantum Institute Quantum Fellowship	NSA	Direct	Scholarship/fellowship	Graduate, postdoctoral researchers
Visiting Faculty Research Program	Air Force	Indirect	Internship	Undergraduate, graduate, postdoctoral researchers

Source: GAO analysis of questionnaire responses by agency officials on Department of Defense (DOD) science, technology, engineering, and mathematics (STEM) education programs. | GAO-24-106284

[a]For the purposes of our report, a STEM education program directly contributes to quantum workforce development if its program goals, objectives, and intended outcomes are specific to quantum science. In contrast, a program contributes indirectly to quantum workforce development if it is tangentially related to quantum science.

[b]"Other" includes activities such as capstone projects, quantum science education, and hiring students as contractors. Some respondents were unsure if their programs met our survey's definitions of internship or apprenticeship.

[c]These programs also reported receiving support from other, unspecified, DOD organizations.

[d]This program reported receiving support from 40 offices and components across the department.

Appendix III: Comments from the Department of Defense

CUI

DEPUTY UNDER SECRETARY OF DEFENSE
3030 DEFENSE PENTAGON
WASHINGTON, DC 20301-3030

RESEARCH
AND ENGINEERING

November 15, 2023

Ms. Candice Wright
Director, Science, Technical Assessment and Analytics
U.S. Government Accountability Office
441 G Street, NW
Washington DC 20548

Dear Ms. Wright:

I am responding on behalf of the Department of Defense (DoD) regarding the draft Government Accountability Office (GAO) report GAO-24-106284, "Quantum Technologies: Defense Laboratories Should Take Steps to Improve Workforce Planning," dated September 28, 2023. Please find DoD's response to draft report GAO-24-106284 enclosed.

Sincerely,

HONEY.DAVID.A.1044947591 Digitally signed by HONEY.DAVID.A.1044947591 Date: 2023.11.15 14:30:28 -05'00'

David A. Honey, PhD

Enclosures:
1. Summary of Recommendations and Comments
2. (CUI) NRL Response

Controlled by: DON DASN(RDT&E)
Controlled by: NRL
CUI Categories: OPSEC
Limited Dissemination Control: FED ONLY
POC: Chris Hills, 703-693-4909

UNCLASSIFIED when separated from CUI attachment
CUI

GAO DRAFT REPORT DATED SEPTEMBER 28, 2023
GAO-24-106284 (GAO CODE 106284)

"QUANTUM TECHNOLOGIES: DEFENSE LABORATORIES SHOULD TAKE STEPS TO IMPROVE WORKFORCE PLANNING"

DEPARTMENT OF DEFENSE SUMMARY OF RECOMMENDATIONS AND COMMENTS

DEPARTMENT OF DEFENSE COMMENTS ON THE DRAFT REPORT

The Department of Defense (DoD) has the following comments on the subject draft Government Accountability Office (GAO) report:

Page 5: "radiofrequencies" should be "radio frequencies".

Page 6: "The Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)), through the DOD STEM office, is responsible for evaluating and assessing progress toward achieving the department's STEM workforce goals."

- The DoD Science, Technology, Engineering, and Mathematics (STEM) office does not evaluate and assess overall progress toward achieving the Department's STEM workforce goals. Evaluating progress toward achieving the Department's STEM workforce goals is conducted at the Service or Component level. The DoD STEM office collects evaluation and assessment data from DoD Components and grant awardees and examines how STEM education and outreach programs impact participants and meet programmatic objectives.

Page 14: "We found that DOD monitors these programs' contributions to quantum workforce development…"

- The DoD STEM office tracks whether DoD STEM education and outreach programs align (directly or indirectly) with each DoD Critical Technology Area, including quantum science. The DoD STEM office does not monitor the extent to which DoD STEM education and outreach programs impact quantum workforce development (i.e., how many participants end up working on a quantum project at a defense laboratory as a result of a DoD STEM education or outreach program).

Page 16: "…21 programs reported not tracking how many participants are assigned to quantum projects."

- Programs may encounter external barriers that limit their ability to track participants and the specific projects the participants are working on.

DoD RESPONSES TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that the Secretary of the Army should direct the Commander of the Army Research Laboratory (ARL) to fully adopt the leading practice of

monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures tailored to its mission needs.

DoD RESPONSE: Concur.

The U.S. Army Combat Capabilities Development Command (DEVCOM) ARL has established high-level strategic priorities and performance measures for monitoring and evaluating progress toward achieving human capital goals and programmatic results.

Additionally, DoD believes there may be confusion regarding the statement that DEVCOM ARL has "transitioned away from using such performance measures after its reorganization in fiscal year 2023 because the measures were inflexible" (GAO-24-106284, p. 12). DEVCOM ARL pivots and updates its initiatives as progress and needs change, continues to clearly and officially define priorities, and tracks progress towards those priorities.

In specific regard to human capital goals and results, DEVCOM ARL follows the DEVCOM Talent Management Strategy (as noted in GAO-24-106284, p. 12), which addresses all five of the Key Principles for Effective Strategic Workforce Planning through the following process:

1. Talent management model
2. Define the talent we need (talent domains, competencies, and core competencies)
3. Assess the talent we have against the talent we need
4. Acquire talent (to include partnering with others)
5. Develop our talent
6. Manage and engage our talent

DEVCOM ARL has already adopted the leading practice recommendation of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures tailored to its mission needs. DoD will continue to evaluate current practices and identify opportunities for improvement.

RECOMMENDATION 2: The GAO recommends that the Secretary of the Navy should direct the Commander of the Naval Information Warfare Center (NIWC) Pacific to fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures for evaluating success across the center.

DoD RESPONSE: Concur.

As part of NIWC Pacific's strategic planning process, NIWC Pacific will include performance measures for monitoring and evaluating progress towards human capital goals and programmatic results in the strategic workforce plans. The timeframe to carry out this action is approximately two years.

RECOMMENDATION 3: The GAO recommends that the Secretary of the Navy should direct the Commander of the Naval Research Laboratory (NRL) to fully adopt the leading practice of

involving top management, employees, and other stakeholders in workforce planning by developing and implementing an enterprise-wide strategic workforce plan or otherwise communicating its workforce goals, initiatives, and metrics for evaluating success throughout the laboratory.

DoD RESPONSE: Concur.

NRL possesses and executes an array of policies and procedures that demonstrates the adoption of Principle 1 (Involve Top Management, Employees, and Other Stakeholders in Developing, Communicating, and Implementing the Strategic Workforce Plan) of the GAO's December 2003 report, "Human Capital - Key Principles for Effective Strategic Workforce Planning." On August 29, 2023, the Department of the Navy (DoN) delivered "NRL Response: 106284 GAO DATA Request #4" (Attachment 1 to this response) to the GAO, which demonstrates how NRL's activities support the five anchors identified in the DoN 2019-2030 Civilian Human Capital Strategy and aligns with Principle 1. NRL's goals, initiatives, and metrics are identified in Attachment 1, column 4, "NRL Programs/actions to monitor (as of 8/24/2023)," and listed in the following examples:

1. NRL established a pipeline of talent by actively utilizing student and postdoctoral programs.
2. NRL has working groups under the Inclusion and Diversity Council and the Science and Engineering Career Track Recruitment Working Group that recommend changes to attract and retain talent. Employees who meet eligibility criteria and have their supervisor's support may apply to NRL's competitive training programs to pursue a higher degree.
3. NRL has established the Knowledge Management Decision Support Office (KMDSO) to provide standardization and best practices related to all aspects of command-wide creation and utilization of knowledge, information, and data. KMDSO is responsible for developing analytics capabilities that make the best strategic use of process and research data.

These NRL activities support Recommendation 3.

RECOMMENDATION 4: The GAO recommends that the Secretary of the Navy should direct the Commander of NRL to fully adopt the leading practice of monitoring and evaluating progress toward human capital goals and programmatic results by developing performance measures for evaluating success.

DoD RESPONSE: Concur.

NRL has adopted Principle 5 (Monitor and Evaluate the Agency's Progress toward Its Human Capital Goals and the Contribution That Human Capital Results Have Made toward Achieving Programmatic Goals) from GAO's December 2003 report, "Human Capital - Key Principles for Effective Strategic Workforce Planning." This is demonstrated via Attachment 1 ("NRL Response: 106284 GAO DATA Request #4"), column 5, "How NRL monitors and evaluates," which the DoN delivered to the GAO on August 29, 2023. Specifically, NRL uses Tableau

workforce data analytics (shown in figure 1.1 of Attachment 1), tracking systems, working groups, focus groups, surveys, and onboarding and exit surveys/questionnaires to evaluate goals and programs and make changes, when necessary.

NRL institutes performance evaluation measures, as outlined in the Federal Register Notice in Volume 64, Number 121, pages 33970 – 34046 of the Federal Register, "NRL Personnel Demonstration Project, DON, Washington, DC," via the Contribution Based Compensation System (CCS). The CCS Elements chart (Federal Register Vol. 64, No. 121, p. 33992, Figure 6) and definitions of critical elements (Federal Register Vol. 64, No. 121, pp 34020-34033) provide additional details on the performance measurements employees are required to uphold.

These NRL activities support Recommendation 4.

Appendix IV: GAO Contact and Staff Acknowledgements

GAO Contact

Candice N. Wright at (202) 512-6888 or WrightC@gao.gov

Staff Acknowledgements

In addition to the contact named above, Joseph H. Cook (Assistant Director), Adam J. Brooks (Analyst in Charge), Hunter J. Graff, Mark A. Kuykendall, Serena C. Lo, Curtis R. Martin, Matthew C. Metz, George J. Nelson, and Ashley Stewart made key contributions to this report.

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