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Securing the Future: Building the US Nuclear Security Workforce Pipeline

By Christina McAllister

March 2026

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Acknowledgments

This paper was funded by the U.S. National Nuclear Security Administration, Office of Radiological Security. The author is grateful for this financial support and would also like to thank all the interviewees and roundtable participants who generously shared their time and insights to inform this research, as well as the colleagues and nuclear security experts who provided introductions or suggestions in the initial stages of the research or thoughtful review and comments to strengthen the draft paper.

Please Cite this Publication As

Christina McAllister, 2026, *Securing the Future: Building the US Nuclear Security Workforce Pipeline*.
The Stimson Center, Washington D.C., USA.

March 2026

Securing the Future: Building the US Nuclear Security Workforce Pipeline

Planning for the future of the U.S. nuclear security workforce

By Christina McAllister

With concurrent modernization of the U.S. nuclear triad and the U.S. civil nuclear energy industry underway, it is critical to consider implications for both security and the security workforce.

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Executive Summary

Modernization of the U.S. nuclear triad and revitalization of the U.S. civil nuclear energy industry will put new demands on public and private sector nuclear security workforces, even as rapid advances in complementary technologies, including artificial intelligence, quantum technology, and more, bring new challenges and opportunities in the nuclear security field. This U.S. nuclear security workforce comprises both a government element — the civilian, military, and contractor personnel aligned with the Department of Energy's National Nuclear Security Administration (NNSA), its laboratories, plants, and security sites, and the Department of Defense (DOD), including the U.S. Air Force, and the U.S. Navy — and a private sector element employed at the fleet of mostly aging nuclear power plants located across the country. Even as they face the new demands of technological modernization and disruption, both the government and private sector are losing significant numbers of retirement-age nuclear specialists while they grapple with recruitment, retention, and development challenges for the remaining workforce. For the military, nuclear weapons modernization is expected to drive a need for more security personnel at a greater number of Air Force bases as well as new and more technical educational and professional development requirements. NNSA and the rest of its nuclear security enterprise, meanwhile, have roles not just in nuclear weapons modernization but in civil nuclear energy, where interest in advanced and small nuclear reactor (A/SMR) technology and anticipated integration of artificial intelligence and other technologies, are driving a parallel demand for new technical skillsets. Novel deployment scenarios and lean economic models built on assumptions of cost efficiency mean the full implications of any potential "nuclear energy renaissance" for nuclear security remain to be seen, but it is likely that the security workforce of the future will need to be curious, interdisciplinary, cybersecurity-savvy, and adept at filling multiple demanding roles at once. Recommendations to address the enduring recruitment, retention, and development challenges of the multi-faceted U.S. nuclear security workforce against this rapidly evolving backdrop of technological change and modernization include:

1. Planning for the future workforce holistically, geographically, and at a systems level given the anticipated competing trends of higher demand for technical skills, decreasing college enrollments, and uncertain timelines and geographies of nuclear modernization and new build projects;

2. Educating and recruiting for the security workforce of the future by focusing on broad educational backgrounds, developing and seeking interdisciplinary expertise, and recruiting for a learning mindset;

3. Leveraging non-traditional talent pools and recruiting tools by reexamining minimum qualifications needed, enabling career transitions from relevant fields with transferrable skills, and facilitating pipelines for non-traditional students and "hidden" workers;

4. Investing in career pathways, professional development, and training by supporting ongoing efforts in these areas; expanding access to training and upgrading the technological profile of offerings; implementing cross-training; prioritizing rotations, secondments, and exchanges; capturing retiring expertise; and considering other ways to professionalize and institutionalize the nuclear security workforce;

5. Improving compensation, work environments, and work-life balance through budgeting and planning for hard-to-source skillsets, upgrading aging and outdated physical workspaces, continuing to combat sexual harassment, and providing greater flexibility of benefits as well as work schedules, job sharing, and rotations.

Introduction

The U.S. nuclear sector has undergone significant shifts in the past decade. A series of legislative and executive measures has sought to revitalize the civil nuclear power industry, driven by historic security challenges. These challenges include deteriorated relations and increased competition with Russia and China that are driving nuclear weapons modernization and a race for energy independence and security. In addition, technological advances including smaller and more flexible reactor designs and the energy-thirsty development of artificial intelligence and associated data centers have driven a renewed interest in nuclear energy solutions. Finally, renewed global interest in nuclear energy has emerged as a potential stable source to address expanding energy needs.[1] Big tech firms Amazon, Google, Meta, and Microsoft have inked ambitious nuclear energy agreements, whether to reopen shuttered nuclear power plants such as Three Mile Island in Microsoft's case, or to build advanced reactors in new locations near data centers.[2] Meanwhile, growing rivalry and tensions with nuclear-armed Russia and China, in particular, including the expiry of the New START treaty with Russia, have put renewed emphasis on modernization of the U.S. nuclear triad and development of new deterrence capabilities.

Much has been written about the need to develop the workforce for the anticipated expansion and modernization of nuclear energy generation and the nuclear weapons complex in the United States. Of the many different nuclear specializations that are required for the nuclear "renaissance" in power generation and the overhaul of the nuclear weapons enterprise, this project focuses on the need for nuclear security specialists.

This paper explores the changing nuclear security landscape and current and future challenges to workforce entry/recruitment, retention, and advancement as well as good practices across industry and government. The paper concludes with recommendations for establishing a successful and enduring U.S. nuclear security workforce pipeline.

Methodology

The findings and recommendations of this paper are based on work conducted between September 2024 and March 2026, including desk research as well as interviews, responses to written questions, and a roundtable discussion with a range of nuclear security practitioners and specialists from industry, government, and academia.

Desk research comprised reviews of academic studies as well as news reports, opinion and editorial pieces, and government and industry reports, strategies, and press releases, including Congressional Research Service (CRS) and Government Accountability Office (GAO) reports.

The roundtable was held virtually under the Chatham House rule in October 2025. Due to the lapse in government funding during that month, some invitees were unable to attend. In all, 12 participants from industry, academia, and the nuclear security enterprise attended the roundtable. The research is also

informed by 17 research interviews the author conducted virtually both before and after the roundtable with participants and invitees, as well as with the U.S. Air Force Security Forces Directorate and the office of the U.S. Air Force Deputy Chief of Staff for Strategic Deterrence and Nuclear Integration (A10). The U.S. Navy office of the Director, Naval Nuclear Weapons Program provided written responses to questions.

Nuclear Security Workforce: Today and Tomorrow

The International Atomic Energy Agency (IAEA) provides foundational guidance on the need for physical protection of nuclear materials and facilities and an adequately educated and trained government and private sector workforce to implement nuclear security through law, policy, regulatory oversight, and on-site operations. While the IAEA Nuclear Security Series publications primarily provide guidance regarding nuclear power plants, research reactors, and other civilian nuclear and radiological installations, they provide an international standard that is applicable to weapons complexes as well, articulating the need for adequately educated and trained staff at both the state and facility levels. Government nuclear security personnel should have technical, legal, and policy expertise related to nuclear security required for the authorization, approval, operation and oversight of the national nuclear security infrastructure.[3] The facility nuclear security organization should include security managers, planners, designers, analysts, operators, guards and response forces, and technicians and may include a mix of staff and contractor personnel.[4]

U.S. GOVERNMENT NUCLEAR SECURITY WORKFORCE

In the United States, the government nuclear security workforce includes not just personnel responsible for the security of nuclear weapons and their means of delivery, but also for civil nuclear and radiological security engagement with domestic and international partners and foreign governments. While there is little literature that directly analyzes the U.S. government nuclear security workforce as such, discussions of this broad Nuclear Enterprise (NE) may be understood to include civilian, military, and contractor personnel aligned with the Department of Energy's National Nuclear Security Administration (NNSA) and the Department of Defense (DOD), including the U.S. Air Force and the U.S. Navy.[5] Some staff of the Nuclear Regulatory Commission (NRC) are also part of the U.S. government nuclear security workforce, although they were not a direct focus of this study.

Within the NE, the Nuclear Security Enterprise (NSE), defined as the NNSA, the national laboratories, and nuclear security sites and plants, includes approximately 62,000 personnel, divided roughly between about 2,000 federal employees and more than 60,000 contractor personnel.[6] Approximately 18% of this workforce is eligible to retire, while more than half has less than five years of experience at their location.[7] Other parts of the NE also bear responsibility for nuclear weapons security. Air Force security forces, the largest career field in the Air Force, which is responsible for two of the three legs of the triad, comprise about 27,000 active duty servicemen and -women, of whom some 6,000 are assigned to nuclear security.[8] In the Navy, approximately 1,000 of the 10,000 servicemembers who work within the Master-at-Arms (MA) career field provide nuclear weapon security. The MA field has become younger over the past two decades, and 85% or more of MAs are early or mid-career. Both Air Force and Navy require only a high

school diploma for acceptance; a study of Navy MA showed only a small, though growing, minority have college degrees.[9]

A confluence of factors, including the pressures of nuclear weapon modernization and race to revitalize the civil nuclear energy sector, has put significant strain on the government nuclear security workforce. NNSA has not felt enduring impacts from the Department of Government Efficiency's 2025 efforts to reduce the size of the federal government; some 350 NNSA employees, apparently a mix of recently hired staff, contractors, and others, were rehired after being fired in February 2025.[10] But NNSA is understaffed according to the benchmark outlined by a 2020 agency study that identified the need for 2,369 personnel by 2026.[11] NNSA's Fiscal Year 2026 budget request targeted a total workforce of 2,003.[12] A 2022 RAND study described a "bimodal" age distribution, or "age bathtub" in many parts of the broad nuclear enterprise, with fewer numbers of middle-aged, mid-career personnel relative to the numbers of retirement eligible and early career staff.[13] The Air Force and Navy nuclear security workforces look healthy based on numbers alone: Manning of Navy MA billets improved to 95% as of January 2026 compared to 92% in January 2025,[14] and Air Force interviewees estimated a similar manning level for nuclear security billets. However, they noted that Air Force levels were a result of policies mandating priority filling of open nuclear security billets, with staffing of other security billets suffering as a result. The robust numbers also mask a shortage of mid-level Air Force officers with specialized experience and expertise in nuclear security, they said.[15] In addition, the departure of experienced civilian nuclear experts following 2025 workforce reductions has created knowledge gaps, increased the burden on military personnel, and heightened the need for technical training. As modernization efforts increase demand for specialized security roles, a focused effort to rebuild and retain this expertise is necessary to ensure long-term enterprise stability and support.[16] The Air Force estimates that need for and competition to fill security billets will grow as nuclear capacity is added to more bases as part of the modernization program.[17] In addition, Air Force workforce planners expect that integrated digital security systems, advanced detection and surveillance technologies, increased cyber physical interfaces, and higher expectations for risk-based security planning anticipated as part of the nuclear modernization program will require a security cadre with greater technical competency in cyber, sensors, and networks; systems level understanding of how operations, maintenance, and security integrate; and data driven threat assessment skills.[18] Navy officials have also stressed the key importance of the workforce to the sustainment and modernization of the sea-based leg of the nuclear triad, with an anticipated increase in nuclear weapons security "operational tempo" being planned for in the 2030s.[19]

U.S. CIVIL NUCLEAR ENERGY SECURITY WORKFORCE

Some sources describe the overall civil nuclear power sector workforce as aging and older than the broader energy sector average, with a lower percentage of workers aged 18-29 and a higher percentage of workers aged 30-54.[20] While it is true that a large number of the nuclear energy workforce is retiring, the workforce is also "skewing younger" due to the replacement of those retirees as well as replacement of workers, primarily those with 10 or fewer years of experience, who left their positions during the 2020-2022 post-pandemic "Great Resignation." Industry figures show a dip in numbers of middle-aged workers compared to younger and older, reflecting something of the nuclear enterprise

"age bathtub." During that period, nuclear security workers had the highest rate of attrition of the workforce categories listed, at 15.6% in 2022.[21]

With advanced and small modular reactor (A/SMR) technology, artificial intelligence (AI), and quantum technology all developing at a breathtaking pace, the future civil nuclear security landscape will be even more complex than today. A/SMRs, in particular, will both enable and require new approaches to civil nuclear security given their anticipated digitization, automation, smaller scale, potential for transportability and remote siting, and greater standardization of design. However, many of these factors point in different directions for the future of the workforce: Smaller footprints and reduced presence of source term material could mean smaller security forces at individual sites, and siting close to or within urban centers could in theory enable greater or even complete reliance on local law enforcement to respond to incidents. The potential for remote siting and operation of A/SMRs also seems to point to smaller workforces. The potential cost savings on security forces are, indeed, a key part of the economic and financial proposition for A/SMRs. Yet the underlying assumptions have yet to be put to the regulatory and real-world test.[22]

In particular, some regulators and security specialists fear that industry and policymakers are pinning greater cost saving hopes on "security by design" than is warranted and that security by design "should consider options to increase the effectiveness of the Protective Force in the event of an attack and should not be used to reduce the reliance on the Protective Force."[23] Participants in the October roundtable voiced skepticism that humans can be entirely excluded from site security measures; traditional "guns and guards" will still be part of the onsite security suite, just as banks, schools, and other civic installations have security guards. They noted that if assumptions are borne out that such reactors will be more numerous than traditional nuclear power plants, the total security workforce is actually likely to expand. In addition, designing security into A/SMRs from the outset requires security and a wide range of other specialists to be integrated into design teams and involved in design at every stage, although roundtable participants and invitees interviewed separately expressed concern that only a few of the many A/SMR vendors vying for design approval are actually integrating security specialists into design teams.

These changes and the risks and opportunities presented by greater automation and digitization, as well as the increasing integration of AI and perhaps other disruptive technologies such as quantum into nuclear sites, will change the educational and expertise profile of the future nuclear security workforce also. Roundtable participants noted that security practitioners will need to understand how a vast array of different sensitive electronic hardware components function in radioactive environments. Cybersecurity, already an increasing concern, will become a non-negotiable requirement for the automated and digitized advanced reactors of tomorrow. Cybersecurity specialists trained in defending not just information technology but also critical infrastructure and operational technology (OT) will take on paramount importance, especially if visions of remote operation become a regulatory reality. However, roundtable participants noted that these specialists are already in high demand yet short supply, and they command significant remuneration. Outsourced workforces for cyber and other security functions may become a hallmark of the new landscape, enabling efficiencies and cost savings but also introducing new vulnerabilities. Fluency in finance and economics, data analytics, and modeling and simulation will also

be critical for future nuclear security hires as the need increases to evaluate different design choices and security solutions for both efficacy and cost efficiency. As the range of skills and knowledge that individuals will be expected to have grows, job descriptions will become broader and more complex.

Roundtable participants also noted that security will be critical to community acceptance of A/SMRs in their "backyards." To this end, cross training and "softer" skills, such as an ability to understand, communicate, and engage across organizations, connect with a range of stakeholders, and bring people together across traditionally stove-piped fields of technical expertise, will be vital for the nuclear security workforce of the future.

Challenges for Recruitment, Retention, and Development

As the United States races both to modernize its nuclear triad and revitalize the domestic nuclear energy sector in the face of global security challenges and domestic policy priorities, addressing existing workforce issues across the government, military, and civilian sectors has gained new urgency. As much of the literature focuses on the nuclear workforce broadly, the October 2025 roundtable and separate interviews were helpful in pinpointing the challenges of greatest relevance to nuclear security specifically.

U.S. GOVERNMENT NUCLEAR SECURITY WORKFORCE CHALLENGES

The causes of NSE workforce recruitment and retention challenges have been well explored, including in a notable 2022 analysis by NNSA's Enhancing Mission Delivery Initiative (EMDI). The EMDI report mentioned in passing challenges "such as moral dilemmas about nuclear weapons, desires to transition to full-time remote or work-from-home status, the complications of acquiring or maintaining security clearances, and specific locality preferences." Key challenges to resolve remain "NNSA controls and reviews on salaries and benefits," especially for management and operation (M&O) contractor staff, the quality of office infrastructure, and inadequate contract vehicles to retain retiring experts as senior advisors. In highlighting the recruitment issues for potential congressional attention, a 2025 Congressional Research Service report also cited comments by national laboratory directors to an industry panel about the negative impacts of limited housing and office space.[24] In testimony to Congress in 2023 and 2024, former NNSA Administrator Jill Hruby provided additional insights into the workforce recruitment challenges, noting competition with established and emerging industries for a limited pool of talent.[25]

Long lead times for NSE staff to develop highly technical expertise mean strong retention rates are even more critical as the enterprise grapples with the dual mandate of nuclear weapons complex modernization and civil nuclear energy revitalization. Annual turnover of the NSE's M&O contract staff has recovered to pre-COVID-19 levels after spiking to more than 10% during the pandemic.[26] However, an external NNSA advisory committee in 2024 identified a trend of shortening median tenures for staff at NNSA's laboratories, plants, and security sites over the past five to 10 years, with median tenure diminishing from 12 to eight years. An analysis of exit survey data across all such sites showed that career progression concerns were a primary or secondary factor causing staff to leave, with retirement as the leading cause for staff at the plants and sites and compensation a secondary factor at the national laboratories (especially in locations with high housing costs). Limited career ladders and promotion slots cause slower career progression in the NSE than is possible in the many private sector jobs hungry for the technical expertise

NSE candidates offer.[27] Participants in the 2025 roundtable convened as part of this study also articulated an unmet need, especially among early career staff, for clear career progression pathways and stepping stones such as access to formal training and other professional development opportunities, noting that continued reliance on informal mentoring and on-the-job experience to build expertise is less satisfying for "Gen Z" staff. National labs face challenges in implementing even those informal cross training and on-the-job opportunities, with roundtable participants describing a gap between budgeted professional development priorities on the one hand and reluctance by project sponsors to fund staff for a project who are not already experts in a novel area. Hruby's congressional testimony added frustrations with workload as a retention issue, as evidenced by NNSA "perennially" receiving the lowest score on the Federal Employee Viewpoint Survey question that states "my workload is manageable."[28]

Beyond the NSE, the Air Force reports difficulty meeting security force recruitment targets, noting that in most cases, the full "accession" goal, or target number of enlistments in the security force, is not met by the end of the fiscal year.[29] The Air Force also reported an 88% security force retention rate, which officials said did not reflect higher attrition rates for nuclear positions.[30] The Air Force cites the isolated location of nuclear bases and a promotion system that prioritizes breadth of experience over specialization as major obstacles to development and retention of a career nuclear security cadre, as those who have received specialized training move to new non-nuclear positions before they have time to train those who come after them. Mid-level non-commissioned officers detailed to nuclear security assignments are frequently learning on the job alongside the junior enlisted staff, rather than providing needed continuity of expertise and serving as an integral component of the training and development program.[31] At the same time, stretched mid-level manning and limited training infrastructure capacity impacts professional development opportunities. Nuclear modernization could further affect retention of nuclear security specialists, if managers closer to retirement decide to leave rather than take on entirely new weapons systems.[32] Meanwhile, the Navy points to a difficulty competing with the private sector for quality staff as a factor in its low overall MA retention levels (54% compared to 60% for the Navy broadly), although retention rates at the Navy's two Strategic Weapons Facilities trend significantly higher than the rest of the MA community.[33]

These issues are consistent with RAND's 2022 findings in its study focused on challenges to recruitment, retention, and advancement of federal employees doing acquisition and STEM jobs to support the overall U.S. nuclear enterprise. This study dove deeper into the fierce competition to recruit qualified candidates, noting that DOD and NNSA are not just competing with industry, including their own contractors, but with each other and other government agencies.[34] This broader study also identified other recruitment issues including a lack of awareness of "nuclear" as a career path not just among college students but also among professionals in other industries who could potentially be good fits for immediate need openings requiring mature candidates. The study also found the bureaucratic federal hiring and security clearance processes and unattractive locations, whether due to climate, geography, lack of job opportunities for spouses, or aging infrastructure, to be recruitment hurdles, and sometimes retention challenges as well.[35] A separate RAND study noted bias in the security clearance process as a potential barrier to entry/recruitment worthy of further research.[36] On development, retention, and advancement, the 2022 RAND study identified workload concerns and lack of promotion opportunities within the enterprise for early and mid-career staff as significant issues, forcing career-minded personnel to move on in order to move up.[37] The report

identified a lack of structured, nuclear-specific career development as problems for the U.S. Air Force and U.S. Navy but noted an overall lack of focus throughout the nuclear enterprise on leader development and succession planning. Another retention challenge could be related to hostile work environments, as the GAO found in 2021 that NNSA and its contractors have limited information on the prevalence of sexual harassment within their security forces due to reliance on reported cases, which are often underreported.[38] Sexual harassment and assault have also been concerns in the armed forces for years; concerted efforts to address the issues over the past several years seem to be having an impact although civilian workforce reductions in 2025 have raised fears that recent progress may be jeopardized.[39] Finally, the GAO has noted that "NNSA does not always share information about its recruitment and retention challenges across the agency, regularly assess the outcomes of its actions to address its challenges, or ensure the effectiveness of action planning to address its challenges."[40]

U.S. CIVIL NUCLEAR ENERGY SECURITY WORKFORCE CHALLENGES

As noted above, the broader civilian nuclear industry experienced workforce recruitment and retention problems during the COVID-19 pandemic analogous to those in the government sector, which study roundtable participants affirmed was the case among nuclear security practitioners in the field. While those dislocations are now evening out, roundtable participants also pointed to an increase in failed background checks for nuclear security positions due to prescription and illicit substance abuse. Additionally, in a sector that recruits heavily among former military personnel, increases in military pay and improved compensation in other sectors that compete to hire retired military have contributed to a decline in recruits to nuclear security, they noted. More broadly, the Nuclear Energy Institute (NEI) Workforce Strategic Plan of 2023 notes that the nuclear industry has "suffered for decades" from lack of visibility, uncertainty, and perceptions of economic instability, which have led, on the one hand, to a lack of understanding of the sector's career opportunities and, on the other, to potential candidates being turned off from an industry understood to be in decline. The issues start even before recruitment begins: NEI reports declining conferment of nuclear degrees and reduced participation by community colleges in the Nuclear Uniform Curriculum Program (NUCP) and declining enrollments in the NUCP at those that still participate, resulting in a shrinking pool of potential government and industry recruits.[41] This phenomenon could be related to the overall affordability of higher education and exacerbated by the impending demographic "cliff" in college-age students.[42] It may also be related to other barriers to recruitment and retention, including the prevalence of shift work in the industry, with its associated negative impact on family schedules, as well as the longer commutes implied by nuclear power plants' typical location away from busy city centers and populated areas. As the civil nuclear power sector, like the government, also faces increasing competition with other "high tech" sectors for qualified staff, such quality of life and work-life balance issues will continue to pose challenges. Roundtable participants cited North American Young Generation in Nuclear data showing that the number of hours worked is the second most important factor after salary affecting willingness to stay in a job.[43] Ironically, the advanced nuclear reactor sector's attractive narrative about providing social benefit through carbon neutral production of energy while leveraging exciting new technology exacerbates the low visibility, image problems, and recruitment challenges of the traditional nuclear sector.

Other studies have noted geographic and systemic planning obstacles to workforce recruitment and development, with workforce estimates unavailable or changing frequently, and relevant technical education programs not staffed and resourced at the levels required to produce the estimated number of workers needed in target locations.[44] U.S. advocacy group Third Way has highlighted the U.S. government's stalled Nuclear Safety Training and Workforce Development program, which appropriated $100 million in 2024 to establish regional workforce consortia but has not yet funded proposals submitted in January 2025 for the first tranche of funding nor requested any further proposals.[45]

Roundtable participants noted that a broader hurdle to recruitment is a tendency for the advanced technology sector to view security as an add-on rather than part of the core functionality of a facility. While DoE has set up the International Nuclear Security for Advanced Reactors (INSTAR) program mandated by Congress to foster the security by design approach,[46] incentive is still lacking to invest resources and recruit the cross-disciplinary expertise needed to build the nuclear security workforce of the future. Workshop participants also noted that weak industry demand for security skillsets is a significant obstacle to nuclear security workforce development initiatives that the educational sector has explored inconclusively for years, such as a nuclear security certification — or multiple certifications. Providing a challenge to some of the other analyses reviewed, an HR specialist commentary in World Nuclear News argued, however, that interest in the sector is robust, and talent is plentiful; instead, "delays, limited information, and disjointed communication create barriers to entry for skilled professionals. Candidate experience in the nuclear sector remains inconsistent."[47]

Best Practices for Recruitment, Retention, and Development

For years, a best practice supporting general U.S. nuclear workforce recruitment has been U.S. government and industry support for the educational pipeline, including development and dissemination of K-12 educational programs about nuclear applications as well as of undergraduate and graduate nuclear engineering programs.[48] For example, DoE supports the American Nuclear Society's "Navigating Nuclear" curriculum for grades 3-12, while the nuclear energy industry collaborated on the development of the NUCP. Participants in the study roundtable emphasized the importance of such early and higher education programs to raise awareness of the nuclear sector as a career path and highlighted ongoing cross-disciplinary efforts in some nuclear security programs integrating both technical and policy coursework as well as other relevant disciplines.

U.S. GOVERNMENT NUCLEAR SECURITY WORKFORCE BEST PRACTICES

Specifically for the nuclear security enterprise, NNSA has sponsored a number of impactful undergraduate, graduate, and post-graduate programs. As an example, the Nuclear Science and Security Consortium (NSSC) of 11 universities and five national laboratories was stood up in 2011 to train the next generation of nuclear security experts. Since 2011, the NSSC has placed 41% of all NSSC Fellows and Affiliates who completed the NSSC Program in positions at the national laboratories or with other government agencies. NSSC's publicly reported impact data also show that it has supported 637 students and 78 faculty. Of the 637 students, 306 (48%) have gone on to government, industry, or academic nuclear security jobs with the rest going on to other industry (24%) and graduate school (15%).[49] The literature also suggests that co-operative educational programs, which combine classroom instruction with multiple substantial segments of relevant paid work experience, can be particularly beneficial for students at the college level in science and engineering programs.[50] One study found NNSA's Predictive Science Academic Alliance Program (PSAAP) to be particularly well suited to supporting students enrolled in cooperative education programs in work experiences within the U.S. nuclear security enterprise.[51] But roundtable participants cautioned that cooperative education programs can also be challenging for students who need to take specific infrequently offered courses. The NNSA Graduate Fellowship Program (NGFP) is another relevant program that has succeeded in routing college graduates and graduate students from a range of disciplinary backgrounds into the nuclear security enterprise. Approximately 85% of more than 750 program alumni take positions with ties to national security after their fellowship terms, and many go on to leadership positions during their career. Within this program, a best practice is the Alumni Ambassador program established in 2023, which has empowered a larger network of professionals to participate in recruiting events and allowed

NGFP to draw on those networks and expand visibility into areas that may not have been reached in the traditional recruiting model.[52] Other important long-running recruitment, retention, and development programs include the NNSA IMPACT Internship Program, which provides professional work experience and mentorship for applicants from minority-serving institutions of higher education, and the NNSA Mid-Level Leadership Development Program, which prepares federal employees for leadership roles.[53]

NNSA has taken meaningful steps to create and publish career paths, competency models, and competency gap assessments, which should be considered a best practice for study and adaptation by other parts of the enterprise.[54] Robust mentoring and networking opportunities also feature prominently in the literature as best practices for retaining nuclear security expertise.[55] Competitive compensation and benefits remain foundational for recruiting and retaining talent in any sector, and former NNSA Administrator Hruby reported in 2023 testimony to Congress that a mid-year salary adjustment and implementation of more flexible benefit packages had indeed helped to slow high staff turnover rates in the nuclear security enterprise. Other best practices found in the literature for recruitment and retention in the national nuclear enterprise broadly include starting intern applications very early to accommodate clearance processes and more intentionally identifying non-classified work for them to do; leveraging direct hiring and excepted service authorities to speed up the otherwise lengthy and off-putting federal hiring process; offering student loan repayment programs and remote work opportunities as incentives; holding multi-employer job fairs; and establishing enterprise-wide HR communities of practice and employee recognition programs.[56] In its infrastructure-focused 2024 "Enterprise Blueprint," the NNSA also recognized the need for additional investments in improving and modernizing offices and other support systems for a productive workforce.[57]

At DOD, the Air Force has recently recreated the Warrant Officer position to help recruit and retain high-demand IT and cybersecurity personnel, a model that nuclear workforce planners are paying close attention to for potential applicability to the nuclear career field. Because the position responsibilities are exclusively technical, it has promise for career fields, like nuclear security as well as IT and cyber, where subject matter expertise and continuity of institutional expertise are at a premium.[58] The Air Force is also moving to strengthen and formalize nuclear security professional identity through structured, nuclear-focused professional development and competency models, deliberate development for nuclear enlisted personnel, better leverage of the nuclear awards program and bonuses, and linkage of nuclear security roles to U.S. strategic priorities such as strategic deterrence and great power competition. Other good practices include predictable schedules and rotations at missile fields and nuclear bases, reduction of administrative burden and stress, mentorship programs pairing junior officers with experienced nuclear professionals, and better recognition and career visibility for nuclear security officers in key nuclear billets.[59] Meanwhile the Navy points to implementation of a $10,000 enlistment bonus for the MA community, Selective Reenlistment Bonuses for sailors with up to 14 years of service, and additional award and pay incentives for nuclear weapons security billets, as well as ongoing efforts to better align manning, training pipelines, and career paths.[60] For all of these recruitment, retention, and development initiatives and interventions across the government nuclear security sector, collecting, analyzing, and tracking data, as the GAO has recommended for NNSA, will be critical to determine their impact and any adjustments needed.[61] GAO also recommends the NNSA adopt Equal Employment Opportunity (EEO) Commission practices and improve EEO program deficiencies.[62]

U.S. CIVIL NUCLEAR ENERGY SECURITY WORKFORCE BEST PRACTICES

Many of the same best practices pertain to the private nuclear energy sector, which is already known for good pay and benefits.[63] Some nuclear plants also support candidate pipeline work-study programs and hands-on experience, for example, by offering prospective employees on-site training during nuclear refueling outages, which can last for several weeks. Roundtable participants identified industry-driven internships as a best practice, where industry identifies a workforce gap, works with academia to establish an internship program, and hires graduates straight into waiting jobs. In addition, industry is already working to target community colleges, trade schools, vocational programs, non-traditional students, and a wider variety of educational backgrounds in its recruitment efforts.[64] Roundtable participants noted that the interdisciplinary nature of the nuclear security field is overall a positive for retention and advancement. Regular interactions with employees from different fields provide both broad and deep knowledge of the facilities and people, building a strong foundation from which enterprising personnel can achieve quick progression through the ranks. Industry participants also noted a strong culture of learning through participating in exercises at other nuclear facilities as well as an increasing shift towards integrating nuclear security officers into broader fleet training and development programs that provide insights and even career pathways into different nuclear fields. Industry also pointed to strong emerging leader programs at nuclear utilities, some specific to nuclear security. However, they cautioned that the legacy nuclear industry's security career model, where security officers have been able to rise through the ranks over the course of their career, will likely have to be rethought and restructured in the coming era of A/SMRs.

Recommendations for Building the U.S. Nuclear Security Workforce Pipeline

The nuclear security field is poised for significant changes as the landscape of nuclear weapons, civil nuclear energy, and disruptive technology evolves rapidly in coming years. As a result, the future nuclear security workforce will not just be "smaller" or doing "more cyber." It will be asked to do fundamentally new things: integrate digital systems, secure smaller plants and novel fuel types in both remote and urban areas, and address completely new AI-driven threats within a coherent security architecture under economic constraints.

Creative and flexible approaches to recruitment, retention, and development are required to meet new educational and job requirements even as historical and institutional knowledge about the evolution of nuclear security policy and practices and enduring principles of the field must be captured and transferred to the rising workforce. In addition to the proven best practices that can be institutionalized and adopted more widely, this study compiled, adapted, and distilled the following nuclear security workforce recommendations for consideration going forward:

PLAN FOR THE FUTURE

1. *Plan for security*: Advanced reactor vendors must "walk the talk" of nuclear security by design, take advantage of NNSA's INSTAR program, and have security specialists on staff and integrated into design teams.[65] Both civil nuclear energy and government nuclear workforce development programs and initiatives must include security and cybersecurity skillsets.

2. *Plan for cybersecurity*: Cybersecurity is as important, if not more so, than physical security, while higher technical qualifications and competition across sectors makes it a much harder and more expensive skill set to procure. The civil and government nuclear sectors should both plan carefully for this critical skillset given economic and budget constraints to ensure an effective and sustainable implementation model for advanced nuclear energy technology and modernized nuclear weapons. Dedicated pipelines and multi-stakeholder planning will be vital.[66]

3. *Plan geographically*: The scale and speed of the U.S. nuclear energy revitalization will depend in no small part on acceptance and buy-in from local communities, who, thanks to advanced and small reactor technology, may find themselves in closer proximity than ever before to nuclear infrastructure. Local communities potentially have much to gain from new nuclear-related jobs, as well as a vested interest in the safety and security of the nuclear infrastructure, both civilian and military, located in their neighborhoods. As

Third Way has noted, NNSA should leverage, as intended, the Nuclear Safety Training and Workforce Development program, established specifically to foster regional workforce consortia, and make it a permanent budget line.[67] Additionally, NNSA should ensure the program explicitly addresses not just nuclear safety but also nuclear security.

4. *Plan at the systems level*: Accurate projections of nuclear security workforce demands are needed, taking into account triad modernization timelines and geography, private sector project timelines and geography, and regional competition for relevant labor categories. Given the diversity of high-tech skills that will be required in both the government and private sector future nuclear security workforce and the fierce competition from other rapidly expanding high-tech sectors, cross-sector and cross-regional workforce planning and coordination are critical.[68] DOE should lead a multi-stakeholder process, to include government, private sector, and academic institutions, to identify needed skillsets and plan how to meet projected demand levels in geographic focal areas.[69]

5. *Invest in the educational pipeline and awareness campaigns*: Given continuing nuclear program enrollment challenges, NNSA should continue to invest in K-12 nuclear awareness curricula and university consortia, which have a proven track record of impact and return on investment.[70]

EDUCATE AND RECRUIT FOR THE SECURITY OF TOMORROW

1. *Recruit from broad educational backgrounds*: Security is not just about nuclear engineering or even traditional law enforcement skills. Skilled trades and other educational backgrounds are also critical to the security of nuclear facilities, and not all specialties require a four-year or even a two-year degree. NNSA, DOD, and industry recruiters should ensure their recruitment efforts are targeted to community and two-year colleges and that job requirements and evaluation practices are targeted to actual desired skills rather than traditional educational signifiers.

2. *Develop and seek interdisciplinary expertise*: As the technological complexity of modernized weapon systems and nuclear power reactors increases, both the government and private sector will need security personnel with greater technical competency in a range of fields. For A/SMRs in particular, as pressure for cost savings intensifies and the need increases to evaluate different design choices and security solutions for both efficacy and cost efficiency, recruits with finance and economics, systems engineering, data analytics, and modeling and simulation skills will also be critical for future nuclear security hires. NNSA, DOD, and industry recruiters should ensure their recruitment efforts go beyond nuclear engineering departments, and universities should double down on cross-disciplinary nuclear security offerings that integrate technical and policy coursework.

3. *Recruit for a learning mindset*: Technological change has become one of the few constants in the modern world, and nuclear security professionals have no choice but to learn continuously about new technologies and how they affect both security threats and available defenses and mitigations. Both government and the civil nuclear security sector should look for curiosity and the ability to learn and adapt quickly as key qualities in the staff they hire.

LEVERAGE NON-TRADITIONAL TALENT POOLS AND RECRUITING TOOLS

1. *Reexamine minimum credentials*: DOD, NNSA, and the civil nuclear security sector should take a hard look at the qualifications that are truly necessary for any given position, an approach that could open up new candidate pools — for example, those with only a two-year degree or no degree, whose skills and suitability could be evaluated through demonstrations of capabilities and expertise such as hackathons.

2. *Enable career transitions*: DOD, NNSA, and the civil nuclear security sector should look to other areas of the economy such as the oil and gas, aerospace, and chemicals sectors where workers may have transferrable skills. This approach would require deliberately identifying cross-sector transferrable skills and investing in training to "nuclearize" new hires from those industries.[71] A related recommendation is to look particularly to relevant industries that have an "age hump," or a preponderance of workers in the middle age band, to match the nuclear field's corresponding deficit, or "age bathtub."[72]

3. *Establish pipelines for nontraditional students*: Research on women who develop an interest in engineering only after finishing college found that tackling a second degree is often impractical. It can also be difficult to move into a four-year program from a two-year program.[73] DOD, NNSA, and the civil nuclear energy sector should work with universities on establishing deliberate pipelines into the engineering field for nontraditional students, including those transitioning in mid-career, as a way to expand the pool of candidates for the nuclear security field.

4. *Activate hidden workers*: Research indicates that traditional recruitment and hiring practices systematically exclude many willing and potentially qualified candidates from consideration.[74] DOD, NNSA, and the civil nuclear security sectors should examine recruitment and hiring algorithms and processes to identify potential ways to broaden the pool of suitable but "hidden" candidates.

INVEST IN CAREER PATHWAYS, PROFESSIONAL DEVELOPMENT, AND TRAINING

1. *Address career management issues*: The Air Force and Navy should continue efforts to foster a nuclear security professional identity and consideration of more defined nuclear security career tracks. NNSA should invest in development of nuclear security career paths, while labs, plants, and security sites should explore ways to add more frequent promotion opportunities in both technical and management tracks.[75]

2. *Upgrade and expand access to training*: NNSA and DOD should explore ways to increase access to advanced training and professional development opportunities, whether through expanded service offerings or by making staff available to take the courses. In addition, NNSA, DOD, and the civil nuclear sector should all invest in more technologically integrated growth and development opportunities to attract and retain a younger workforce as well as provide efficiencies and expand learning opportunities. Digital twins, model-based vulnerability assessments, and AI tools can all play important roles.

3. *Implement cross training*: NNSA, DOD, and the civil nuclear sector should all prioritize cross training their specialists in areas of complementary expertise. For example, to truly implement "security-by-design," civil nuclear engineers and scientists need to be trained on security concepts and adversary tactics and capabilities so that they are informed and equipped to participate in the detailed design of a secure reactor facility. Security experts need to understand economics, finance, and data analytics. Nuclear weapons maintenance and security operations specialists need to understand each other's domains, while cybersecurity specialists need to understand the difference between defending enterprise information technology and nuclear power plant operational technology. Cross-disciplinary communication and stakeholder engagement will also be crucial skills for the nuclear security professional of the future and should be included in professional development training curricula.

4. *Prioritize rotations, secondments, and exchanges*: DOD, NNSA, and the civil nuclear security sector should implement lessons learned and knowledge sharing programs, including through rotations, secondments, and exchanges, between private sector and government facilities and between different parts of the nuclear security enterprise. Such programs could be very beneficial in helping staff do their jobs better and facilitating career growth and retention.

5. *Capture retiring expertise and talent*: Even as modernization and technological change overtake both the government and civilian sector, nuclear security fundamentals endure. With so much of the workforce retiring, both the government and civilian sector stand to lose an unprecedented amount of institutional knowledge and expertise. NNSA, DOD, and the civil nuclear energy sector should each develop a deliberate and comprehensive strategy to capture knowledge and expertise from retiring staff.[76] Mechanisms could include audio/video interviews and oral histories for use in online courses, documentation as part of a lessons learned and best practice databank, or a program to hire back retiring staff as consultants and trainers.

6. *Create nuclear security certification pathways*: As a new generation of nuclear security experts seeks more certain career paths and the government and civilian nuclear sector seek talent with ever more diverse and interdisciplinary education and skills, the DOD, NNSA, and the civil nuclear security sectors should work with academia to explore and shape different levels and types of professional nuclear security certification.[77]

IMPROVE COMPENSATION, ENVIRONMENT, AND WORK-LIFE BALANCE

1. *Improve Pay and Other Compensation*: Pay is a key factor in attracting and retaining a next generation nuclear security workforce that will be expected to bring a more varied and interdisciplinary background to their jobs and asked to do more and more complex tasks than in the past. The traditional civil nuclear sector prides itself on good pay and benefits but the A/SMRs' cost-efficient economic model is likely to put significant pressure on these perks. Industry, NNSA and its contractors, and DOD should budget and plan for compensating nuclear security specialists, including cybersecurity and other highly qualified experts, with salaries that are commensurate with competing high-tech and industrial

sectors. NNSA and DOD should also ensure housing support is provided in high-cost areas as a way to ensure adequate compensation.[78]

2. *Upgrade and modernize workspaces and technologies*: Many of the government offices and traditional nuclear sites where the workforce is retiring have not kept pace with the technological advances of the past few years. NNSA should continue to invest in infrastructure as outlined in the Enterprise Blueprint, including the planned modernization and upgrades to workspaces. DOD should likewise invest in infrastructure improvements at aging Air Force nuclear bases.

3. *Combat hostile workplaces*: NNSA, DOD, and the civil nuclear workforce should all continue to invest in proactive measures and best practices to combat sexual harassment in the workplace.

4. *Enhance work-life balance*: NNSA, DOD, and the civil nuclear workforce should all continue to enhance work-life balance through flex work options, explore a "cafeteria" approach to benefits, and promote job flexibility through more and better designed rotations and cross training.[79]

Conclusion

From the military to the private sector, the U.S. nuclear security workforce will undergo major evolution over the coming years. Whether guarding modernized nuclear weapons or advanced nuclear reactors, the workforce will be challenged to develop a more technologically sophisticated skillset, take on more complex roles and tasks, and operate within a more financially constrained model. The numerous challenges to recruitment, retention, and development of the future nuclear security workforce are not simple to overcome, but the best practices underway in different sectors offer a roadmap for further development, investment, and the creative thinking that will be necessary to meet the needs of the future.

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