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Nuclear Nondestructive Examination Workforce Study

Nuclear Nondestructive Examination Workforce Study

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ABSTRACT

The nuclear power industry relies on a competent and capable nondestructive examination (NDE) workforce to perform essential examinations that help to ensure the safety, integrity, and reliability of nuclear power plant components. The goal of this project is to understand the state of the nuclear power industry's current and future NDE workforce. Studies implemented over the past 20 years indicate that the number of personnel in the nuclear NDE workforce has been declining, with the recent attrition being due primarily to retirements. This attrition of experienced NDE personnel with more than 20 years of experience, coupled with the slow influx of new personnel, negatively affects the NDE workforce's capabilities to meet future industry needs.

This nuclear NDE workforce study comes at a critical time as the U.S. and global nuclear power industry is evolving. In the United States, two new pressurized water reactor plants, Vogtle 3 and 4, are now operational; more existing plants are operating under plant life extension licenses; and the new, advanced reactor fleet is progressing through research and development, design, and licensing, moving closer to becoming a reality. In addition, the energy industry is implementing a significant decarbonization effort—the energy transformation, along with industry's digital transformation with advancements in the use of digital technologies and information, such as artificial intelligence tools, will play a more important role in the inspection, maintenance, and operation within the nuclear power industry and its workforce.

Working closely with U.S. electric utilities, NDE service vendors, NDE personnel providers, colleges with NDE programs, and NDE practitioners, the project team collected data to gain input and better understand the state of the future nuclear NDE workforce. It also assessed where the industry wants to be in 10 years from a workforce standpoint.

The nuclear NDE workforce is still declining and is close to a tipping point, with the results providing insights for proposed initiatives requiring collaborative industry support to provide a long-term resolution to transform the future workforce. Therefore, we urge chief nuclear officers and the Nuclear Strategic Issues Advisory Committee (NSIAC) to support these initiatives and ensure a sustainable future for the nuclear NDE workforce.

Keywords

American Society of Mechanical Engineers (ASME)

American Society for Nondestructive Testing (ASNT)

Digital transformation for NDE

Monitoring and NDE (MANDE)

Nondestructive examination (NDE)

Structures, systems, and components (SSC)

EXECUTIVE SUMMARY

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KEY RESEARCH QUESTION

The key research question is, "Will the current nuclear NDE workforce be able to support the existing fleet and future long-term NDE needs of the nuclear industry?" Previous industry studies indicated that the numbers of personnel within the nuclear NDE workforce have been declining, due primarily to attrition from retirements. There has not been a sufficient influx of new personnel to make up for this attrition. Other contributing factors include shorter-duration outages and overlapping outage schedules. In addition, the nuclear industry is in the process of adjusting to the energy and digital transformations that will result in changes to the industry's technology, operation, and workforce. The risks associated with the decline in numbers within the NDE workforce can be significant, resulting in failure to meet licensing inspection requirements, and potential delays in outage, affecting outage durations and operational costs.

RESEARCH OVERVIEW

The workforce study collected information by surveying utilities, NDE practitioners, NDE services vendors, and NDE personnel providers. An NDE Workforce Focus Group was formed to collaborate and provide input through discussion, workshops, and focus group meetings. The survey information was reviewed and analyzed to determine the state of the current NDE workforce, evaluate future impacts on the industry, and develop recommendations for actions. Future NDE workforce skill set needs were described to provide information on the potential skill set changes needed to work in the new nuclear energy/digital transformation ecosystem (digital transformation for NDE). The survey results were summarized by grouping key issues, and actions were proposed to address the specific challenges with the declining workforce and to develop plans to remedy, transition, and transform the future NDE workforce. A key action from this study is for all affected stakeholders to work collaboratively on the initiatives and specific actions identified and defined in Section 6 of this report to address the declining NDE workforce issues.

KEY FINDINGS

The following key findings are taken from the NDE Practitioners survey results discussed in Section 3 and were used to develop initiatives and specific actions captured in Section 6.

The results from the NDE Practitioners survey indicate that actions proposed to resolve the imminent loss of the NDE workforce issue should be given a high priority under the title of "recruitment." Detailed recommended actions are captured under Initiative 1 in Section 6 of this report. In addition, Initiative 2 details what is needed to address the issues with gaining NDE experience and creating additional work opportunities. Initiative 3 identifies the need to be proactive in monitoring the needs of the industry, going forward, and to establish follow-up actions when warranted to prevent our getting into a similar workforce bind in the future. Finally, Initiative 4 identifies the need for the NDE Workforce Focus Group to oversee the development of a guideline to assist industry stakeholders in carrying out the proposed initiatives and actions outlined herein.

HOW TO APPLY RESULTS

Four overarching industry initiatives are proposed because of this study, for which detailed specific actions are provided in Section 6. These initiatives focus on recruiting new personnel, enhancing career sustainability for the existing workforce, supporting efficient personnel development, monitoring industry changes, and providing implementation guidance to help utilities and vendors make lasting improvements.

The following are the initiatives:

1. NDE Personnel Recruitment
2. Improving Opportunity and the Environment for Gaining Experience
3. Monitoring and Adapting Workforce Needs
4. Creating Detailed Guidance for Implementation of Initiatives

LEARNING AND ENGAGEMENT OPPORTUNITIES

- *Advanced Reactor Roadmaps*. EPRI, Palo Alto, CA: 2023. 3002027504.

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IMPLEMENTATION CATEGORY: Category 2 - Plant Optimization

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1 INTRODUCTION

Background

An adequate workforce of nondestructive examination (NDE) personnel is necessary for the nuclear power fleet to meet regulatory requirements, license commitments, and operational goals. This study updates a continuing issue with the declining availability of NDE workforce to meet the future needs of the U.S. domestic nuclear power fleet. Previous industry studies over the past 20 years indicated that the supply of qualified NDE personnel will not be able to meet the needs of the current nuclear fleet. The most recent EPRI report on the topic, *NDE Work Force Availability Study for the Nuclear Power Industry*, dated December 2016 [1], concluded that the numbers of NDE personnel were already in decline at that time and that the industry needed to take action to resolve this NDE workforce issue. The 2016 study concluded the following:

- Approximately half of the NDE workforce was 45 years of age or older, and about a quarter of the NDE personnel were age 55 or older.
- Almost 70% of NDE personnel were contractors (working for NDE service vendors or personnel providers representing a more fluid, transient type workforce than utility NDE personnel).
- Over 75% of the workforce has more than 8 years of experience; 45% of those NDE personnel had more than 20 years of experience.
- There was a 3% decline in the NDE workforce from 2014 to 2016.

Overall, the study noted that this NDE workforce is declining because of aging and attrition, due largely to retirements. With half of the workforce being 45 years of age or older, the 10-to-20-year workforce forecast continues to decline. Along with the personnel losses, the loss of individuals with 20-years-plus of knowledge and experience hinders effective knowledge transfer. The data in the 2016 report echo NDE workforce projections from previous NDE workforce studies and reflect similar data for skilled nuclear power plant workers. Although this report provided information on the declining availability of the nuclear NDE workforce, no actionable solutions were offered except that the nuclear industry should work together to recruit and hire new personnel for NDE jobs in the nuclear industry.

The U.S. and global nuclear power industry has changed since the 2016 NDE workforce study report. In the United States, two new plants recently became operational, more plants are operating under plant life extension licenses, and the new, advanced reactor fleet is progressing through research and development, design, and licensing and ever moving closer to becoming a reality. In addition, the energy industry is implementing a significant decarbonization evolution, in which net-zero carbon targets are being set that will rely on low- to no-carbon energy sources such as nuclear, wind, solar, hydrogen, hydroelectric power, and innovative sources to be the primary future energy supply; see *Powering Decarbonization, Strategies for Net-Zero CO_2 Emissions* [2]. Integrating the energy transformation with the digital transformation, which includes advancements and implementation of new inspection technologies, robotics, automation, data processing, and artificial intelligence (AI) tools, will require the future NDE workforce to possess new skill sets along with the traditional NDE skills. These changes in the nuclear industry are driving the need to update the current NDE workforce studies to include not only the availability of personnel, but also future additional knowledge and skill sets yet to be determined that will be needed in the future.

Study Approach

The long-term growing concern over the loss of experienced, qualified NDE personnel through retirement and attrition continues, coupled with a slow influx of new personnel, all of which negatively affect the future of meeting nuclear power's NDE needs. The goal of this project was to understand the state of the nuclear power industry's current and future NDE workforce needs. Working closely with the stakeholders—nuclear NDE service vendors and personnel providers and utilities—the project collected survey data to better understand where the industry workforce is today, and where it needs to be in 5 to 10 years and beyond.

A primary goal of the project was to review the current state of the NDE workforce and gain an understanding of the 5-to-10-year goals and future needs for the industry. This included understanding not only the number and availability of qualified, experienced NDE personnel, but also the longer-term effects of potential technical and workforce skill set gaps. The project collected information by surveying NDE practitioners, NDE service vendors, NDE personnel providers, and utilities. An NDE Workforce Study Focus Group was formed to collaborate and provide input through discussion, workshops, and focus group meetings. Key project tasks included the following:

1. Formed an NDE Workforce Study Focus Group, consisting of NDE stakeholders, utility NDE personnel, NDE service vendors, NDE personnel providers, and NDE training organizations
2. Created a list of vendors and members who will participate in the project surveys
3. Created a list of survey questions to ask for information about current and future workforce and skill sets
4. Received and analyzed the responses from the three surveys, collating the responses to gain insights
5. Evaluated results from the surveys and reviewed them against current nuclear industry workforce studies
6. Evaluated future industry skill needs for the future NDE workforce who will work within the nuclear energy/digital transformation world
7. Developed observations from the survey results, which led to the development of four initiatives, all with specific actions to be considered by nuclear NDE industry stakeholders
8. Communicated the results to the focus group, soliciting their input prior to report publishing
9. Benchmarked other NDE industry organizations, like ASNT, to solicit experiences and share ideas to address expected future NDE workforce shortages

2 NDE INDUSTRY AND WORKFORCE EVOLUTION

This section provides an overview of the NDE workforce history, its evolution, and challenges for the future fleet. The discussion is provided to give the reader a sense of how the NDE workforce evolved with the current generation nuclear fleet, how it affected the workforce, how inspection technological advancements will affect the workforce, and the challenges associated with understanding the effect that new manufacturing and construction of future nuclear power plants will have on existing operations.

NDE Workforce, Past and Present

The nuclear industry's use of NDE started when components—such as reactor pressure vessels, pumps, valves, and piping components—were being designed and fabricated to support the plants being planned during the 1960s. The nuclear NDE industry grew based on the demand for verifying the adequacy of the design, fabrication, construction, and installation quality for these components. The requirements for each aspect of the process were specified through one or more of the following industry accepted codes and standards: American Society of Mechanical Engineers (ASME) Section III—Rules for Construction of Nuclear Facility Components, Division 1, various subsections [3]; American National Standards Institute (ANSI)/ASME B31.1—Power Piping [4]; or, for early plants, ANSI Addenda to B31.7-1969 Nuclear Power Piping [5]. Those codes and standards specified the types of examinations that were to be performed during fabrication and construction of power plant components. Typically, the NDE methods were of three main types: volumetric (radiography, ultrasonic examination), surface (liquid dye penetrant or magnetic particle testing), and visual examinations.

The various nondestructive examinations were performed by NDE personnel trained, qualified, and certified in accordance with the guidelines of American Society for Nondestructive Testing (ASNT) Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing [6]. This nuclear power plant boom in the 1960s and 1970s caused the growth of the nuclear power NDE business and the influx of personnel to get training and qualification in the various NDE techniques needed to support this new industry. NDE training and qualification opportunities were created through Nuclear Steam Supply System (NSSS) suppliers, original equipment manufacturers (OEMs), trade or vocational technical schools, NDE service providers, and private NDE training schools. This booming industry provided the pipeline for people to enter the NDE industry, get the training and experience required to reach Level I, get more experience and training and progress to Level II, and gain still more experience and eventually reach Level III. Nuclear NDE was a niche industry but was sufficient to enable workers to make a good living and provide a career. As these plants completed construction and became operational in the 1970s and 1980s, personnel qualified during the construction phase continued their NDE careers in the rising operating nuclear power plant market. It was the nuclear power boom that started in the 1960s–1970s that created the original pipeline for the nuclear NDE workforce.

As plants transitioned into operations in the 1970s, 1980s, and 1990s, the United States Nuclear Regulatory Commission (USNRC) Code of Federal Regulations, 10 CFR 50.55a, Codes and Standards [7] specified the use of American Society of Mechanical Engineers (ASME) Section XI—"Rules for Inservice Inspection of Nuclear Reactor Facility Components, Division 1, Rules for Inspection and Testing of Components of Light-Water-Cooled Plants" [8] to perform periodic in-service inspections (volumetric, surface, or visual examinations). These examinations were performed during plant refueling outages, which typically occurred at 18-to-24-month intervals.

Initially, the refueling outages were months-long events, occurring in the spring and fall seasons, and provided plenty of work opportunities to support a career in NDE. However, by the end of the 1990s, utilities had made massive strides in optimizing outage planning to reduce costs and reduce outage durations from months to as short as two to three weeks. In addition, most outages are scheduled concurrently, on top of one another, in the spring and fall, causing a high demand for trade and skilled labor, such as NDE, but for a very short time. NDE personnel are left with very short deployment windows in the spring and fall to get work, gain experience, and make a living. Although some NDE personnel were able to move to full-time NDE positions at utilities, information from previous studies indicates that 70% of the NDE personnel supporting plant outages still come from NDE service vendors and personnel providers [1]. These contract NDE personnel have been hardest hit by the limited number and duration of work opportunities, which has caused some personnel to move out of the industry.

ASME Section XI, Appendix VIII: Performance Demonstration

A big change to the nuclear NDE industry came in the early 1990s. To improve the capabilities and reliability of ultrasonic examinations, the industry developed—and, in 1989, issued—ASME Section XI, Appendix VIII, "Mandatory Appendix VIII Performance Demonstration for Ultrasonic Examination Systems" [9]. In the early 1990s, the USNRC approved Appendix VIII for use. With the USNRC's adoption of Appendix VIII into the Code of Federal Regulations, the nuclear industry was required to qualify all ASME Section XI ultrasonic testing (UT) procedures and personnel through a rigorous performance demonstration (PD) process. This process required testing, validation, and qualification of the UT procedures, personnel, and equipment on test specimens that are representative of the as-built field conditions and expected flaws of components and welds in the operating plants.

In response to these new requirements, the nuclear utilities founded and funded a collaborative Performance Demonstration Initiative (PDI) organization and engaged EPRI to develop and manage the qualification program. Through EPRI, over several years, PDI developed the protocols and procedures to meet and implement the Appendix VIII requirements, which included the design and fabrication of a large inventory of PD test specimens. The PD program now addresses ultrasonic examinations applicable to the following Appendix VIII supplements (2021 Edition of ASME Section XI):

- Supplement 1: Evaluating Electronic Characteristics of Ultrasonic Systems
- Supplement 2: Qualification Requirements for Wrought Austenitic Piping Welds

- Supplement 3: Qualification Requirements for Ferritic Piping Welds
- Supplement 4: Qualification Requirements for the Clad/Base Metal Interface of Reactor Vessels
- Supplement 5: Qualification Requirements for Nozzle Examination from the Outside Surface
- Supplement 6: Qualification Requirements for Reactor Vessel Welds other than Clad/Base Metal Interface
- Supplement 7: Qualification Requirements for Nozzle Examination from the Inside Surface
- Supplement 8: Qualification Requirements for Bolts and Studs
- Supplement 9: Qualification Requirements for Cast Austenitic Piping Welds
- Supplement 10: Qualification Requirements for Dissimilar Metal Piping Welds
- Supplement 11: Qualification Requirements for Full Structural Overlaid Wrought Austenitic Piping Welds
- Supplement 12: Requirements for Coordinated Implementation of Selected Aspects of Supplements 2 and 3
- Supplement 14: Qualification Requirements for Coordinated Implementation of Supplements 10, 2, and 3 for Piping Examinations Performed from the Inside Surface
- Supplement 15: Qualification Requirements for PWR Reactor Vessel Upper-Head Penetrations

This listing shows the breadth, depth, and complexity of the PD program. The effect of the Appendix VIII requirements on the nuclear NDE ultrasonic examination service and workforce providers was significant. The qualification process is lengthy, rigorous, and labor- and travel-intensive. NDE service companies committed significant resources of time, labor, and funds to accomplish the required qualifications for their examination procedures and personnel. Independent NDE personnel had to acquire the appropriate qualifications as well. The implementation of the PD program had a big impact on the process of populating the NDE ultrasonic personnel workforce.

The USNRC initially allowed the industry the ability to set a timeline for implementation of Appendix VIII, but there was considerable work to accomplish. Previously, the NDE service vendors qualified their own UT procedures and trained and qualified their personnel through internal procedures. It took several years to design and fabricate the required test specimens before qualification testing activities could occur. Initially, attempts by the NDE vendors to qualify procedures and personnel were seldom successful. Largely through iterative development and practice testing, procedures were improved and qualified along with personnel. Some supplements, such as Supplement 2 on wrought austenitic piping welds; Supplement 10 on dissimilar metal piping welds; and Supplements 5 and 7 on nozzle examinations from the outside surface and inside surface, respectively, used higher levels of technology and were more challenging, which reduced the numbers of personnel who would successfully qualify to perform those examinations.

Implementation of the PD process changed the makeup of the NDE workforce with respect to personnel qualified and certified to perform ultrasonic examinations. Before PD, a generous population of Level II UT examiners were considered qualified and certified to do a wide range of ultrasonic examinations: manual and/or automated piping, vessel, and specialty examinations. Some examinations required a higher level of knowledge and experience; the NDE service vendors managed their examination qualification processes internally through their own NDE training, qualification, and certification programs. Appendix VIII created an intricate substructure of personnel qualifications. First, the UT workforce was split by personnel who had attained some Appendix VIII qualifications and those who did not obtain any. The Appendix VIII qualified workforce was further divided by the various supplement qualifications—no one qualified for all the supplements, and most people qualified for very few. This fine structure in the workforce was further differentiated by manual versus automated examinations, by reactor pressure vessel and nozzle weld examinations vs. piping weld examinations, and by subsets of material and degradation types with piping categories. Of all the examinations, the austenitic and dissimilar metal weld examination supplements were often the most challenging and difficult to obtain qualifications for procedures and personnel. Ultimately, some of these highly specialized qualification "buckets" were—and are today—populated by a mere handful of individuals, posing the risk that at a moment of dire need a properly qualified individual may not be available.

During the first 10 to 20 years of PD program implementation, the management and administration of the various UT procedure and personnel qualifications challenged the NDE service providers and the utilities. At numerous times, the availability of some personnel was quite limited. In addition, the industry now had a split between PD qualified and non-PD qualified UT personnel. The PD personnel could perform ASME Section XI examinations within their qualified supplements; other UT personnel were relegated to support primarily non-ASME Section XI examinations, such as balance of plant (BOP) or flow-assisted corrosion (FAC) ultrasonic examinations. Wages were accordingly higher for the PD qualified personnel. Despite these challenges, the Appendix VIII PD program did result in improved detection capability, reliability, and consistency. This evolution occurred at a time when the NDE workforce was beginning to see a slight decline in personnel numbers, and the existing workforce had to adapt to the shifting and division of UT resources. For UT personnel, the challenge of obtaining one or more PD qualifications/certifications may be seen as a career opportunity for some or an overwhelming barrier for others.

Plant Operation after 40 Years

Most of the domestic fleet have completed the first 40 years of operations and have been granted approval for extended plant operations into 60 or even 80 years of operations. Plants that are under plant life extended operations must perform additional inspections of components and structures previously not required to be examined under regulated codes and standards. Although this may provide additional scope for inspections, it has not had a significant impact in providing more opportunities for NDE personnel. It appears that the industry has simply enlarged the responsibilities of the existing workforce and, at the same time, will continue its existing outage planning methodology, which is to minimize outage durations, to maintain overlapping outage schedules, and thus provide increasingly limited opportunities for substantial work for NDE personnel. This may be a contributor for some of the more experienced nuclear NDE practitioners to seek careers in other industries or to accelerate their retirement.

There are still people working in NDE who started during the late 1970s–1980s construction boom; however, the industry has lost significant numbers due to attrition, mostly caused by retirements. Beyond the loss of numbers of qualified NDE personnel, it is the loss of decades of experience, knowledge, and technical capabilities that is difficult to measure in terms of impact to the industry. Around 2010, a renaissance appeared to be on the horizon that would revitalize the nuclear industry and, hopefully, the workforce. This would have rejuvenated the valuable pipeline to bring in new personnel, train and qualify them, and allow them to grow from Level I to Level II and eventually to Level III. Owing to a burgeoning supply of low-cost natural gas and the risky economics of building new nuclear power plants, that renaissance and workforce pipeline did not occur and the numbers of NDE personnel continue to decline, with fewer new people entering the business. On a positive note, the industry did implement risk-based inspection and examination optimization methodologies. These methodologies resulted in a decrease in the number of inspections required on lower safety-risk components and in optimizing the frequency and scheduling of certain examinations, resulting in reduction of examinations and more consistent equalization of the numbers of examinations between outages. This was a recognized boon for the utilities, as it has reduced the numbers of NDE personnel needed to support outages, made the workload planning more consistent between outages, and minimized the impact from the declining NDE workforce. However, the implementation of risk-based methodologies contributed to several downsides, including the fact that fewer required examinations result in fewer opportunities for NDE personnel to gain vital experience hours, and that the remaining work scope comprises all the examinations with the highest risk significance, increasing the impact of any workforce gap. In addition, it drove the need for more cross-qualified Appendix VIII Supplement personnel and strained the vendor workforce.

Challenges for the Future Fleet

The NDE workforce challenges for the future fleet arise from parallel nuclear industry activities that require NDE resources. First, the nuclear industry has anticipated that the introduction of the small modular and advanced reactor technologies will be the industry’s next major evolution and expansion. This next generation of technology plants is currently being designed and is beginning the licensing phases for reactor technologies such as small modular reactors, molten-salt high-temperature reactors, and high-temperature gas-cooled reactors. While this evolution occurs, the existing fleet will remain operational past their initial 40-year life through regulatory approved plant life extensions to 60-, 80-, and possibly 100-year life.

Over the decades of operation of the existing fleet, most of the component and materials degradation issues have been identified and are being managed, monitored, mitigated, or remediated in accordance with industry and regulatory accepted guidance. The challenges to the plants that affect the implementation of NDE are understood and expected, and the numbers and types of examinations are becoming more consistent. As previously mentioned, the implementation of risk-based inspection and examination optimization technologies has reduced numbers of examinations and refined examination scheduling. This has resulted in more consistency in the number of required examinations and how they are scheduled for implementation over multiple outages. For most plants, scheduling and managing of the NDE workforce to support plant outages and non-outage periods has become more predictable and consistent. It is still possible to have an unexpected event that requires emergent NDE support, but the plants and industry have documented and industry-approved processes and protocols in place to manage these situations.

The impact of future advanced reactor plants on the NDE workforce is a totally new situation because of the unknowns and the steep learning curve ahead. We do know that most of these advanced reactor designs will operate in much higher temperature regimes than current light water reactors, using different coolant media and materials and with disparate material properties and degradation mechanisms from the existing fleet. It is expected that these operational and materials differences will require new innovative examination and monitoring approaches to adequately assess the material condition and structural integrity of components and materials. Although the conventional NDE techniques—visual, surface, and volumetric—prescribed by Division 1 of ASME Section XI are still viable options, operating conditions may limit or prohibit their use. To address the future advanced reactor fleet, ASME Section XI recently approved ASME Section XI, Rules for Inservice Inspection of Nuclear Reactor Facility Components, Division 2, “Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Reactor Facilities,” 2023 edition [10]. Division 2 offers a different approach for selection of structures, systems, and components (SSCs) for examination or monitoring, using methodologies that may differ from those currently used in the deterministic, prescriptive approach of Division 1 for the current fleet.

Division 2 uses a risk-informed methodology to evaluate and make examination selections based on the SSC safety significance, as it relates to the potential materials degradation mechanisms. The reliability and integrity management (RIM) process includes the selection and use of monitoring and NDE (referred to as MANDE) technologies that may be new or different from the conventional NDE techniques in use today. The Division 2 approach allows advanced reactor designers and future nuclear facility owner/operators more flexibility in determining which SSCs need to be monitored and examined and in selecting MANDE technology. ASME Section XI, Division 2 was recently approved by ASME and has been published in the 2023 edition of ASME Section XI. The USNRC has also issued a new Regulatory Guide (RG) 1.246, “Acceptability of ASME Code, Section XI, Division 2, ‘Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants,’ for Non-Light Water Reactors” [11], for future use for the advanced reactor facilities. Discussions in the industry about the implementation of Division 2 are ongoing, but the industry is waiting for further development of the advanced reactor designs and guidance. From the NDE workforce perspective, there are many unanswered questions, such as 1) what needs to be examined or monitored, 2) what is the best MANDE method or technology to use, 3) how frequently should examinations be performed, and 4) how can these examinations or monitoring activities be implemented within the operational constraints for these new reactor designs. Another challenge is that Division 2 requires these MANDE technologies to be performance demonstrated, prior to use, in a manner similar to ASME Section XI, Appendix VIII for ultrasonic examinations.

With the current state of the advanced reactor design research and development cycle, the answers to the questions needed to support the development of a Division 2 RIM program are still a work in progress. Without those definitive answers, it is difficult to anticipate the full extent of the effects that the future advanced reactor fleet will have on the NDE workforce. However, new and innovative monitoring and NDE technologies will definitely be needed, and it will certainly require the NDE workforce to transition to the Division 2 program approach and use the new MANDE technologies. This is an opportunity for the nuclear industry to be proactive in assessing this transition and to be prepared to serve the future fleet.

Nuclear and Electric Power Industry Transformation

The energy industry has begun what is being called the energy transformation for net-zero (carbon) emissions. This is a global initiative across all industries using carbon-based fuels and reducing carbon dioxide emissions to net-zero. This effort is publicized daily in the media and is the subject of the EPRI report *Powering Decarbonization, Strategies for Net-Zero CO_2 Emissions* [2]. For the electric power industry, this means less reliance on and the closure of power plants using fossil fuels (coal and gas) and increasing the use of more “green, clean” sources of energy such as wind, solar, hydroelectric, and nuclear power. This electric power transformation is changing the industry’s generation, transmission, and distribution of power. The following are key items associated with the energy transformation:

- Expanding the energy supply assets to meet the public needs for low-cost energy
- Evolving the energy supply capabilities to be more reliable, efficient, and resilient
- Developing clean energy solutions for the betterment of the environment and communities
- Accelerating the development and implementation of low-carbon technologies

Although this energy transformation does not appear to have a direct effect on the current nuclear NDE workforce, the construction and operation of the next-generation nuclear fleet will create a higher demand for personnel with nuclear NDE workforce skills.

In parallel and aligned with this energy transformation for net-zero carbon is the broader digital transformation that is also occurring globally throughout industry. This digital transformation, sometimes referred to as Industry 4.0, relies on the increased use of data and automation to improve processes, business models, products, and sustainability, providing a better workplace and life for workers and the public. The digital transformation involves the use of the following:

- Data—analysis, integration of data streams, visualization, and automation
- Process improvement through monitoring and diagnostics
- People—new roles and skills, the “digital worker”
- Innovative technologies—to generate more useful data, remotely to improve worker safety

The digital transformation is not a new concept for industry but is one that has been evolving through the successful use and implementation of digital technologies. It continues to gain industry recognition, support, and acceptance. The use of automation and robotics in component inspections and NDE has increased the capabilities, reliability, and usefulness of examination data while minimizing impacts to personnel safety. The recent introduction of artificial intelligence into assisting analysis of NDE data streams will improve the speed, reliability, and consistency of the data analysis and will reduce human errors. The digital transformation for NDE takes a holistic approach to assess the whole NDE ecosystem, which will include addressing the changes needed to align the future nuclear NDE workforce with the changes that will occur as the result of the energy and digital transformations. Although we cannot predict exactly what changes in the nuclear NDE workforce will be needed, we can begin to prepare the industry and workforce for these changes. This is the subject of Section 4 of this report.

Summary

The nuclear NDE workforce evolved as the result of the design, fabrication, construction, and operation of the current operating fleet. It was the pipeline that brought new people into the industry in the 1970s, 1980s, and 1990s, and continues to be the makeup of the current NDE workforce. However, that NDE personnel pipeline has become dysfunctional, with fewer young people being attracted into this industry and, at the same time, more experienced workforce continuing to leave for retirement or for other opportunities. The nuclear industry is expecting that advanced reactor development will create a new nuclear industry personnel pipeline, including the NDE workforce. At this point, we do not understand the impacts of this energy and digital transformation, except that more people with new and different skill sets will be needed to support the future NDE workforce. Both the current operational and future advanced reactor fleets may be at risk having an adequate supply of qualified, capable NDE resources. This should be envisioned as the opportunity to be proactive and be prepared for this transformation.

3 SURVEY RESULTS

Survey Approach

To collect pertinent data for the nuclear NDE workforce study, the project first formed an NDE Workforce Study Focus Group consisting of NDE subject matter experts from utilities, NDE service vendors, NDE personnel providers, and NDE training organizations. The focus group developed three survey types and questionnaires that would be sent out to nuclear utilities (workforce end users), NDE service vendors and personnel providers (NDE workforce service and personnel suppliers), and NDE practitioners (the personnel performing NDE). The utility and NDE service vendor and personnel provider surveys contained questions focused primarily on the number and type (NDE method, qualification type, and level) of NDE personnel needed or provided for a typical outage. These surveys requested information for present-day needs as well as 5-year and 10-year projected needs. The NDE practitioners' survey contained 18 questions pertaining to their experiences and perceptions working as part of the nuclear workforce.

Within each survey type, the survey questionnaires were broken down as follows:

- Utility
  - Boiling Water Reactor (BWR) Plant
  - Pressurized Water Reactor (PWR) Plant
  - Fleet
- NDE Service Vendors
  - Boiling Water Reactor (BWR) Plant
  - Pressurized Water Reactor (PWR) Plant
- NDE Personnel Suppliers
  - Boiling Water Reactor (BWR) Plant
  - Pressurized Water Reactor (PWR) Plant
- NDE Practitioners

Survey Process

Surveys were initially sent out in the fourth quarter of 2023. The surveys were sent to a list of participants for each survey type (utility, NDE service vendors, NDE personnel providers, and NDE practitioners). The participant list was developed by the NDE Workforce Study Focus Group. The initial response rate for each survey type was lower than desired, due to NDE personnel still supporting plant refueling outages. An additional request was made in January 2024, and additional data were collected for the workforce study. The EPRI project team began reviewing the data sets to determine methods to extract useful information. The most useful data came from the NDE practitioner survey, with 82 responses. The practitioner survey contained 18 open-ended questions requiring written comments or responses. Pertinent qualitative information was contained within those comments, which revealed information about the current state and future perspectives of the nuclear NDE workforce. It was apparent that many of the respondents had applied considerable thought and effort because the subject was important to them, and they appreciated the opportunity to make their perspectives known.

The data contained within the utility and NDE service vendor and personnel provider survey responses were more difficult to analyze because of the complexity of the survey questionnaire spreadsheet. After several attempts to evaluate and summarize the data, it was determined that because of inconsistencies in the survey responses, the quantitative information was not useful. The pertinent information from these survey responses was collected and is discussed in the last subsection of this section.

The following sections provide the analysis results for each survey type in more detail and discuss the potential takeaways from the results.

NDE Practitioner Survey Results

The NDE practitioner survey received 82 responses, providing relevant information and perspectives on the current and future state of the nuclear NDE workforce. The survey contained 18 questions pertaining to the practitioners' NDE work experiences, perceptions about their future careers, and qualifications in nuclear NDE (see Table 1 for the questions). The responses and comments were qualitative in nature, but the EPRI project team developed a methodology for extracting useful information from the responses.

The project team reviewed the various responses for each question and categorized them by keywords that are representative of the nature of the response. The list of categorized keyword responses for the questions were tallied. A "word cloud" was created that shows visually the occurrence frequency of each keyword response (larger font means a higher response rate). The responses were categorized into groupings such as pay and compensation, job security and stability, travel, work schedule, advancement opportunity, and personal considerations. These results are shown in a comment frequency histogram, which provides a better representation of the human factor considerations that are important to the NDE practitioners. Finally, for some questions a list of representative comments is provided. An example of the comment response data is provided for Question 1, later in this section.

The following subsections provide the results to the 18 questions included in the NDE practitioner survey. In general, response histograms are provided for each question, but the word cloud and examples of comments are presented only as needed.

Table 1. NDE practitioner survey questions

1. What are the aspects of commercial nuclear power NDE that are most attractive as a career?
2. What are the aspects of commercial nuclear power NDE that are least attractive as a career?
3. At present do you work for a utility, a services company, a personnel provider, or freelance?
4. How many months per year do you typically work in NDE nuclear power?
5. Are you satisfied with the amount of nuclear NDE work you are achieving, or would you like to see additional work assignments?
6. In what year do you expect to leave the nuclear NDE field, through retirement or otherwise?
7. Do you provide NDE to other industries outside of nuclear? If so, in what industries, and give reason(s) why you feel it is necessary. If not, why do you feel it isn't necessary?
8. Do you feel there are adequate advancement opportunities afforded to you to continue working in nuclear NDE?
9. Do you feel your company has invested in your future development, such as training, and are you willing to make the same investment in time and dedication?
10. What is your opinion of current nuclear NDE work scope durations? What would you like to change if you were royalty for a day?
11. Is the salary paid for non-nuclear NDE workers comparable to nuclear NDE workers? Why do you feel it is different?
12. What types of incentives would you like to see to retain your commitment to support nuclear NDE?
13. What are the attributes of a utility or site you like to work for?
14. What are the attributes of a utility or site you do not like to work for?
15. Do you feel there are enough nuclear NDE personnel in the industry to support current needs and future needs? Why or why not?
16. Have you or would you recommend NDE as a future career path to members of your immediate family? Why or why not?
17. Do you expect the workload to be about the same during the next couple of years? Or is this unknown?
18. Which of the following qualifications do you have? Do you expect to have this qualification by 2030?

Question 1: What are the aspects of commercial nuclear power NDE that are most attractive as a career?

Figure 1 provides the word cloud for the Question 1 responses as to the aspects of commercial nuclear power NDE that are most attractive as a career. Figure 2 is the Question 1 response histogram of the response comment groupings.

Figure 1. Question 1 response word cloud

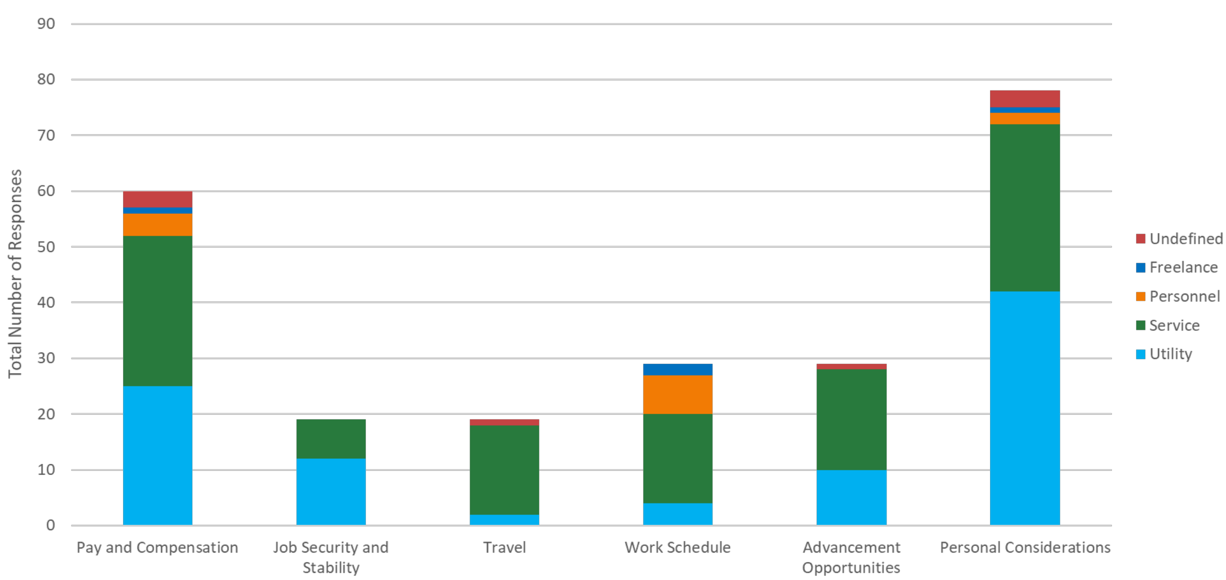

Figure 2. Question 1 response comment frequency histogram

The following are examples of response comments to Question 1:

Pay and Compensation:

- “Good compensation” (Utility)
- “The pay is good” (Service)

Job Security and Stability:

- “Pretty consistent outages and job security” (Service)
- “Good job security” (Utility)

Travel:

- “You get to travel to new places” (Utility)
- “Traveling to new places while learning new things” (Service)

Work Schedule:

- “Non-traditional work schedule” (Service)
- “An actual off-season of time to not focus on work and pursue other interests.” (Service)

Advancement Opportunities:

- “The opportunity to move up” (Service)
- “Rapid career advancement opportunities” (Service)

Personal Considerations:

- “Great people to work with” (Service)
- “Knowing that you are contributing to the USA’s power needs” (Service)

Whereas the word cloud chart provides a visual perspective of the categorization of response comments, the response comment grouping histogram and actual comments provide a clear representation of the data.

Question 2: What are the aspects of commercial nuclear power NDE that are least attractive as a career?

The results from Question 2 are shown in the response histogram, Figure 3, and examples of the actual response comments are provided following the figure.

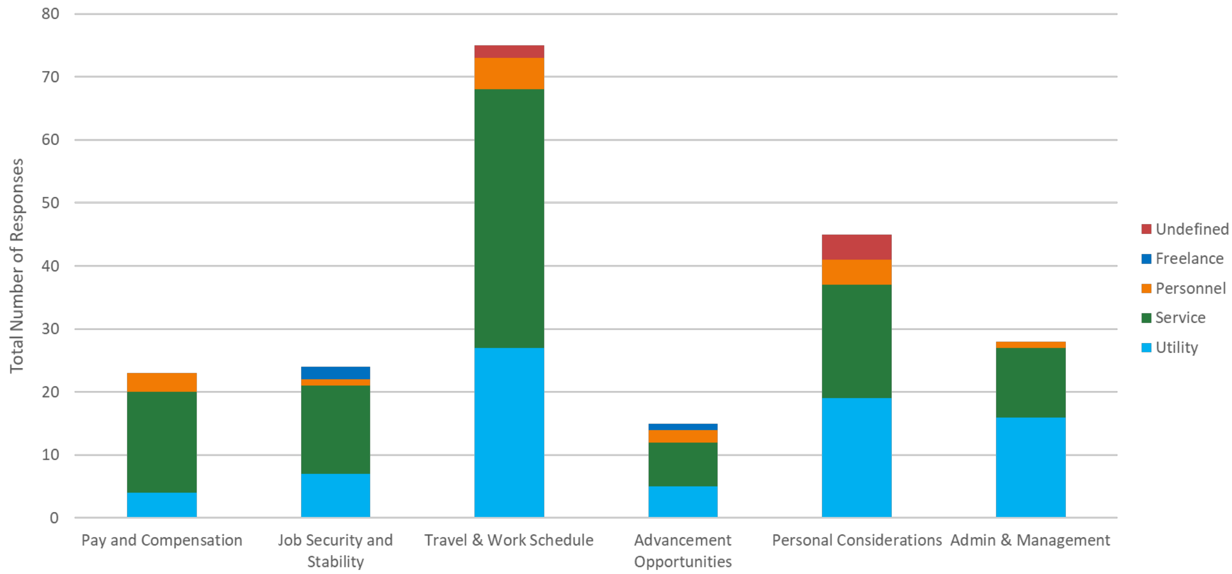

Figure 3. Question 2 response comment frequency histogram

The following are examples of response comments to Question 2:

Pay and Compensation:

- "UT Certifications with no pay increase" (Utility)
- "Travel time not paid correctly" (Service)

Job Security and Stability:

- "Not knowing what the future holds for nuclear power" (Utility)
- "Outage timing has made it difficult to make nuclear a primary source of income" (Service)

Travel and Work Schedule

- "Time away from family" (Utility)
- "Unreliable schedules" (Personnel)

Advancement Opportunities:

- "Not a lot of advancement/monetary growth" (Personnel)
- "Difficult to accumulate OJT for advancement" (Service)

Personal Considerations:

- "Radioactive" (Personnel)
- "Puts a strain on personal relationships" (Undefined)

Admin and Management:

- "Paperwork/documentation" (Utility)
- "Overburdensome nuclear work process (more talk/less work)" (Utility)

NDE practitioners' responses to Questions 1 and 2 indicate divergent perspectives with respect to job satisfaction, travel, work schedule, job security and stability, advancement opportunities, personal considerations, and other factors shown in the charts. Although some feel that pay is good, others feel that pay is not commensurate with certifications. Travel is a key response area, in which some like the travel opportunities and others say that there is too much travel. These responses directly relate to the person's work–life balance preferences. Job security responses differ, with some saying they have job security—likely those who are working full time versus contract personnel, who are concerned with the number of hours they work and the overall future of nuclear power. Some personnel see opportunities for advancement and others do not, with the difficulty of obtaining experience hours due to short outages and work duration being a hindrance to advancing in their NDE careers.

The overall perspective from the responses to Questions 1 and 2 is that the NDE practitioners are uneasy about the future of their nuclear NDE careers. As personnel mature and grow in their NDE work and personal lives, they see that it becomes more difficult to get secure, stable work that supports a good work–life balance and for gaining work experience that allows for career advancement. They are also somewhat unsure of the future of the nuclear industry that would support their careers. The key takeaway from these results points to a need for the industry to become advocates for and for promoting nuclear NDE. The industry must communicate and develop better ways for suitable candidates to gain an interest in NDE as a stable career, and allows them to gain work experience, maintain stable work, and provide growth for a long, secure, and rewarding career.

Question 3: At present, do you work for a utility, a services company, a personnel provider, or freelance?

Question 3 shows the breakdown of the practitioners' responses, shown in the Figure 4 pie chart. Of a total of 82 respondents, 50% (41 respondents) were from the NDE services vendors, 40% (33) worked for nuclear utilities, 6% (5) were from NDE personnel providers, 3% (2) were undefined, and 1% (1 person) was considered freelance. For the purposes of this study, this is a good cross section of the NDE workforce.

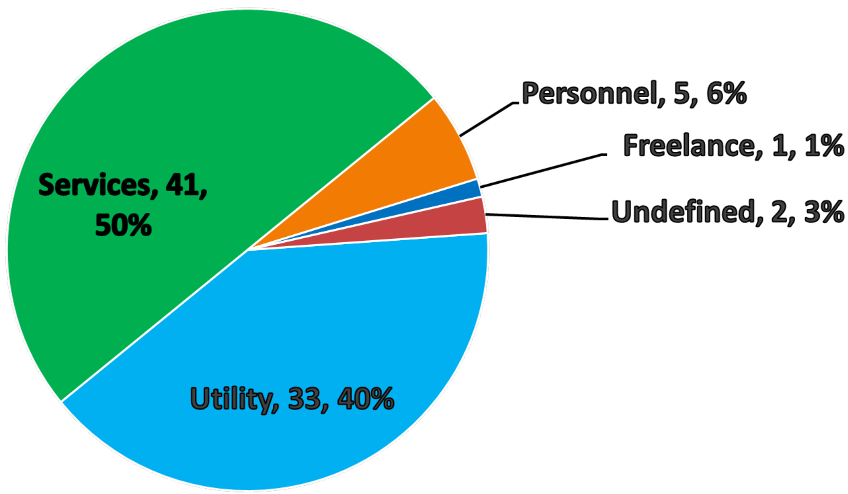

Figure 4. Pie chart breakdown of practitioners' responses

Question 4: How many months per year do you typically work in NDE nuclear power?

Question 4, "How many months per year do you typically work in NDE nuclear power?", is one of the most important questions with respect to job security and stability in this study. Figure 5 shows the breakdown by the category of personnel in the NDE workforce.

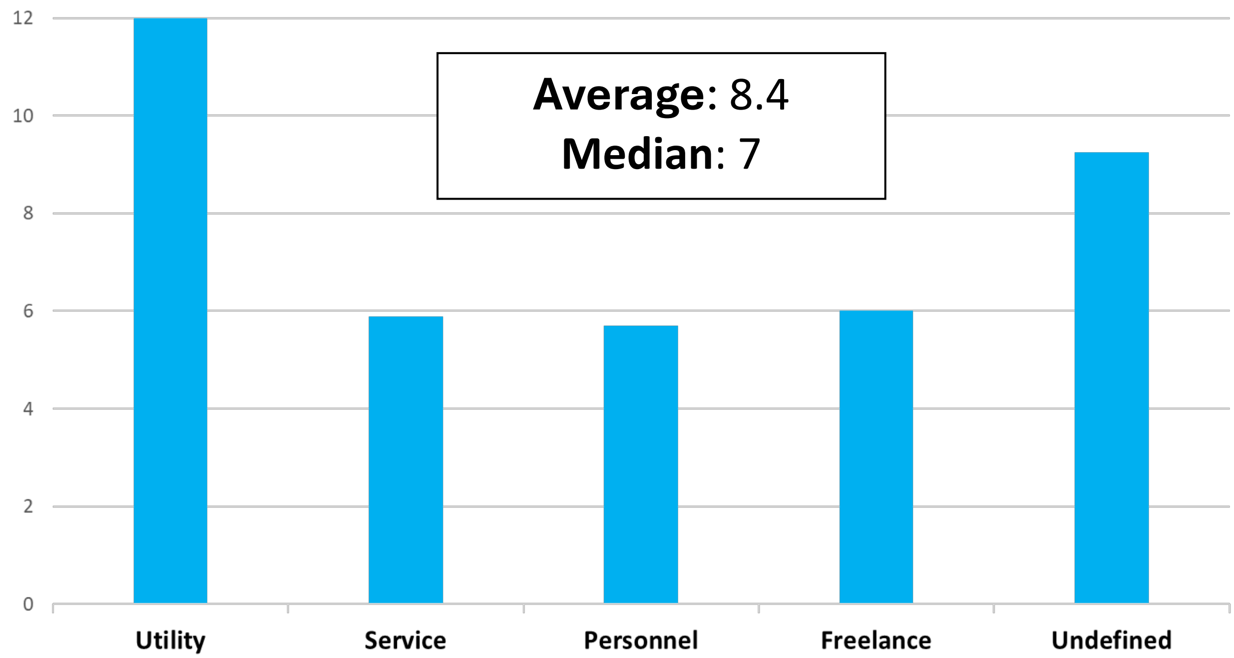

Figure 5. Months per year respondents worked in NDE nuclear power

The months per year worked in NDE nuclear power is an important figure with respect to the NDE workforce. Utility NDE personnel have full-time jobs and are working 12 months per year. The two undefined personnel are working about nine months per year. However, the NDE service vendors, NDE personnel providers, and freelance personnel are working slightly less than 6 months per year. The average work duration per year is 8.4 months. From these figures, it is straightforward to see that the utility NDE personnel have stable work throughout 12 months of the year, which allows them to gain NDE experience, offering future advancement opportunities for career growth and supporting a steady, stable income. The "contracted" NDE workforce, working for NDE service vendors and NDE personnel providers or freelance, are able to work a little under six months out of the year, on average. With six months of work or less per year, it is hard for NDE personnel to efficiently gain work experience that would allow for career advancement and growth and maintain a steady, stable source of income.

Short-duration nuclear power plant refueling outages are the norm in the industry, resulting from electric power grid system operational dynamics and plant operation and maintenance economics. The short outages being performed in only the spring and fall seasons significantly reduce the opportunities and duration that the contracted NDE workforce can work during the year. The key takeaway is that this reduced amount of available work is one of the biggest challenges the nuclear NDE industry has in maintaining its workforce. The nuclear industry power plant owners are adamant about not being able to change the duration and scheduling of the refueling outages in the spring and fall seasons. The industry needs to look for other opportunities to provide relevant work for these contracted workers if they want to gain more NDE work and experience to further their careers. The responses to Question 7 will provide some additional insights into what, if any, additional work outside nuclear is being pursued by the workforce.

Question 5: Are you satisfied with the amount of nuclear NDE work you are achieving, or would you like to see additional work assignments?

Question 5 asks whether the NDE workforce personnel are satisfied with the amount of nuclear work they are achieving or if they would like to see additional work assignments. Figure 6 provides the histogram of the responses.

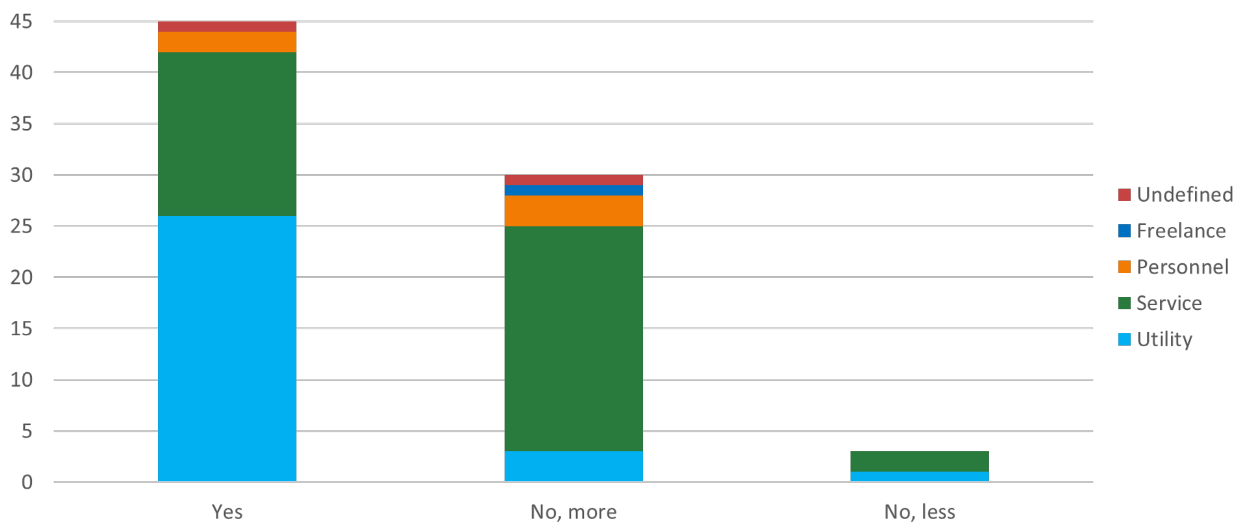

Figure 6. Histogram of responses to Question 5 on satisfaction with work assignments

Of the fewer than 80 responses, 45 of the responses were “Yes” and 30 were “No, more work assignments were desired.” Three responders indicated “No” but wanted fewer work assignments. The majority, 26 of the 45 “Yes” responses, were from utility personnel, which is a good indicator that utility NDE personnel are satisfied with the amount of their NDE work assignments. Of the responses, 30 were “No, more additional work assignments would be desired.” The vast majority of those “No” responses were from the contracted NDE workforce. These responses align with the Question 4 responses indicating that most of the contracted NDE workforce is receiving just under an average of six months’ worth of work assignments. The key takeaway is that this result emphasizes the challenge that the nuclear NDE workforce has in providing adequate work to gain experience and maintain a stable NDE career.

Question 6: In what year do you expect to leave the nuclear NDE field, through retirement or otherwise?

Aligned with Question 4, Question 6 asks the very important question pertaining to attrition of the current and future NDE workforce: “In what year do you expect to leave the nuclear NDE field, through retirement or otherwise?” Figure 7 provides the histogram from the 82 responses, and Figure 8 provides a breakdown of the categories of responders.

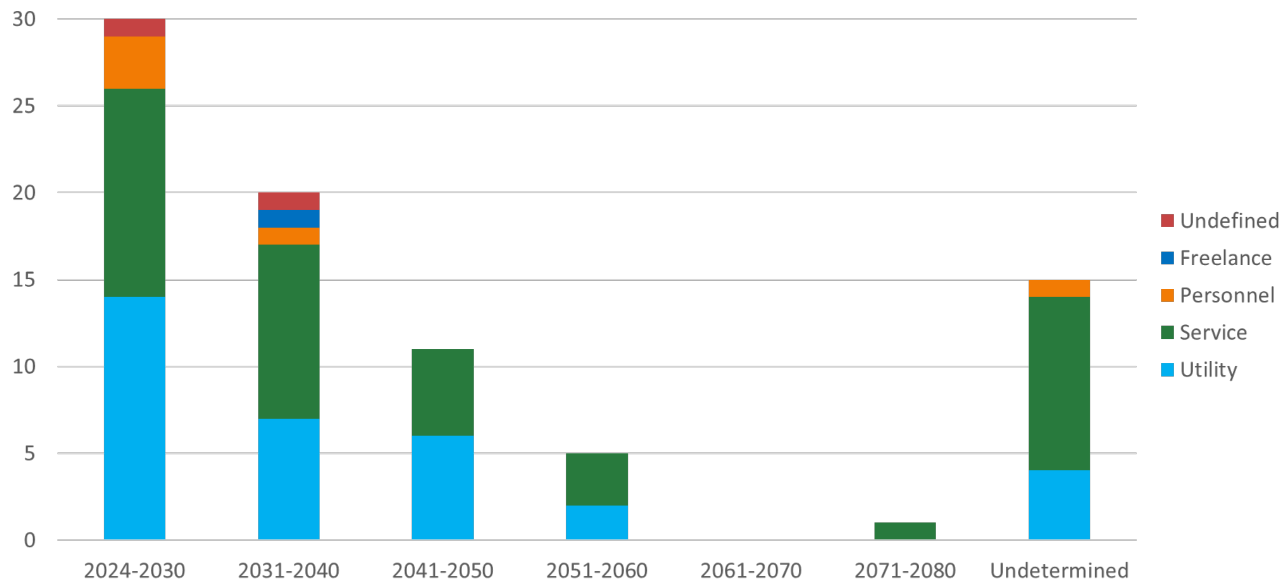

Figure 7. Histogram of responses to Question 6 on what year respondents expect to leave the nuclear NDE field

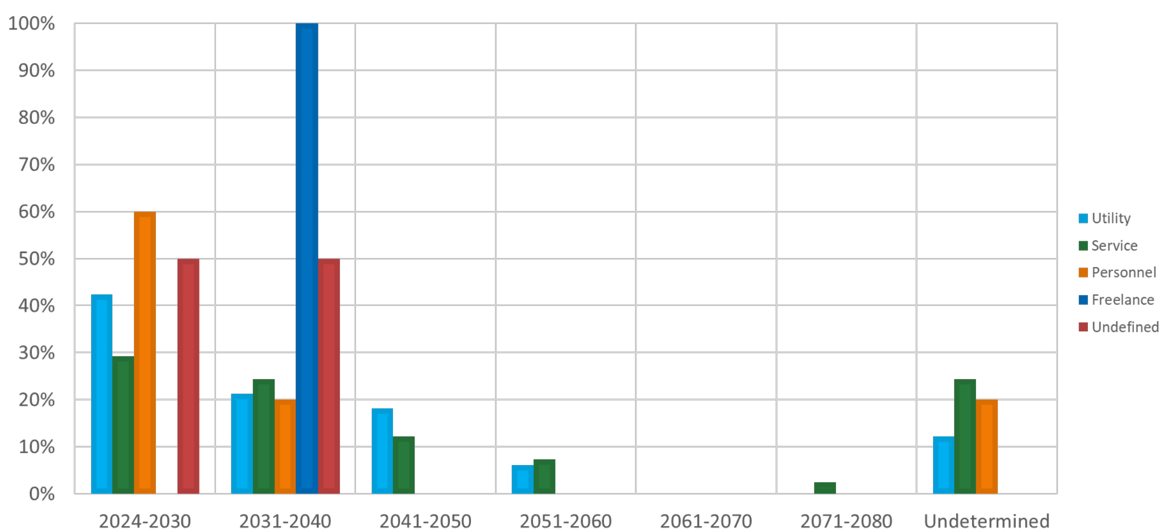

Figure 8. Breakdown of the category of responders to Question 6

The Figure 7 histogram shows the following statistics based on a total of 82 responses:

- 30 of 82 (37%) of the respondents expect to retire in the next six years, by 2030.
- 20 of 82 (24%) of the respondents expect to retire within the following 10-year period, between 2031 and 2040.
- 11 of 82 (13%) of the respondents expect to retire within the 10-year period between 2041 and 2050.
- 15 of the 82 (18%) of the respondents were undetermined.

Figure 8 provides a breakdown of the responses, based on the categorization of the workforce person's employer (utility, NDE service vendor, NDE personnel, freelance, or undefined). These data show that the attrition levels are somewhat similar for the utility, NDE vendors, and NDE personnel categories for the years up to 2040. Note that there are only two members in the undefined category and only one person responding as "freelance," showing up as 100% in the 2031–2040 histogram grouping.

The key takeaway from the responses received to Question 6 is that the nuclear NDE industry is expected to lose 37% of its workforce by 2030 and another 24% by 2040. These data represent a total loss of 61% of the nuclear NDE workforce in the next 16 years, which is a substantial number. These data reflect 82 survey responses, which are statistically significant, especially when the responses are coming from the practitioners, who are directly responsible for making the decision to retire or leave this industry.

For comparison purposes, the results from a 2004 NDE workforce study concluded that in the following 10 years, by 2013, only 37% of the current NDE workforce would remain. More details can be found in the EPRI report *Implementation of Initiatives to Improve the NDE Workforce Gap: Projected NDE Requirements, Workforce Availability, and Related Issues Through 2013* [12]. The last NDE workforce study was performed in 2016 [1]. This report concluded, "In 2016, about half of the NDE workforce was 45 years of age or older and about a quarter of the NDE personnel were 55 or older." These 2016 figures would have predicted that between 25% and 50% (≈37%) would be at or around retirement age in the 2024–2030 timeframe. Many variances can affect the actual outcomes, but based on responses to Question 6, a 37% loss of workforce by 2030 closely resembles the 2016 study data. The 2016 study indicated that 50% of the workforce was 45 years of age or older. Extrapolating the 2016 data would bring their retirement age midway in the 2030–2040 timeframe. These latest study data show correlation with the 2016 data, indicating the continuing attrition of the NDE workforce. The 2030–2040 timeframe also correlates with a critical period when operating plants may be entering the next relicensing period and the advanced reactor plants will be in construction, adding to the risk of having insufficient qualified, capable NDE personnel to serve the industry's needs. This current study clearly shows that the current nuclear NDE workforce is declining in numbers, with age-related retirements being the most likely factor in the attrition. Based on the current study, no current information or data provide evidence that the industry is acquiring new people in sufficient numbers to make up for the attrition. In the future, a more in-depth analysis may be needed to get more accuracy in the actual current workforce numbers to predict future needs.

The key takeaway from Question 6 data is that the nuclear NDE workforce continues to decline in numbers and industry actions are necessary to correct this risky trend to ensure a steady, stable, and competent NDE workforce for the future.

Question 7: Do you provide NDE to other industries outside of nuclear? If so, in what industries, and give reason(s) why you feel it is necessary. If not, why do you feel it isn't necessary?

The responses to Question 7 are a corollary to the responses to Question 4 on the number of months worked in nuclear NDE. Figure 9 is the histogram of the responses to Question 7 on whether practitioners work outside the nuclear NDE industry.

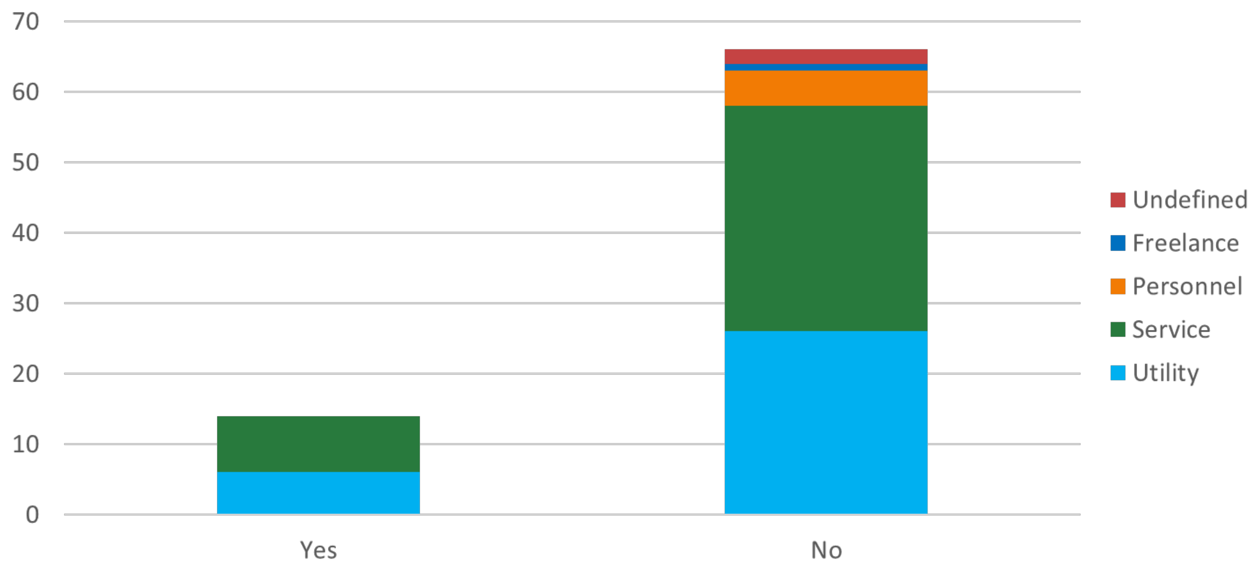

Figure 9. Responses to Question 7 on supporting work outside nuclear industry

Of the 82 respondents, 65 (79%) indicated that they did not work in any other industries outside nuclear. Only 17 of the 82 (21%), representing utility and NDE service vendor personnel, indicated that they did work outside nuclear. Five of the 17 were utility NDE personnel who were required to provide NDE support for their utility's other power generation assets. These data directly correlate to the average months of nuclear NDE work per year, with utility staff and contracted NDE vendor and personnel provider personnel included, of 8.4 months. Information from practitioners and service vendor personnel indicate that outside NDE work opportunities either are not available or are not being presented to personnel to ensure that personnel stay available to the nuclear NDE workforce pool. The key takeaway is that through collaboration and coordination with other NDE industries, outside opportunities should be made available to allow personnel to work during times when they are not supporting nuclear outage work.

Question 8: Do you feel there are adequate advancement opportunities afforded to you to continue working in nuclear NDE?

Figure 10 is the histogram of responses to Question 8 on adequacy of advancement opportunities to continue working in nuclear NDE.

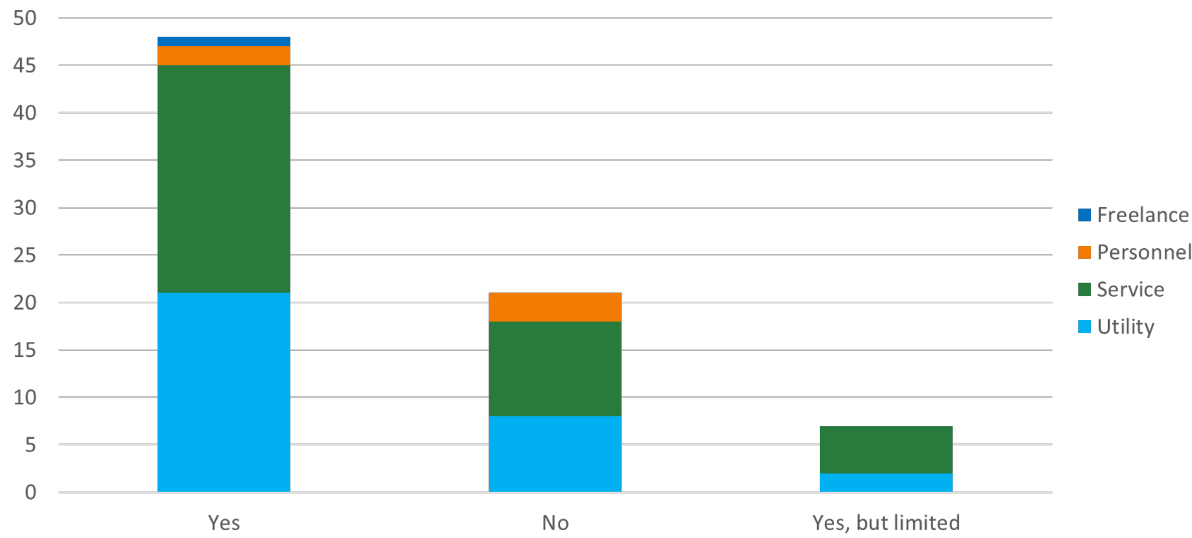

Figure 10. Responses to Question 8 on adequacy of advancement opportunities to continue working in nuclear NDE

The majority (48 of 82) of responses were “yes,” with most coming from utility and NDE service vendor personnel. The following are examples of responses to Question 8 on adequacy of advancement opportunities:

Yes:

- “Yes, opportunities for growth are plentiful. I have only run into a couple instances that I was kept from learning something new, but it kept me from being exposed to more negativity, so it worked to my benefit.” (Service)

No:

- “No. If I want to advance, I will have to change companies or go into a utilities job.” (Freelance)
- “No, growth is so slow and higher opportunities are rare.” (Utility)

Yes, but:

- “Yes and no. Some people get stuck in a spot because of the lack of individuals in the industry; others find ways to advance.” (Service)
- “Yes and no, the path to Level 3 certifications does exist; however, there are limited Level 3 positions and once a person is a Level 3 there isn’t much further we can go.” (Service)
- “Yes, but once you have reached Level 3 status, unless you have an engineering degree you are pretty much topped out.” (Utility)

Although most responses (≈59%) indicate a straight "yes," the remaining responses (>40%) and comments suggest that a clear path toward advancement opportunity seems hard to achieve. Some comments specifically tie to attaining Level III certifications. The difficulties in gaining field experience because of short-duration outages and job assignments are a key contributor to the challenges to personnel trying to advance their careers. The key takeaway is that industry must create, develop, communicate, and implement advancement opportunities for competent NDE personnel seeking to gain more experience and career advancement.

Question 9: Do you feel your company has invested in your future development, such as training, and are you willing to make the same investment in time and dedication?

Figure 11 provides the histogram of the responses to Question 9 on investment for future development.

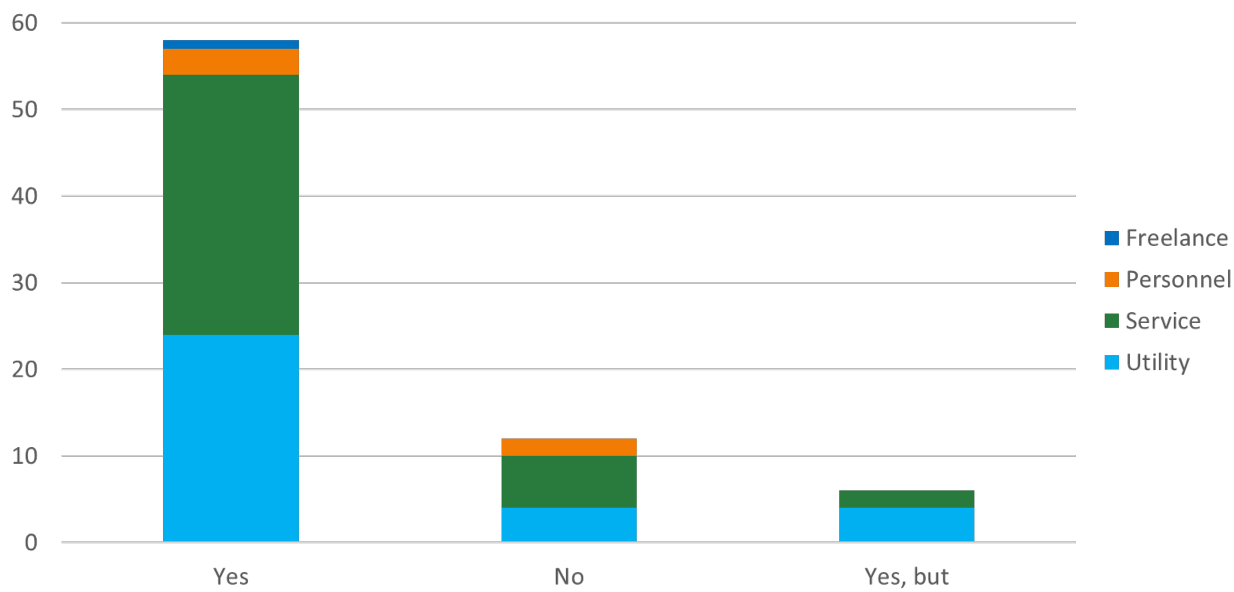

Figure 11. Histogram of responses to Question 9

The following are examples of the responses to Question 9 on companies' investment in practitioners' future development:

Yes:

- "I feel dedicated to the company I work for because of that investment and the overall way that I am treated." (Personnel)
- "Yes, they have. Many off seasons have had the opportunity for training classes." (Service)

No:

- "There needs to be more training for the newer workers within the industry." (Personnel)
- "My company does not do a good job in investing in our future development." (Utility)

Yes, but:

- “Partially. Due to current exit of long-term employees and the delay in replacing employees, time is a commodity.” (Utility)
- “I think the company invests the bare minimum in employees. The investment is made by the employees learning a new role and the other employees mentoring.” (Service)
- “I do but it’s also not in the direction I wanted it to go. I feel like my company just pushed me in the path they needed from me instead of the one I would’ve chosen.” (Service)

As with Question 8, the “Yes” responses (58 of 82, 70%) to this question on the company’s investment to the practitioners’ development are positive. Once again, the difficulties in gaining field experience owing to the short-duration outages and job assignments hinder a company’s ability to further develop entry- or lower-level NDE personnel. Gaining NDE experience takes more time because of short-duration outages and work assignments; that time is measured in years, not weeks or months. The key takeaway is similar to that of Question 8 in that industry must develop, communicate, and implement advancement opportunities for competent NDE personnel who seek to gain more experience and career advancement.

Question 10: What is your opinion of current nuclear NDE work scope durations? What would you like to change if you were royalty for a day?

Figure 12 is a histogram of the responses to Question 10 on opinions of the current nuclear NDE work scope durations.

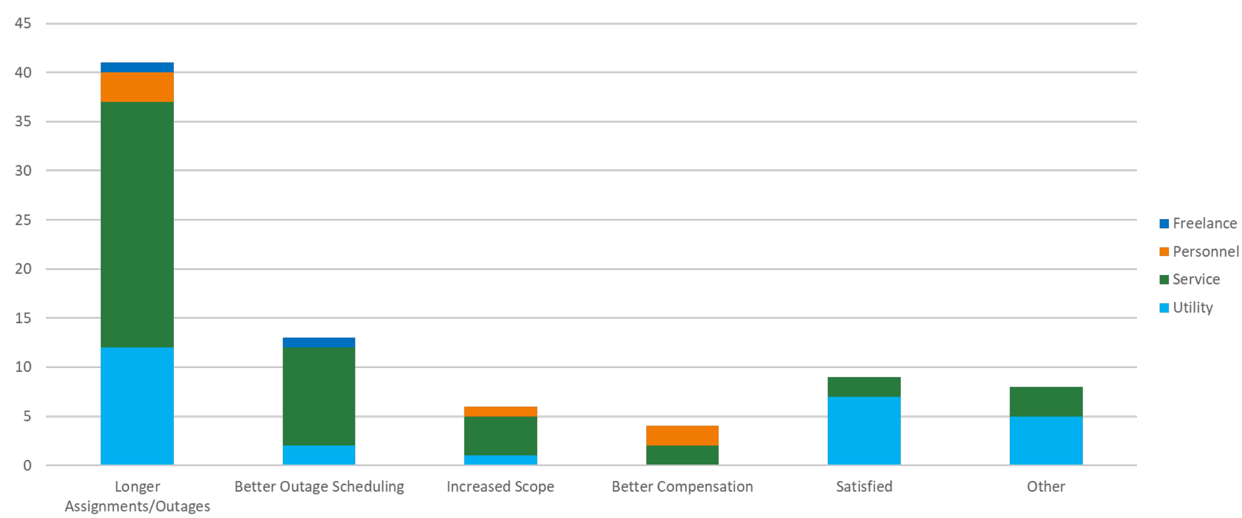

Figure 12. Histogram of practitioners’ opinions on current nuclear work scope durations

About 75% of the responses, representing all categories of practitioners, indicate discontentment with the current work scope durations, citing need for longer assignments/outages, better outage scheduling, increased scope, and better compensation. Only 10% of respondents were satisfied with the current outage work scope durations. These data correlate with Question 4 on the months per year worked in nuclear NDE, and Question 5 on satisfaction with the amount of nuclear NDE work assignments. The responses indicate a desire for more work through longer work assignments/outages. As explained in Section 2, the industry has evolved from its early days of months-long refueling, maintenance, and inspection outages to outages that are only weeks long, performed during the spring or fall. This has reduced the NDE work assignments considerably, especially for the contract NDE workforce. The reductions in work assignment durations make it more difficult to gain needed field experience in the various NDE methods, which reduces career growth opportunities and, more importantly, makes it difficult to maintain a steady, stable income to support a good work–life balance.

The key takeaway is that the nuclear NDE industry needs to find better ways and more opportunities for NDE practitioners to get more work, including longer work assignments that allow them to gain needed work experience to maintain a more steady, stable income that supports a good work–life balance and a rewarding career.

Question 11: Is the salary paid for non-nuclear NDE workers comparable to nuclear NDE workers? Why do you feel it is different?

Figure 13 is a histogram of the responses to Question 11 on the comparison of salary paid for non-nuclear NDE workers versus those for nuclear NDE workers.

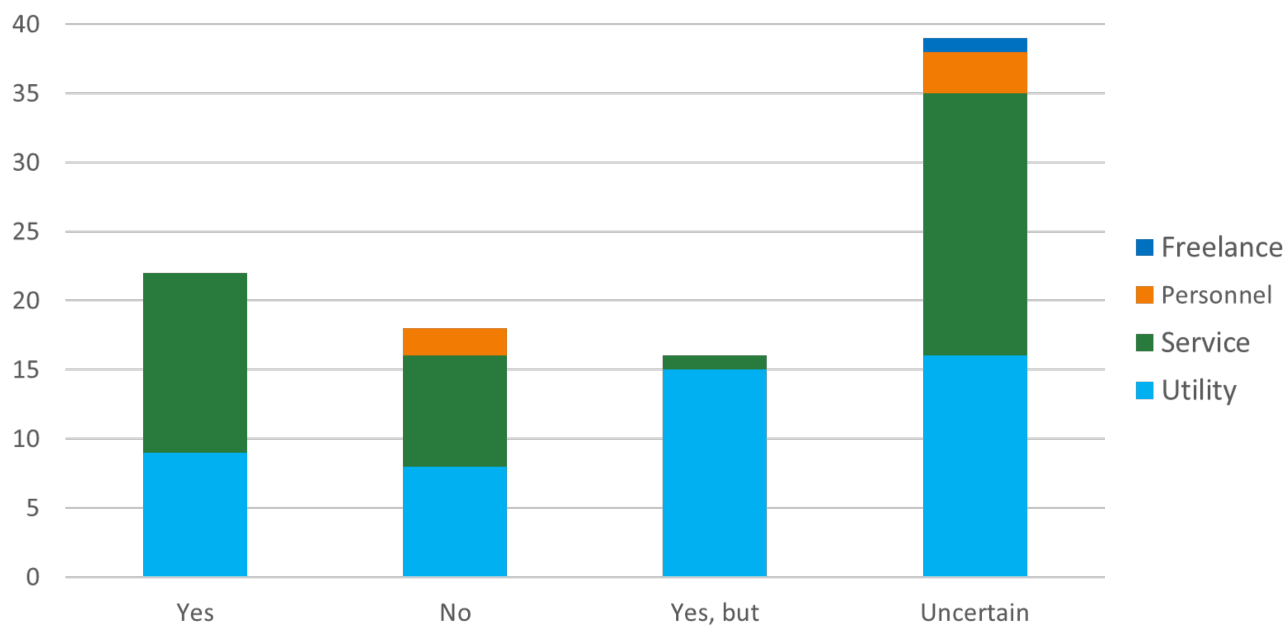

Figure 13. Histogram of NDE practitioners' responses to comparison of salaries between non-nuclear NDE and nuclear NDE workers

The following are examples of the responses to Question 11 on the comparison of salary paid for non-nuclear NDE workers versus nuclear NDE workers:

Yes:

- "Yes. All the other energy divisions are catching up to nuclear." (Service)
- "Yes, according to non-nuclear workers spoken with." (Utility)

No:

- "No, I think nuclear workers travel more, are gone on longer assignments, and sometimes are in riskier positions to earn that higher pay." (Personnel)
- "NO. DOD and Aviation salaries for NDE personnel are the only comparable pay scale to nuclear. "(Utility)

Yes, but:

- "Yes and no. The salary for a year is made within half that time. If the work provided is more than what is given, the salary would be much higher. Other than that, the salary can arguably be comparable." (Service)

N/A:

- "Not sure what they make at other places." (Service)
- "Since I've been at one site for 27 years, I am not familiar with wages of non-nuclear NDE workers and have not looked for NDE work outside of nuclear." (Utility)

The "Yes" and "Yes, but" responses represent about 50% of the overall responses and indicate that nuclear NDE practitioners are, in general, paid better than some of their non-nuclear counterparts. The responses reflect NDE industry salary information from a 2019 NDE industry salary study that is posted on the PQNDT organization website, www.pqndt.com. Although these responses are positive, one comment, "The salary for a year is made within half that time," reflects the reality of the true salary situation for a typical contract nuclear NDE worker. On an hourly rate basis, nuclear NDE workers are paid at a higher rate, but for an hourly contract worker that does not translate to a higher annual pay/salary. The "Uncertain" response by almost half of the respondents reflects that most of the practitioners are not aware of what their counterparts in other industries are paid on an annual basis. The key takeaway is that even though nuclear NDE workers' annual base pay may be above other non-nuclear NDE workers' pay, the apparent pay advantage is negatively affected by the shorter-duration availability of steady, stable work.

Question 12: What types of incentives would you like to see to retain your commitment to support nuclear NDE?

Figure 14 provides a histogram of the responses to the question of what incentives NDE practitioners would like to see to retain their commitment and careers to support nuclear NDE.

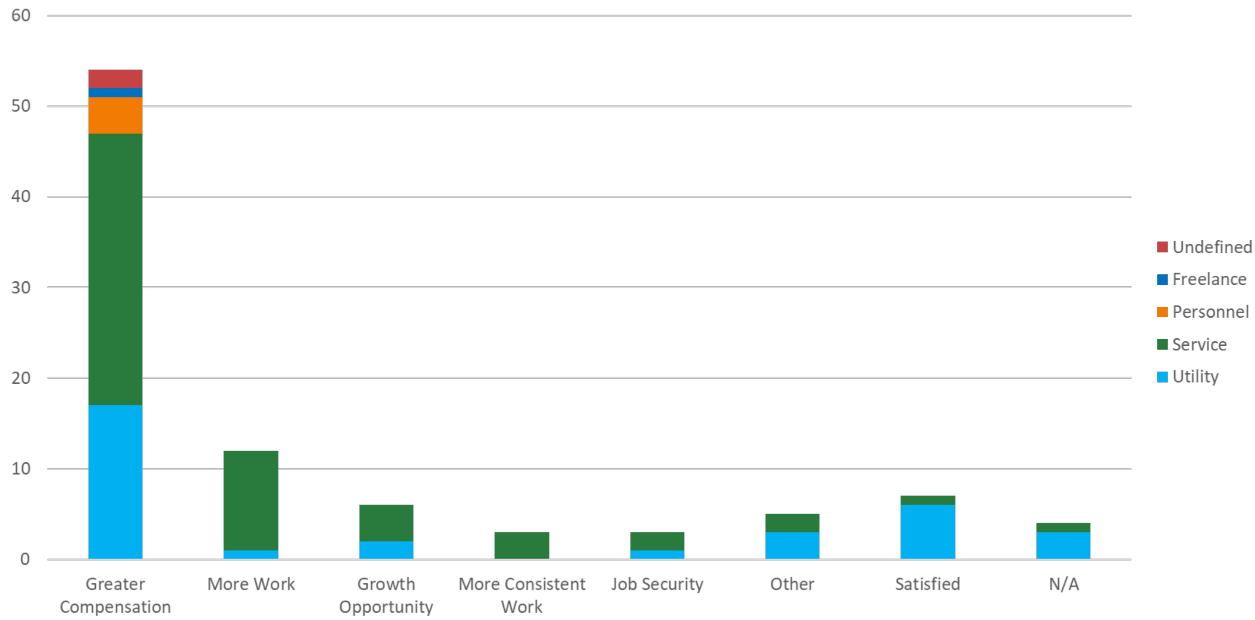

Figure 14. Histogram of responses to Question 12 for incentives to NDE practitioners to continue to support nuclear NDE

Most responses to Question 12 on incentives needed for NDE practitioners to continue support of nuclear NDE follow the common themes of greater compensation, more work, growth opportunities, more consistent work, and job security. Less than 10% of respondents indicated satisfaction with their work. These responses directly correlate to the input received on the previous five questions. The key takeaway is that the industry's workforce issues stem primarily from perceptions of poor assignment duration, job growth potential, and job security and stability. Ideas around improving these situations and perceptions would likely serve to improve the overall retention of NDE practitioners in this business.

Question 13: What are the attributes of a utility or site you like to work for?

Figure 15 provides the word cloud of the responses to Question 13 on the attributes of a utility or site respondents like to work for.

Figure 15. Word cloud of responses to Question 13 on the attributes of a utility of site that NDE practitioners like to work for

The key takeaway shown from this word cloud is that NDE practitioners desire the same things that most people would like in their working environments: consistent work, good people, helpful and considerate management, integrity, teamwork, safety consciousness, and a pleasant working environment. While supporting nuclear outages, most NDE practitioners are working away from home and their families, and they simply want a safe, pleasant environment where their efforts are appreciated.

Question 14: What are the attributes of a utility or site you do not like to work for?

Question 14 is the inverse to Question 13: "What are the attributes of a utility or site you do not like to work for?" The responses to Question 14 are shown in the word cloud in Figure 16.

Figure 16. Word cloud of responses to Question 14 on the attributes of a utility or site that NDE practitioners do not like to work for

The key takeaway shown from this word cloud is that NDE practitioners do not like to work in an environment where they are feeling stress, demands, and pressure from management on the outage schedule, time, and work completion, coupled with lack of support and a safe, conscientious workplace. With many NDE activities, the examination results may not always be positive, such as the detection of a relevant indication or a flaw. Unfortunately, NDE personnel are the messengers of those results, which may not be received well by the end user. This can result in negative interactions between NDE and plant personnel that can lead to future poor perceptions by the NDE practitioners. Like the responses to Question 13, the NDE practitioners simply want a safe, pleasant work environment, where people work together as a team and their conscientious work is appreciated.

Question 15: Do you feel there are enough nuclear NDE personnel in the industry to support current needs and future needs? Why or why not?

Question 15 asks if there are enough nuclear NDE personnel to support the current and future industry needs and is a very important question in the context of this workforce study. Figure 17 is the histogram of the responses to Question 15 from the perspective of the practitioners who represent the current nuclear NDE workforce. Examples of their responses are also shown here.

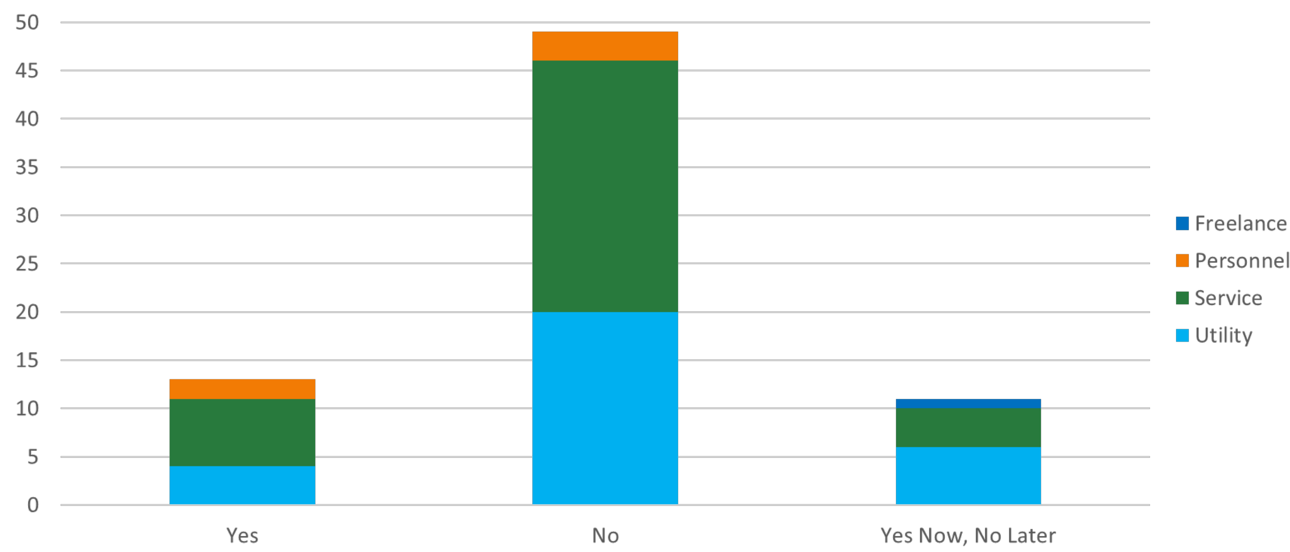

Figure 17. Histogram of response to Question 15, as to whether there are enough nuclear NDE personnel to support the current and future needs

The following are examples of the responses to Question 15:

Yes:

- “Yes, because right now the nuclear industry isn’t really growing.” (Utility)

No:

- “No, I do not, and it’s hard for someone starting out in the business because of stacked outages, the sites cutting personnel hours as much as possible.” (Service)
- “No. Many are leaving due to the lack of wages. They can be at home and make the same amount of income as working 16 weeks a year in nuclear.”

Yes, but:

- “Yes, but there does seem to be a changing of the guard with large groups getting older and ready for retirement.” (Freelance)
- “Current? Yes, I think we manage, but as far as future support, I think more people need to be trained.” (Service)
- “At the moment we are at the tipping point and will soon, not many years from now, be at the crossroads of a dire need for a more experienced work force.” (Utility)

Over 60% of the responses were negative. Even the “yes” and “yes, but” comments recognize a declining trend in the current nuclear NDE workforce, with potentially more impact in the future. The key takeaway is that there is clearly a declining trend in the nuclear NDE workforce. The NDE practitioners see the changes and the effects directly: coworkers retiring or leaving the industry; senior, more experienced Level IIs and IIIs no longer there to give advice; and few, if any, new people entering the industry. At the practitioner level, this trend can be dismal, a demotivator. A comment from a utility person highlights the situation: “At the moment we are at the tipping point and will soon, not many years from now, be at the crossroads of a dire need for a more experienced workforce.” This clearly emphasizes a “call for action” now from all the nuclear NDE workforce stakeholders.

Question 16: Have you or would you recommend NDE as a future career path to members of your immediate family? Why or why not?

Question 16 provides an interesting perspective and asks whether respondents have or would recommend NDE as a future career path to members of their families. Figure 18 is the histogram of the response to Question 16.

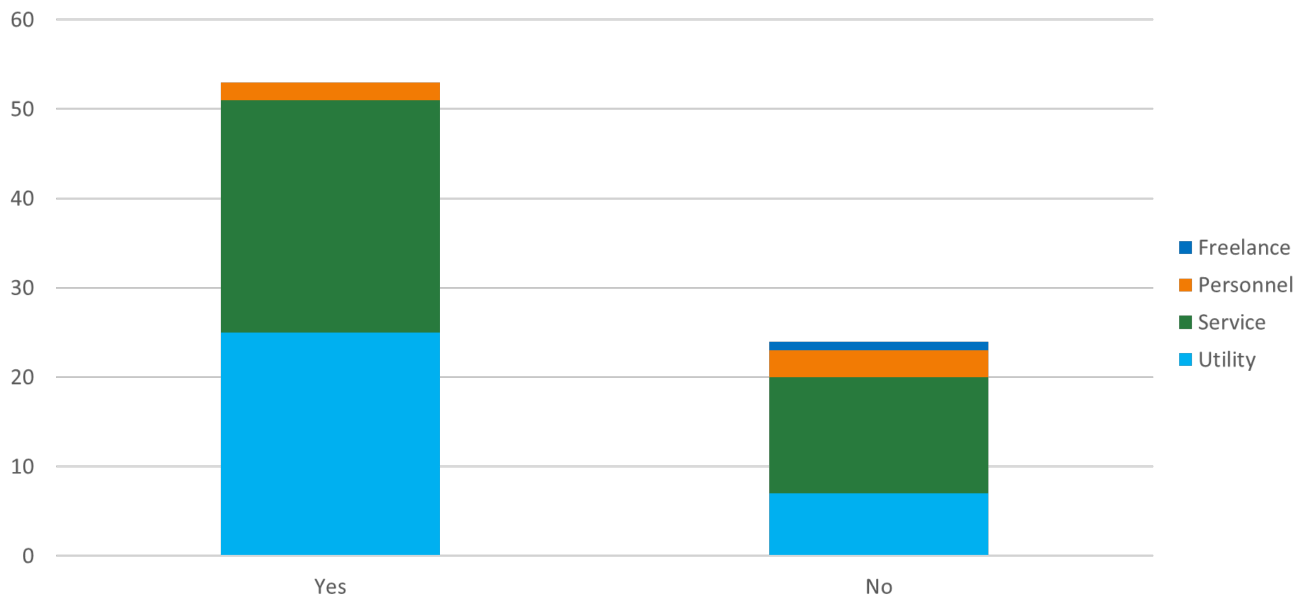

Figure 18. Histogram of responses to Question 16, would respondents recommend NDE as a career path to members of their families

The “Yes” responses outnumber the “No” responses by a factor of 2 to 1, which is a positive. The “Yes” responses included comments about future opportunities but added the caveats that one needs to consider negative factors such as travel, work duration, and stability. Most “No" responses indicated not seeing future opportunities or career growth, too much travel, and not enough work. These responses reflect similar responses and comments to Questions 1 and 2. The key takeaway is that the responses are positive and that a majority of the current NDE practitioners would recommend a career in NDE to their immediate family members but recognize the negative aspects of choosing a career in NDE.

Question 17: Do you expect the workload to be about the same during the next couple of years? Or is this unknown?

Question 17 asks the question whether the practitioner expects the workload to be about the same during the next couple of years or is it unknown. This question is a corollary to Questions 5 and 10, about satisfaction with amount of work and opinions about current nuclear work scope durations. Figure 19 is the histogram of the responses to Question 17 on expectations of the workload for the next couple of years.

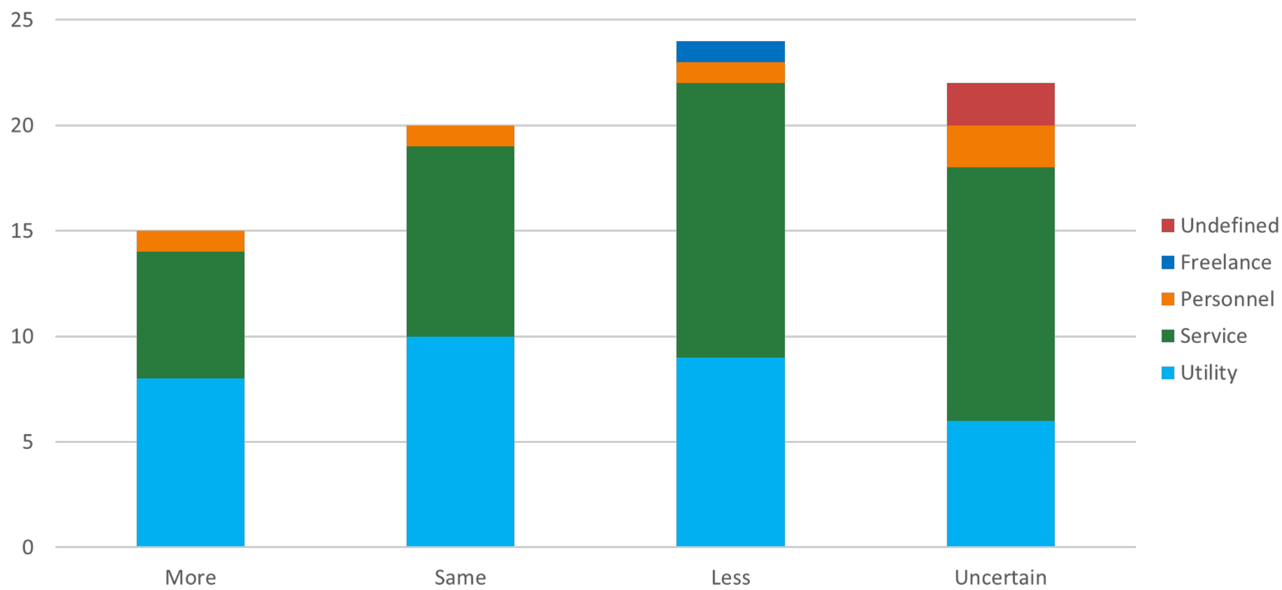

Figure 19. Histogram of responses to Question 17 on expectations of the workload for the next couple of years

The responses to Question 17 show that only about one in five practitioners expect the workload to increase in the near future. The distribution of the responses is probably reflective of the information that the NDE practitioners are likely to hear from their industry peers about future outage durations and workload. Although utility personnel may have better access to information on future outage duration and workload for their plants, it is unclear if the information given to them is well informed or from the actual decision makers. The key takeaway is that although the practitioners are interested in and have expectations about their future two-year workload, their perceptions may be based on hearsay and not facts, reflecting uncertainty in their responses.

Question 18: Which of the following qualifications do you have? Do you expect to have this qualification by 2030?

The last portion of the NDE practitioners' survey was a checklist on the NDE practitioners' current NDE qualifications and expected future qualifications. The checklist was broken down by NDE level and each NDE method. For ultrasonic examinations, it was further broken down by the ASME Section XI Appendix VIII examination supplements, current and future. The UT certification data, shown below, provide a representative perspective on the current and potential future state for examiners' certifications, in general. Figure 20 presents the histogram of responses for the current number of ultrasonic qualifications. Figure 21 presents the histogram of responses for the number of UT qualifications after 2030.

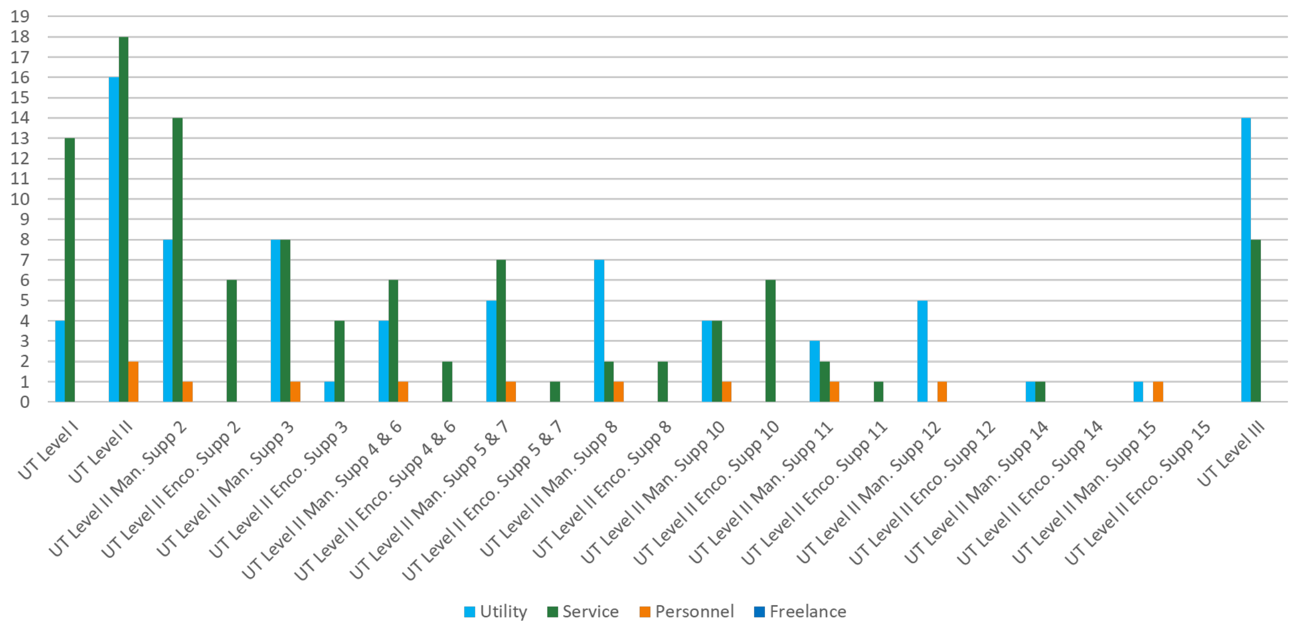

Figure 20. Histogram of responses for the current number of UT qualifications

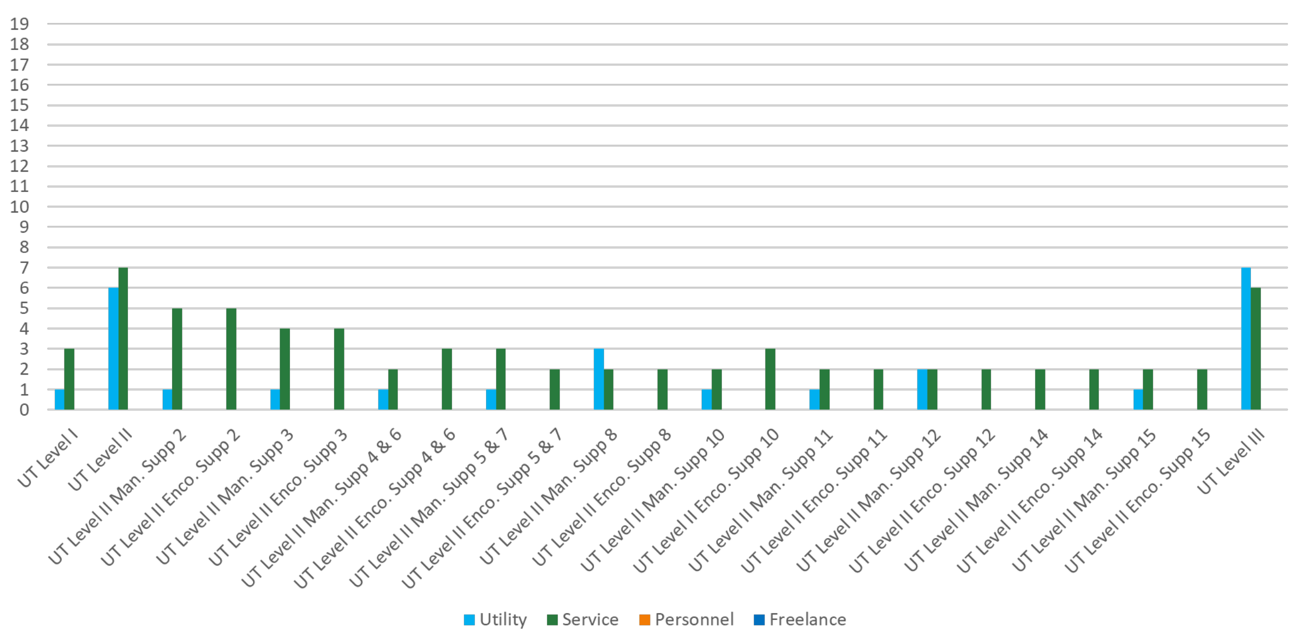

Figure 21. Histogram of the responses for number of UT qualifications after 2030

The survey responses shown in both Figures 20 and 21 reflect the data from more than 80 responses to the NDE practitioners' survey. The "after 2030" data clearly show a significant downward trend between the current number of qualifications for almost every examination supplement category. This fall-off is attributable mainly to the loss of personnel in the NDE workforce due to attrition but is perhaps also reflective of the uncertainty about the long-term career prospects of the individuals responding to this survey. The key takeaway is that these data reflect a significant downward trend in the number of qualified UT personnel available to perform future examinations, which both creates a potential difficulty for utilities in completing required outage scope and indicates the need for a large, required investment, on the part of the industry, to qualify personnel to replace what has been lost to attrition.

Summary of Utility, NDE Service Vendors, and NDE Personnel Provider Survey Responses

The purpose of these questionnaires was to gain information on the numbers of NDE personnel who are currently used for both a typical outage and a heavy outage, broken down by examination category or requirement, NDE method and type, and qualifications. In addition, the questionnaires requested estimates for 5 to 10 years in the future, in terms of these same outage needs. Unfortunately, the response rate to these surveys was less than desired. For the surveys that were received, the responses were difficult to analyze into any usable quantitative data about the far future, even after attempts were made to get clarification. The responses were not consistent in that some did not address all the requested information, and many did not address the future needs. The inconsistencies in the responses were likely due to the complexity of the questionnaires and a deficiency in the provided instructions. After numerous attempts to analyze, summarize, and simplify the data from these survey responses, it was decided that the data were not usable for the quantitative information needed to obtain numbers of NDE personnel needed to support current and future outages. Based on the NDE Workforce Focus Group's input, another survey could be developed and issued to the NDE workforce stakeholders to get data that would be usable for obtaining the quantitative data needed to analyze current and forecast future NDE workforce needs.

Even though the utility, NDE service vendors, and NDE personnel provider survey data will not be used for quantitative data, some of the qualitative information provided in the responses may be useful, as follows:

- The utility survey responses showed that many utilities limit use of Level I personnel for only flow-assisted-corrosion (FAC) examinations or do not use Level I personnel at all. FAC examinations are good examinations for ultrasonic Level I/trainees to gain some basic field experience, but the usable ultrasonic method experience from these exams is somewhat limited in nature. Given the issues associated with NDE personnel gaining required field experience, it would be better for utilities to integrate the use of Level I personnel for other, more advanced ultrasonic examination types and for other NDE methods in general for the typical outage support.
- For the utilities submitting responses for the 5- and 10-year forecasts, the data were typically the same as the current data. Over the years, many utilities have taken steps to levelize their outage inspection workloads, but the data do not indicate whether levelization was involved.

- The number of Level III personnel supporting an outage is critical to successful management of inspection completion, analysis, resolution of technical issues, and closeout of inspection outage work. However, the data on Level IIIs used for an outage were inconsistent among utilities. Although differences between reactor type and inspection work scopes may explain some of the variances, it seems likely that not all Level IIIs being used were properly accounted for in some surveys. If any future survey is carried out, it should be specifically designed so that all Level IIIs are documented and accounted for accurately.
- After discussions with one personnel provider and a review of some survey responses, it was determined that some of the NDE personnel required for Boiling Water Reactor Vessel Internals Project (BWRVIP) and Materials Reliability Program (MRP)-required examinations were not factored into the survey responses, in terms of outage NDE manpower needs. This could result in a significantly underreported need for personnel. For instance, BWRVIP in-vessel visual examination personnel can account for an additional 16 to 40 qualified visual examination personnel needed, depending on the work scope, for a typical to heavy outage. Any future NDE workforce surveys should consider improving the survey design and the survey questions to ensure that BWRVIP and MRP-required examination scopes are factored in when answering questions around manpower needs.
- The assumptions used for reporting qualified level IIs varied in the responses. Discussion with respondents indicated that some of the personnel numbers may or may not have reflected overlapping use of the same qualified individuals for various categories and examination methods. This results in either overstating or understating the actual numbers of personnel supporting the outage. If another survey is conducted, clearer questions or more detailed instructions should be provided to ensure that personnel numbers are fully accounted for and are not potentially conflated.

The key takeaway from these surveys is that the survey questionnaires were too complex to obtain the quantitative data that were being sought on the numbers of NDE personnel needs, both in current and projected future outages. However, there are aspects of the numbers and other information provided that can be useful in future discussions on decisions about what actions are needed to resolve the declining nuclear NDE workforce.

4 FACTORS AFFECTING THE NDE WORKFORCE

This section of the report provides a discussion of various industry factors that play an important role and need to be considered when considering the future of the nuclear NDE workforce.

Technology Advancement and Digital Transformation

Globally, industry is currently in the digital age, or what is called the *digital transformation*. What constitutes the digital transformation? Digital transformation is the adoption of digital technology by society or organizations to develop new innovative products or processes that create new industries or disrupt existing ones. For example, according to several published reports, over 90% of the U.S. population have cellphones, and 85% of the population have smartphones. Most smartphones' computing power likely exceeds the capabilities of large mainframe computers used by industry and by educational and research institutes during the 1970s and 1980s. Smartphones are definitely a disruptive digital technology. It is a technology that is always moving forward in all aspects of our lives and progressing to improve industry, productivity, and the economy while trying to make life better. The world, industry, and the domestic public are definitely in the digital transformation.

Most U.S. nuclear plants were designed using technology of the 1960s–1970s and were constructed and progressed into operation in the 1980s through 1990s. These plants are still operating safely, effectively, and efficiently based on the 1960s' analog technologies. Although digital instrumentation and control technology is available to update and modernize operating plants, plants are resistant to implement these changes because of the regulation and licensing burden associated with the review and approval to upgrade and replace existing licensed technology. Although technologies continue to advance and improve, it is often difficult to implement them in operating nuclear power plants.

NDE serves a very important role in ensuring the safety and structural integrity of components in the nuclear plants. For example, for UT technology, the NDE industry has improved its detection capabilities, reliability, speed, and efficiency. Through these technology advancements—along with industry initiatives to develop codes, standards, and guidelines—the industry ensures that only the best, optimized, and performance-demonstrated NDE equipment, procedures, and personnel are used to meet the ASME Section XI volumetric examination requirements. For many volumetric examinations, improvements in computer technology allowed the progression from analog to advanced digital UT instruments. UT technology transitioned from manually acquired and evaluated radiofrequency signal readout data to digital instruments with multiple element phasing and high capacity and speed computing, allowing faster data acquisition and recording, as well as improved imaging capabilities. These computer-based technology advancements have resulted in the successful evolution for UT flaw detection and reliability improvements. Similar advancements have been made in the camera and manipulator technology applied to remote visual examinations, which are used for numerous inspections of critical reactor internals components.

As the digital transformation progresses, globally, industries are developing and implementing advanced technologies to improve the acquisition and analysis of critical data that allow them to improve and streamline processes, manufacturing methods, and products to improve the quality of life. Robotics, automation, unmanned aerial vehicles, autonomous mobile robots, data science and analytics, artificial intelligence (AI), artificial reality (AR), and virtual reality (VR) are the technology enablers for this digital transformation. Industry is just beginning to learn how to develop and implement these technologies to provide value for society's industrial, data processing, manufacturing, and product needs. The digital age/transformation presents itself as both an opportunity and a concern as industry tries to determine how to use these transformative technologies. For NDE, it allows new ways to acquire, analyze, and process examination data and to make the data readily accessible and usable to the end user and stakeholders. It is a step change that will drive the industry to assess capabilities and comfort levels for allowing computers and AI to process and analyze data to make better decisions.

For continually advancing technologies to be truly effective and advantageous, the workforce must be knowledgeable and competent in their use. The digital transformation will cause the NDE industry to evaluate and advance NDE skill sets so that its workforce will possess more computer literacy, digital, scientific, and engineering skills. It will also require the industry to evaluate, revise, and/or develop new codes and standards, guidelines, and training programs that will address the changes needed to adapt to the digital transformation. Technology will always advance, but this digital transformation step change offers the opportunity to step back and take a much broader assessment of all the critical areas in the nuclear NDE industry, in the context of training, qualification, and guidance for the workforce, to ensure success in the future.

NDE Workforce Stakeholders' Roles

This section explains the different roles of nuclear NDE workforce stakeholders to better understand the challenges and differing perspectives in implementing actions needed to address the workforce issues.

1. **Utilities**: Utilities are typically the nuclear power plant owners/operators and the reactor operator licensees that have been granted licenses from the regulator. They are the end users for NDE services. With respect to NDE, the utility/plant owner is responsible for compliance with the in-service inspection requirements of ASME Section XI [8,10], as modified by Title 10 of the Code of Federal Regulations—10 CFR 50.55a. Within the utility, there are other NDE-related stakeholders, as follows:
   - Engineering personnel: Rely on NDE personnel to provide reliable inspection and NDE information for performing engineering evaluations and structural assessments of components and systems.
   - NDE personnel: Perform and oversee NDE activities in the plant, evaluate the results, and communicate the results to the appropriate plant personnel, such as systems engineering, maintenance and operations, and plant management. Senior NDE personnel, like Level IIIs, may also be in-service inspection or FAC project managers as well as training, qualification, and certification program administrators.

- Maintenance and operations personnel: Rely on NDE personnel to provide reliable inspection and NDE information on plant component condition to assess and make decisions about component and system operability.
- Plant management: Rely on NDE personnel to provide reliable inspection and NDE information to engineering, maintenance, and operations personnel to make informed decisions concerning the safe and efficient continued operation of plant components and systems.

2. **NDE service vendors and personnel providers**: These entities provide qualified NDE personnel and equipment to support performance of NDE at the plant. NDE service vendors provide both NDE services and personnel, whereas NDE personnel providers primarily supply only qualified NDE personnel to NDE service vendors or directly to utilities. Both of their roles are critical and important for the NDE workforce, as they acquire, hire, train, certify, and pay the needed NDE services and personnel.
3. **NDE equipment suppliers**: These are designers and manufacturers of NDE equipment, which includes NDE instruments (hardware and software), manual or automated delivery tooling and equipment, search units, and other ancillary equipment. In general, the NDE equipment suppliers sell their equipment to NDE service providers or to the utilities for use in the nuclear power plant examinations.
4. **NDE practitioners/examiners**: These are the individuals who are trained, are qualified, gain experience, and are certified in accordance with industry codes and standards to perform NDE at operating nuclear power plants. These individuals typically work through an NDE service vendor or personnel provider.
5. **NDE consultants**: NDE consultants represent another group of contracted NDE experts who provide technical support, oversight, and governance of NDE examinations for utility personnel before and during outages.
6. **Educators and NDE training organizations**: These are organizations, such as NDE trade schools, community colleges, and other educational organizations providing NDE training, laboratory experience, qualification, and certification services.
7. **Research and development (R&D) organizations**: These are organizations, such as universities, private or not-for-profit institutes, or government-funded national laboratories that perform R&D of new and advanced technologies to support the NDE industry. The R&D organization's role is to advance technologies and provide guidance to assist the NDE workforce and the industry in improving NDE capabilities and reliability.
8. **Codes and standards agencies**: These are the organizations, such as the ASME, the ASNT, and American Society for Testing and Materials (ASTM) that play a key role in developing, reviewing, and issuing codes and standards to be adopted by industry and the regulator for use at nuclear power plants. The role of codes and standards is critical to the NDE workforce. Any changes in codes and standards related to the performance of NDE and training, qualification, and certification of NDE personnel will have an impact on the NDE workforce.

9. **Insurance agencies**: These are the entities that insure the operating nuclear power plant facilities. They provide the authorized inspector and authorized nuclear in-service inspector services responsible for verifying the owner's compliance with ASME Section XI. Their role in the NDE workforce is to ensure that the NDE is being performed by qualified, certified personnel and in accordance with qualified procedures.
10. **Regulators**: In the United States, the USNRC regulates the commercial nuclear power industry through federal regulations, which are published through the Code of Federal Regulations. The various CFR regulations endorse various industry codes, standards, and guidance documents to address all aspects of nuclear power plant operation. For example, through 10 CFR 50.55a, the NRC endorses editions and addenda of ASME Section XI—Rules for Inservice Inspection of Nuclear Reactor Facility Components for the implementation of in-service inspection at nuclear power plants. Regulators have a critical impact on the NDE workforce in that they must review and approve any codes and standards related to the performance of NDE at the nuclear power plant.

Many stakeholders have a role or responsibility directly tied to the implementation of NDE at the plant. To some degree, they each have some impact on the NDE workforce. When assessing the future of the NDE workforce, it is important that all stakeholders provide their input and perspectives on what is adopted by industry to address the NDE workforce issues.

Digital Transformation for NDE

As previously discussed, the electric power industry is currently transitioning to new energy and digital paradigms. The energy transformation ties directly to global goals of net-zero carbon generation. The digital transformation is a much larger transition, moving industry beyond the third industrial revolution, which implemented widespread use of computers, microelectronics, and digital technologies. The digital transformation is the fourth industrial revolution (Industry 4.0), which takes digital technology to new levels of integration with the physical world. Commercial products such as driver mapping tools like Google Maps and Waze, automated vacuum cleaners and lawn mowers, and other similar "smart" tools and devices are examples of this Industry 4.0 "Internet of Things." All around us we see more and more digital technology integrated into all aspects of daily activity and striving to make our lives easier.

As industry undergoes this digital transformation, NDE must adapt accordingly. With the continuous development of new and advanced digital systems and integration capabilities, such as the use of digital twins for helping to make smarter decisions around plant operations and maintenance, it is critical that NDE is smoothly integrated into the larger ecosystem. NDE data must be readily accessible to the process stakeholders in order to make quicker, better-informed decisions with less risk. This is effectively changing the paradigm from NDE being a cost center to a profit center, better integrating with plants' technical, operational, and financial needs.

As next-generation advanced reactor plants are currently being designed within the context of the energy and digital transformations, now is the best time to make decisions related to the integration of NDE and monitoring technologies that will be needed to fabricate, construct, install, functionally test, and operate the advanced reactor plant components and systems. The integration of NDE and monitoring at the beginning of the life cycle of an advanced reactor ensures efficient and cost-effective integration of those activities throughout the plant’s life. It allows for a better workflow for the acquisition, analysis, and end use of data and information to assess component and plant health, ensuring safe, efficient plant operation. Evaluating the future needs and demands for the nuclear NDE workforce, in terms of skills and knowledge of digital systems, is a critical part of this process.

5 MEETING FUTURE WORKFORCE NEEDS

A big challenge that the industry is facing is to properly assess the future NDE workforce needs and to ensure that the proper resources and infrastructure are in place to support its sustainability. Section 2 briefly discussed the active development of a future advanced reactor fleet at the same time as most of the current fleet is in the process of modernizing, performing inspections and NDE, and undergoing the necessary maintenance for extended life operations. Both the new fleet and the existing fleet have their parts to play in the energy and digital transformations, which will bring many new challenges and positive opportunities for the nuclear and NDE workforce. However, there are also many unknowns, such as the final designs, materials, and operating conditions of the new plants; how many new plants there will be; what NDE or monitoring will be needed to assess structural integrity; when and how often NDE will be required; technology options; and so on. This section discusses the potential changes to be considered when evaluating the future NDE workforce. It is not intended to be an all-inclusive list, with recommendations, but rather a listing of focus areas to assess and stimulate further thought and discussion.

NDE Skill Set Changes and Needs

Technical Skills

The current NDE workforce has a combination of prescriptive technical and physical skills that were obtained through training, experience, and qualification. Even with those skills, to ensure consistency and reliability, nuclear NDE technicians are required to follow approved detailed procedures, to use approved equipment and materials. Over the past 20 years, there has been an increased use of automated inspection tooling and data acquisition and analysis equipment that require higher technical skill levels for NDE personnel. For the future fleet, ASME Section XI, Division 2 allows the use of monitoring and NDE to assess SSC integrity. However, the materials, sizes and shapes, and even the temperatures of these systems and components will be quite different from that of today's nuclear fleet. These differences will drive the development and implementation of many newer and more advanced examination technologies that are unlike conventional NDE techniques. Couple this change with the digital transformation, and NDE personnel will need more technology-related skill sets in addition to basic NDE knowledge and experience. The additional skills and knowledge needed for the future workforce may include NDE engineering, knowledge of electromechanical digital control for robotic and automated NDE data acquisition equipment, computer-aided data acquisition and processing skills, data analytics, data science, and AI algorithm development and integration expertise. These new digital skill sets, roles, and responsibilities will need to be clearly defined and may result in an augmentation of personnel working alongside the NDE practitioner, if not simply integrated as part of the required NDE personnel training and qualification process.

Level III and NDE Engineers—Skills Needs

Level III is the highest level of certification and responsibility for NDE personnel. The roles, responsibilities, and certification requirements for NDE Level IIIs is clearly delineated in various industry-endorsed codes (ASME) and standards (ASNT). In the nuclear industry, it takes hundreds of hours of training and thousands of hours of documented field experience for ultrasonic examination personnel to reach Level III. With the short duration of nuclear plant outages, it takes many years to obtain the required experience to achieve Level III qualification. The extended length of time needed to reach this Level III certification can be considered a workforce barrier. Once a person attains Level III qualification/certification, they transition from being a Level II NDE technician to a role with increased tasks and responsibilities, many of which are not delineated in the NDE codes and standards. In addition to performing and overseeing nondestructive examinations, Level IIIs are responsible for developing NDE procedures that conform to the applicable codes and regulations. They may also become a company's Principal Level III, which carries additional responsibilities including managing and administering the NDE personnel training, qualification, and certification program, as well as directing and leading challenging performance demonstration activities. When working for a utility, NDE Level IIIs may also be responsible for the contract administration of NDE service vendors, management of the in-service inspection activities, oversight of critical or specialized NDE activities, interfacing with plant management on NDE issues, and interfacing with authorized nuclear in-service inspectors and regulators. These roles are not addressed within current codes and standards as part of the NDE training, experience, qualification, and certification requirements, but these are some of the many "soft" skills that are necessary for a Level III to be competent. Discussions held with several Level IIIs in the industry today revealed that they never received any "soft skills" training, but rather acquired these as part of the job. To develop a productive, competent, and valuable Level III, soft skills training should be integrated along with the required technical training and experience. "Soft skills" training may include, but is not limited to, leadership training, project management and contract administration training, decision-making skills training, and communication skills training to ensure accurate and consistent information transfer. These "soft" skills should be developed for any NDE person who has the potential to rise into a Level III position.

In conjunction with or in addition to qualified Level IIIs, the future NDE workforce will likely need more engineering skills to augment the Level III or to integrate into the NDE implementation team as a support function or position. As the nuclear industry progresses into the digital transformation and operation of advanced reactors, new complexities will be added to the job scope of performing NDE in power plants. The ASME Section XI, Division 2, RIM methodology requires a person, or a team of people, who are knowledgeable and experienced in engineering and NDE to develop a comprehensive plan for how to assess the structural integrity of the plant, both during construction and through its lifecycle. This requires a person or team that possesses an engineering background, along with a basic understanding of material properties and material degradation mechanisms, a knowledge of plant and systems operation and constraints, an understanding of regulatory requirements, a command of plant safety requirements, and expertise in NDE. This person or team should also understand and be able to communicate with plant design, plant systems, maintenance and operations, and engineering personnel on matters associated with specifying and implementing a MANDE program. On the NDE service vendor side, engineers will also be needed to design the automated inspection tooling and to integrate the tooling design and use with the MANDE methodology, such that the MANDE program is fully implementable.

The NDE “engineering” person is not a new concept. Most of the current fleet of operating nuclear plants started out using engineers for implementation of programs for in-service inspection, pressure testing, FAC, reactor internals inspections, steam generator inspection, and other specialty areas. These NDE engineers helped bridge the knowledge gap between NDE and the plant systems and operation engineering functions. Over time, as plant experience grew, some of these NDE engineering functions were consolidated into other functions, were eliminated, or were converted to part-time consulting positions. The next-generation NDE workforce will likely need engineering skills as they develop and implement MANDE programs that effectively and efficiently integrate NDE with the plant’s operational needs. The NDE engineering function will be an integral part of NDE and must be seriously considered and integrated into the future NDE workforce planning.

Training, Qualification, and Certification Changes and Needs

NDE training, qualification, and certification in the nuclear industry are implemented in accordance with the requirements of ASME Section XI, IWA–2300, “Qualifications of Nondestructive Examination Personnel” [13]. IWA-2300 through 2311 require that NDE personnel be qualified and certified in accordance with a written practice, prepared by the employer in accordance with ANSI/ASNT CP-189, “Standard for Qualification and Certification of Nondestructive Testing Personnel” [14]. In conjunction with CP-189, ANSI/ASNT CP-105, “Standard for Topical Outlines for Qualification of Nondestructive Testing Personnel” [15] is the standard used for NDE training curriculum outlines. In addition to CP-189 and CP-105 guidance, ultrasonic examination personnel must be qualified in accordance with ASME Section XI, Mandatory Appendix VII, “Qualification of Nondestructive Examination Personnel for Ultrasonic Examination” [16]. The requirements for qualification and certification of NDE personnel have evolved since the early days to become a very prescriptive curriculum- and time-based process to train, gain experience, qualify, and certify through Levels I, II, and III. Volumetric examinations, such as ultrasonic examinations, require the longest duration of time to gain experience, and qualification requires a performance-based practical demonstration to the requirements of ASME Section XI, Appendix VIII, “Mandatory Appendix VIII Performance Demonstration for Ultrasonic Examination Systems” [9]. As discussed in Section 2 of this report, with the short outage durations and the overlapping of outages, in the spring and fall, personnel cannot obtain the hundreds to thousands of hours of experience that they need to advance in the field without investing many years in the industry. The long duration required to gain experience for advancement through the qualification levels for ultrasonic examination has been a primary demotivator for maintaining qualified UT personnel in the NDE workforce.

Gaining Experience—The Challenge Today and for the Future

Over the past 10 to 15 years, there has been much discussion and many attempts to streamline the UT training, experience, and qualification process. These changes were typically developed as code cases to ASME Section XI and, though approved by ASME, none of these methodologies have been endorsed by the USNRC. The most recent ASME approved code case was N-930-1, "Alternative Experience Requirements for Nondestructive Examination Personnel for Ultrasonic Examination" [17]. This case was accompanied by an EPRI technical basis document [18] that demonstrated that the Appendix VII experience hour requirements were unnecessarily inflated. This was done through a process of breaking down the ultrasonic Level II and III skills and knowledge to their constituent components and determining the actual time needed to obtain proficiency in each one. At present, the USNRC has not endorsed Code Case N-930-1 in Regulatory Guide 1.147, but since it did not oppose the case when it went through the ASME consensus code committees, it is expected that it eventually will. As soon as this occurs, it will be important for utilities and inspection vendors to adopt this code case into their written certification practice procedures and start to take advantage of far more realistic experience time scales, as well as the alternative options for obtaining the experience hours needed for qualifying Level II and III ultrasonic examiners.

The industry needs to continue the pursuit of more flexible alternatives to the current prescriptive "field" experience requirements, in the current codes and standards, to provide a better, streamlined path to moving Level I/trainee personnel to Level II and beyond. These alternative approaches should incorporate the use of new digital technologies to effectively augment the manual hands-on and field experience hours required today.

Training—Integrating Innovation

The current NDE training requirements prescribed in the ASNT documents were based primarily on the use of classroom-type training, with supervised laboratory training. Technology advancements have improved these training processes. Computer-based training is a fairly common method for delivering technical training and testing on textbook material, without having to schedule around and travel to an in-person training class. Are the current NDE training hour and curriculum requirements still necessary, given other options available for providing classroom training and lab exercises? The use of simulators has recently been introduced as a tool to provide learning opportunities for ultrasonic examination practitioners. These devices have great potential to provide technicians, at all ultrasonic qualification levels, with the laboratory and practice time needed to gain experience and become better examiners. Recent developments in the use of AR and VR for training show that they are not just valuable indoctrination and training tools, but they can also be used for specific site, component, and examination skills training for pre-job briefs or for on-the-job training.

As this technology develops further, it is possible that AR/VR technology, integrated with simulation, could place a technician in an environment so lifelike that it is, in many ways, equivalent to performing the same examination in the field. This is why the aeronautical and aerospace industries have been using simulator technology for decades for training pilots and astronauts for both testing and maintaining competency in flying aircraft. NDE personnel could use these technologies to attain just-in-time direct knowledge of the examination they will perform, improving the NDE performance and reliability on the actual component. Experience hour requirements in the codes and standards have always been based on fulfillment of time spent performing hands-on examinations in the field. However, recent ASME Section XI code activity, such as Code Case N-930-1, as well as recent modifications that the USNRC has made to 10 CFR 50.55a, are now making it possible to obtain a percentage of ultrasonic examination experience through laboratory practice. Devices such as ultrasonic simulators and AR/VR technologies can be used to simulate the components to be examined while also simulating the plant environment in which the component is actually found, enabling a deeper level of learning and practice for the NDE workforce. Development of these same types of innovations for all other nuclear NDE methods should be considered because in-plant, hands-on NDE experience, of all kinds, is becoming so hard to achieve.

Considering changes to NDE training, experience, qualification, and certification requirements to allow more flexibility and efficiency in implementation methods is critical. In addition, the industry should consider the integration of new digital, engineering, and “soft skills” training to provide new NDE personnel with a more comprehensive, valuable set of skills. Proactively addressing NDE workforce development during this digital age will enhance the NDE industry’s ability to attract new talent, a key issue that must be addressed with our current declining workforce. By updating NDE job skills education to include more digital, engineering, and soft skills curricula, the industry can highlight NDE as a dynamic, forward-looking field with diverse opportunities for career and technical growth. NDE service providers and utilities can attract new talent who are looking for engaging and impactful careers, bringing new perspectives and ideas, and enriching the industry’s overall capabilities.

While looking at creating a more diverse environment for personal growth and development in the nuclear NDE industry, we need to continue to retain the experienced, qualified professionals that we already have. The impending retirement of seasoned experts leads to a loss of institutional knowledge, experience, and ability. Encouraging experienced professionals to stay engaged, to mentor younger generations, and to contribute to ongoing education efforts is essential.

Organizational and Human Factors—Limited Awareness and Outreach

The preceding discussions highlight the limited awareness and outreach pertaining to the NDE workforce. Previous studies indicated that the workforce was declining, due to attrition from personnel retiring and lack of new people entering the industry. Despite its critical role, NDE is still unknown to most young people considering technical career options. Limited awareness of NDE as a practical and rewarding career path is impeding efforts to attract new talent. The question at hand is, “How does one find one’s way into a rewarding career in NDE?” This is currently a difficult question to answer in any broad sense. A key to developing a new generation of nuclear NDE professionals, therefore, will be through outreach. This will require all stakeholders to join forces to address the issue. The entirety of NDE ecosystem, and especially nuclear industry employers, must invest resources into effective advocacy campaigns to introduce young people to NDE, as a career, and to highlight its importance and the range of opportunities it offers. The path to a career in NDE must be clearly defined, communicated, and integrated with support from all stakeholders for its successful implementation. Nuclear power and the NDE industry are functioning in a new age and environment; the energy and digital transformations will require many changes, with the most important area for change being the workforce. This transformation requires the collaborative support and teamwork from all stakeholders to be successful.

Information from Other NDE Industries

As part of this nuclear NDE workforce study, we reached out to other industries to benchmark the current state of their NDE workforces and gather any information that may assist the resolution of our workforce issues. Although we were able to connect with people representing ASNT, the petrochemical industry, and the aerospace industry, we received little useful input from them. There seemed to be a reluctance on the part of other industries to share any pertinent information about the state of their NDE workforce. However, they did think it would be a good idea if the collective NDE industry shared more information to help generate interest for recruiting people into the NDE field, in general. The key takeaway is that if we want to benchmark and collaborate with other NDE industry organizations, we will need to invite them into the focus group or create other opportunities for their participation.

6 ACTIONS TO ADDRESS NUCLEAR NDE WORKFORCE ISSUES

Several compelling issues are evident from the results of the industry surveys presented in this report. Among the most important of these is shown in the responses to Question 6, “In what year do you expect to leave the nuclear NDE industry, through retirement or otherwise?” Of the 82 respondents, 37% indicated that they will retire or leave the industry by 2030, with another 24% leaving by 2040. Those numbers represent a significant loss to the NDE workforce. Similarly, responses to Question 15 indicated that 60% did not feel that there will be enough nuclear NDE personnel in the industry to support future needs.

For two decades, NDE workforce studies have indicated that the nuclear NDE workforce is declining. This study’s results indicate that we are now reaching a tipping point, which demands action. With heavy attrition on one end of this problem, and a lack of adequate recruiting of new personnel on the other end, the condition is quickly becoming critical. This NDE workforce challenge has a few facets that have been discussed here and will require the collaboration of all NDE workforce stakeholders, including those at the executive levels of the utilities, to collectively attract, recruit, retain, and maintain a stable, competent workforce that can support this industry into the foreseeable future. As such, this section presents specific actions, under four main initiative headings, that are recommended to address the nuclear NDE workforce issues identified in this study.

Proposed Initiatives and Specific Actions to Address Nuclear NDE Workforce Issues

Initiative 1: NDE Personnel Recruitment

The first proposed initiative is aimed at the declining NDE workforce issue and, therefore, is to embark on a holistic approach to create interest and attract young candidates to enter the nuclear NDE industry and to show them a path to grow and advance to obtain and maintain a stable, steady career.

Specific actions include the following:

1. Industry leadership (NSIAC, Nuclear Energy Institute [NEI], Nuclear Power Council [NPC], Midwest Microelectronics Consortium [MMEC]) should support collaborations with regional or local education providers, particularly at the community college, junior college, and vocational school levels, for development of NDE practitioner curricula and infrastructure. Leadership also should support industry efforts to leverage collaboration with potential government funders such as the Department of Labor, the USNRC, and DOD programs that assist service personnel re-entering the civilian workforce.

2. Industry should coordinate with the efforts of ASME and ASNT in this area. Workshops and materials targeted at the high school level should be implemented (EPRI developed such materials in the 2000s). Industry should connect with state and regional craft workforce initiatives targeted at K-12 levels.
3. Vendors should expand their practice of using NDE personnel from other industry sectors and from other nations.

Initiative 2: Improving Opportunity and the Environment for Gaining Experience

With the issues that have been discussed in this report about a general lack of recruitment, coupled with short-duration outages and other issues that may discourage the people who do discover this career from sticking with it, there is a need to find some "quick wins" as well as some innovative longer-term approaches to providing better career opportunities for our NDE workforce.

In terms of improving opportunities, a few improvements came to light when reviewing the industry survey responses. For instance, from the utility survey results, it was noted that some utilities are not using, or restrict the use of, Level Is or trainees for outage NDE work. This restricts the pipeline to introduce Level Is and trainees to gain valuable and documentable nuclear NDE field experience. Think of it as the situation with plumbers. To create the future master plumbers who will be needed to supply the needs of our homes and businesses, it is critical to have a pipeline of plumbers' helpers who are gaining the experience needed to someday advance, first to plumbing apprentices and eventually to master plumbers. This is a critical process, ensuring that there are always individuals readying themselves to take the place of the master plumbers who eventually retire. What if all the homes and business established a habit of not allowing these plumbers' helpers to work on their jobs? Pretty soon, we'd have a situation in which no one knew that trade. So, in the "quick win" category, it is important that we find a place in our outage staffing routines to include new people, with very little or no prior experience, and enable those people to make a living while learning this trade.

Another relatively easy maneuver that the industry should implement is making the available NDE training courses, computer-based training, workshops, and conferences accessible by newcomers to the field and our inspection vendor personnel. Many of our current training courses, such as those created for our industry by EPRI, are made readily available only to the membership. This is because EPRI members fund the work to create these training opportunities and conferences. However, in light of what we are seeing of the dwindling workforce, it may be time to make these resources vastly more available to the individuals needing to learn the ropes, which are largely part of our vendor staffs.

Specific actions around improving opportunities include the following:

1. Utilities should support the use of junior-level NDE technicians in preparing for and executing outages, thereby increasing the opportunities for early-career personnel development with vendor Level Is or junior-college interns. This action is geared toward advancement to higher qualification levels. Industry executives should support their outage planning staff in this effort.
2. NDE training resources should be reviewed and considered for becoming available to vendors.
3. Nuclear NDE stakeholders should look for other industries that have similar NDE qualification requirements and examine opportunities to align the qualification rules so that individuals who work seasonally in the nuclear field can easily supplement their work opportunities in these similar fields.

The other set of issues under this heading, that becomes apparent from the NDE practitioners' survey responses are challenges associated with NDE personnel gaining the required NDE work experience. The effects of this issue are evident in the responses to Questions 4, 5, 7, 8, and 10, which show that the short-duration outages and work assignments limit individuals' ability to gain experience within their qualification levels that would allow them to grow and advance in the NDE careers.

There are several causes for this issue, as follows:

- The contracted nuclear NDE (service, personnel, and freelance) workforce currently works only an average of 5.86 months per year, owing to the short duration of outages and work assignments (see Question 4 results). Although utility NDE personnel are typically full-time employees working 12 months per year, the contract NDE workers have much less of an opportunity.
  - This short duration of outages and work assignments places a challenging limit on the amount of time the NDE workforce can gain and document actual field experience in their NDE methods.
  - In addition, by reducing the ability to gain experience within their qualification levels in a timely manner, the chances for career growth and advancement are lowered by increasing the length of time needed to advance. This is a key demotivator, especially for Level Is wanting to become Level IIs and, eventually, Level IIIs.
- Opportunities to perform additional NDE work outside nuclear are not readily available, with only approximately 21% of responders indicating that they are able to obtain such work (see Question 7 results). Even for in-house utility personnel, opportunities to gain experience in their home plant are usually limited outside of outages. For these practitioners, workforce sharing between plants and even with other utilities should be considered, as this would provide more good opportunities for experience and advancement. However, in general, workload must be managed to minimize the risk of practitioners reducing their commitment to nuclear work or being lost, outright, to other industries.

- Current code and standards requirements for gaining NDE experience are primarily time based, allowing credit only for experience gained performing actual duties and responsibilities in the field and applicable to the specific NDE method and level of qualification. When coupled with the limited time allowed to gain experience during short outages, this time-based approach slows the growth of NDE personnel, requiring many years to rise through the certification levels of some of the key NDE methods. Recently, following the development of new NDE training and laboratory tools and technology, such as simulators, VR, AR, data simulation tools, and improved computer-based training, we are seeing other effective ways to implement equivalent training and experience for advanced NDE skills. However, codes and standards changes may be needed to allow for use of these alternatives. Using the "recipe" [18] created by EPRI to reduce hours for ultrasonic testing, via Code Case N-930-1, can help accomplish this task.

Specific actions around improving the environment for gaining experience include the following:

1. To the extent possible, practical utilities should consider either of the following approaches to manage the outage schedule impacts that have manifested for U.S. utilities:
   a. Coordinate and stagger outage schedules across utilities to minimize overlap, potentially reducing the required overall headcount. It is recognized that compelling business considerations will limit the implementation of this recommendation.
   b. Allow resource sharing across utilities to minimize said scheduling conflict impacts and to increase experience-gaining opportunities for the existing utility NDE practitioners.
2. Nuclear industry NDE stakeholders should actively engage with other industries that have similar qualification requirements for NDE practitioners, and coordinate with them in the following ways:
   a. Consider fully aligning the qualification rules, so that nuclear NDE personnel can easily transition from one industry to another and continue to gain experience and make a living when there are no nuclear outage opportunities available.
   b. Communicate these cooperative engagements, so that the NDE workforce from all affected industries are aware of and can take advantage of these opportunities.
3. Utilities should revise their NDE certification program written practices to implement ASME Code Case N-930-1, "Alternative Experience Requirements for Nondestructive Examination Personnel for Ultrasonic Examination," Section XI, Division 1 [17], which optimizes training and experience hours for UT personnel. Utilities should also consider developing contractual requirements for vendors to complete the same action.

Initiative 3: Monitoring and Adapting Workforce Needs

As discussed in Section 5, the active development of a future advanced reactor fleet at the same time as most of the current fleet is in the process of modernizing, performing inspections, and undergoing the necessary maintenance for extended life operations poses new challenges for the existing and future NDE workforce. In the license renewal space, NDE practitioners are challenged with determining the best approach for examining equipment and systems, such as buried piping and other components, that have not traditionally been required to be examined. These components are often hard to access and have degradation mechanisms with which our workforce is less familiar. There are also new, innovative repairs that even the codes are grappling with, in terms of the best ways to ensure proper application and longer-term integrity. There are also many unknowns for the future fleet, such as the final design, materials, and operating conditions of the new plants; how many new plants will be built; what NDE or monitoring will be needed to assess structural integrity; when and how often NDE will be required; technology options; and so on. Finally, the industry has embarked on a digital transformation that will be very advantageous for the continued monitoring and operation of the plant and its equipment, and this brings with it a need for all plant personnel—NDE practitioners included—that will need to be trained to understand how their work must dovetail with these systems to fully manifest the sought-after advantages. There will also be new advanced technologies, digital transformations, and equipment that will be a necessary part of these changes, and with which NDE personnel will have to stay abreast and learn how to effectively use.

Specific actions include the following:

1. The nuclear NDE workforce stakeholders should establish a process for continuously monitoring the evolution of factors affecting workforce needs. Such factors include, but are not limited to, plans for new build of light water reactors (LWRs), small modular LWRs (SMLWRs), and advanced reactors, and emergent NDE requirements related to degradation mechanisms or requirements in support of subsequent license renewal.
2. Utilities should monitor and actively engage with the development of advanced reactor designers and industry codes and standards that are currently being modified to accommodate them. This includes helping to develop RIM plans and programs that will be required. Engaging in this way will provide the necessary clarity on the unique technical demands that the ARs will pose. NDE technologies, and therefore also NDE personnel skill set needs, will depend on the temperatures, radiation environments, and materials that will be encountered; the degradations mechanisms of interest; and the strategies of using NDE at entry opportunities versus using continuous monitoring.
3. As utilities implement the use of new digital technologies and systems, part of the change management plan should be to include NDE subject matter experts in the implementation processes, and to ensure that adequate training is made available for industry NDE practitioners in how to effectively interact with these systems, what types of information they will be expected to provide, and in what format the NDE data will need to be provided.

Initiative 4: Creating Detailed Guidance for Implementation of Initiatives

The initiatives and specific actions identified thus far provide actionable recommendations for vastly improving the NDE workforce issues that our industry is currently facing. However, manifesting these solutions will require coordination and collaboration among all stakeholders. Detailed guidelines are needed to help ensure that the industry is aligned on how to proceed and is able to effectively stay in front of the problem. The actions that have been defined here do not provide a specific timeline for completion of tasks. However, it is essential that each action is efficiently executed and properly managed for a successful outcome. Therefore, a final list of recommended specific actions is provided here.

Specific actions include the following:

1. Creating guidance: As a follow-up to this report, EPRI should work with the NDE Workforce Focus Group and other industry stakeholders to develop a guidance document detailing how to implement each initiative and its associated specific actions.
2. Prioritization: The NDE Workforce Focus Group should prioritize the actions proposed, based on factors such as logical implementation order, timeliness, relative cost and ease of implementation, and expected impact toward solving the issue.
3. Collaboration: The NDE Workforce Focus Group members, along with other organizations in the nuclear industry, should guide and support the implementation of these actions.

7 SUMMARY

This latest update to the Nuclear NDE Workforce study provided valuable and actionable information about the state of the current workforce and its future needs to support the U.S. nuclear fleet. Most importantly, the study validated that the nuclear NDE workforce personnel reductions continue as the numbers of experienced, qualified NDE personnel leave the industry primarily as a result of retirements. With this loss of experienced personnel, the industry loses the transfer of knowledge and experience needed to develop less experienced personnel in the workforce. Based on the NDE practitioner survey responses, the data reflect attrition numbers that confirm and reinforce the findings of the 2016 workforce study [1]:

- 30 of 82 (37%) of the respondents expect to retire by 2030.
- 20 of 82 (24%) expect to retire between 2031 and 2040.
- 11 of 82 (13%) expect to retire between 2041 and 2050.
- 15 of the 82 (18%) were undetermined.

With an estimated loss of 37% of nuclear NDE personnel by 2030 and another 24% by 2040, the workforce needed to support the existing and future nuclear fleet looks to be in trouble. A noteworthy response to survey Question 15, whether there are enough NDE personnel to serve the current and future nuclear fleets, stated, "At the moment we are at the tipping point and will soon, not many years from now, be at the crossroads of a dire need for a more experienced work force." The survey data appear to confirm that the industry is at that tipping point.

In addition to the aging workforce issue, the following key factors are directly associated with the decline in the nuclear NDE workforce:

- Loss of the personnel pipeline that originally attracted, trained, and retained personnel into the nuclear NDE workforce. Because of the lack of new nuclear construction on a grand scale in this country, there have not been any natural drivers for providing enough new people entering the industry.
- Short-duration outages and work assignments result in the average contract NDE personnel being able to work just under six months per year, and only in the spring and fall timeframes, which affects their ability to maintain job stability and obtain steady earnings.
- These short-duration work assignments also result in challenges for NDE personnel in gaining the required hands-on work experience necessary for career growth and advancement. Most current NDE training, qualification, and certification standards allow crediting experience hours only for time spent performing actual field and lab activities—and that time in the field is getting harder and harder to come by.
- There is a perceived lack of available work opportunities, outside of nuclear, to supplement earnings when personnel are between job assignments. Only about 20% of the NDE workforce surveyed are finding related work outside of nuclear, and those assignments usually are subject to limitations.
- Personnel are unsure of future career growth and advancement in nuclear NDE.

These factors all point to a compelling need to find effective ways to recruit new people into the nuclear NDE industry. We need these new recruits to find themselves entering a job situation that has a robust pipeline and career path that fosters growth, development, and advancement. This pipeline should include plenty of opportunities to obtain on-the-job training, as well as ready access to training courses and other options for practicing and gaining the necessary skills and experience hours. Both junior and mid-level nuclear NDE practitioners should either be able to see possibilities for full-time employment that provides a regular paycheck, or at least know that there are other work opportunities available to them that can supplement their incomes during the off-season.

The situation described here is a career environment that would be attractive enough to not only attract new people, but also to retain them. Manifesting that environment will require the alignment and cooperation of all the NDE workforce stakeholders, following a well-thought-out roadmap for success. This report has provided a set of four initiatives, each containing specific recommended actions, that the NDE Workforce Focus Group believes can be the roadmap that moves this industry into the solution.

Nuclear power is a clean and efficient resource that is a critical component to meeting the world's ever-growing energy requirements, while also helping us achieve the carbon emission goals that we seek. To keep nuclear energy production viable, there must be a sustainable workforce to operate, maintain, and support every aspect of these plants, including a competent and sustainable NDE workforce. Therefore, the time is now for the nuclear NDE stakeholders to come together and embark on an action plan that can address and solve this declining NDE workforce issue.

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A NDE PRACTITIONER SURVEY RESULTS

The NDE practitioner survey contained 18 questions pertaining to the practitioners' experiences and perceptions from working in the current nuclear NDE workforce. The practitioners' responses also provided useful qualitative data for the workforce study that reflects their perspectives on the current and future state of the nuclear NDE workforce. The results from the NDE practitioner survey are listed in Table 2. The table lists the questions, the key takeaways from the results, proposed actions to the key takeaway, and the stakeholders that need to be included in resolving the issues.

Table 2. Results from the NDE practitioner survey, with proposed actions

Practitioner Survey Question	Results—Key Takeaway	Proposed Action	Stakeholders*
1. What are the aspects of commercial nuclear power NDE that are most attractive as a career?	Practitioners' responses to Questions 1 and 2 show divergent perspectives. See Question 2 for key takeaway.	Need for industry to become advocates for and develop programs to recruit suitable candidates for careers in nuclear NDE.	U, EPRI, NSV, NPP, NTI, ASNT
2. What are the aspects of commercial nuclear power NDE that are least attractive as a career?	There is a need for industry to become advocates and promote nuclear NDE to attract new people.	Need for industry to become advocates for and develop programs, to recruit suitable candidates for careers in nuclear NDE.	U, EPRI, NSV, NPP, NTI, ASNT
3. At present, do you work for a utility, a services company, a personnel provider, or freelance?	N/A—there was no key takeaway for this question.	The survey responses indicated a good cross-section of the industry was represented; no actions.	N/A
4. How many months per year do you typically work in NDE nuclear power?	The reduced amount of available work is one of the biggest challenges the nuclear NDE industry has in maintaining the NDE workforce.	Need for industry to address short work durations for nuclear NDE workforce, possibly providing additional work opportunities.	U, EPRI, NSV, NPP, NTI, ONDE

*Legend for stakeholders:
U, utilities; NSV, NDE service vendors; NPP, NDE personnel providers; NTI, NDE training institutions; NR, nuclear regulators; EPRI, Electric Power Research Institute; ASME, American Society of Mechanical Engineers; ASNT, American Society for Nondestructive Testing; ONDE, other NDE industries; N/A, not applicable

Table 2 (continued). Results from the NDE Practitioners' Survey, with proposed actions

Practitioner Survey Question	Results—Key Takeaway	Proposed Action	Stakeholders* (See legend above)
5. Are you satisfied with the amount of nuclear NDE work you are achieving, or would you like to see additional work assignments?	The response emphasizes the challenge that the nuclear NDE workforce has in providing adequate work to maintain a stable NDE workforce.	Need for industry to address short work durations for nuclear NDE workforce, possibly providing additional work opportunities.	U, EPRI, NSV, NPP, NTI, ASNT, ONDE
6. In what year do you expect to leave the nuclear NDE field, through retirement or otherwise?	The key takeaway clearly shows that the nuclear NDE workforce continues to decline in numbers: expected 37% loss by 2030, another 24% loss by 2040.	Industry needs to implement actions to reduce this risky, declining trend to ensure a steady, stable, and competent NDE workforce for the future. Ties into recruitment action for Questions 1, 2.	U, EPRI, NSV, NPP, NTI
7. Do you provide NDE to other industries outside of nuclear? If so, in what industries, and give reason(s) why you feel it necessary. If not, why do you feel it isn't necessary?	Only 21% of the workforce performs work outside nuclear NDE but the feeling is that opportunities should be available for more work outside nuclear.	Need for industry to address short work durations for nuclear NDE workforce and provide other work opportunities (see Questions 4, 5).	U, EPRI, NSV, NPP, NTI, ASNT, ONDE
8. Do you feel there are adequate advancement opportunities afforded to you for you to continue working in nuclear NDE?	Most respond that advancement opportunities are available but indicate that difficulties in gaining experience due to short outages and work durations hinders career growth.	Need for industry to develop methodologies to gain "equivalent to" field experience using new technologies and develop, communicate, and implement advancement opportunities for competent NDE personnel wanting to gain more experience and career advancement.	U, EPRI, NSV, NPP, NTI, ASME, NR
9. Do you feel your company has invested in your future development, such as training, and are you willing to make the same investment in time and dedication?	Like Question 8, most respond that companies are investing in their future development and growth, with caveats.	Need for industry to develop and invest in the advancement of NDE personnel seeking growth. Should be part of the recruitment process.	U, EPRI, NSV, NPP, NTI

Table 2 (continued). Results from the NDE Practitioners' Survey, with proposed actions

Practitioner Survey Question	Results - Key Takeaway	Proposed Action	Stakeholders* (See legend above)
10. What is your opinion of current nuclear NDE work scope durations? What would you like to change if you were royalty for a day?	75% of respondents are discontented with the current work scope durations, citing need for longer assignments, outages, better scheduling, increased scope, and better compensation.	Need to develop better opportunities for NDE practitioners to get more work and longer work assignments, allowing them to gain needed work experience and maintain steady, stable income (see Questions 4, 5, and 7).	U, EPRI, NSV, NPP, NTI, ASNT, ONDE
11. Is the salary paid for non-nuclear NDE workers comparable to nuclear NDE workers? Why do you feel it is different?	Over 50% indicate that nuclear NDE workers' annual based pay may be above non-nuclear NDE workers' pay. However, this apparent pay advantage is negatively affected by shorter work durations for nuclear work.	Need to develop better opportunities to get more work and longer work assignments to gain work experience and help maintain a steadier, stable income (see Questions 4, 5, 7, and 10).	U, EPRI, NSV, NPP, NTI, ASNT, ONDE
12. What types of incentives would you like to see to retain your commitment to support nuclear NDE?	Most responses indicate the desire for greater compensation, more work, growth opportunities, more consistent work, and job security.	Need for nuclear NDE industry to be better aligned with NDE practitioners' needs, perceptions on compensation, work assignment duration, job growth and security, and maintaining a steady, stable career (see Questions 1, 2, 4, 5, 7, and 10).	U, EPRI, NSV, NPP, NTI, ASNT, ONDE
13. What are the attributes of a utility or site you like to work for?	NDE practitioners desire a good working environment, consistent work, good people, helpful and considerate management, integrity, teamwork, safety consciousness, and a pleasant working environment.	Need for industry to be aware that NDE practitioners simply want a safe, pleasant work environment, where people work together as a team and their work is appreciated.	U, EPRI, NSV, NPP

Table 2 (continued). Results from the NDE Practitioners' Survey, with proposed actions

Practitioner Survey Question#	Results - Key Takeaway	Proposed Action	Stakeholders* (See legend above)
14. What are the attributes of a utility or site you do not like to work for?	NDE practitioners do not like to work in an environment where they feel stress, demands, and pressure from management on outage schedule, time, work completion coupled with lack of support and a safe, conscientious workplace.	Same as 13, need for industry to be aware that most NDE practitioner are working away from home, and they simply want a safe, pleasant work environment where people work together as a team and their work is appreciated.	U, EPRI, NSV, NPP
15. Do you feel there are enough nuclear NDE personnel in the industry to support current needs and future needs? Why or why not?	Over 60% of the responses are negative, with the key takeaway being that there is clearly a declining trend in the nuclear NDE workforce.	Comments indicate a clear need for a "call to action" by all nuclear NDE workforce stakeholders to address this declining trend. Ties into recruitment action for Questions 1, 2, and 6.	U, EPRI, NSV, NPP, NTI
16. Have you or would you recommend NDE as a future career path to members of your immediate family? Why or why not?	Most responses are positive, indicating they would recommend a career in NDE to their immediate family members but recognize the negative aspects of choosing a career in NDE.	Responses indicate the need to address future opportunities, career growth, too much travel, not enough work. Ties into recruitment action for Questions 1, 2, 6, and 8.	U, EPRI, NSV, NPP, NTI
17. Do you expect the workload to be about the same during the next couple of years? Or is this unknown?	The responses indicate that although practitioners are interested in their future workload, they are uncertain about the actual extent.	Response indicates the need for the industry to better communicate the potential future workloads to the NDE workforce.	U, EPRI, NSV, NPP
18. Which of the following qualifications do you have? Do you expect to have this qualification by 2030?	With the focus on UT qualification, the data reflects a significant downward trend in the number of qualified UT personnel needed to perform UT examinations for the various ASME Section XI supplements.	Need for industry to further investigate this potential downward trend in UT and other NDE qualifications. Determine if it is related to the declining NDE workforce or some other factors.	U, EPRI, NSV, NPP

About EPRI

Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

PROGRAM
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