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Human Factors and Ergonomics Society

Policy Statement on Nuclear Power

HFES Policy Statement: Nuclear Power

Nuclear power is receiving renewed interest as a method for supporting future energy needs which includes projections for continued increases in demand. Nuclear power helps to stabilize the grid and is capable of producing a large, reliable, and consistent zero-emission energy supply that is not subject to the fluctuations of wind and sunshine. Any continued or increased use of nuclear power, however, is dependent on the presence of highly reliable, safe systems that are designed and operated with significant attention to the performance capabilities and limitations of human operators and maintainers.

Background

Emergent nuclear technologies, including fission batteries, as well as micro- and small-modular reactors, can enable the increased deployment of nuclear energy sources in remote areas and at military installations where maintaining a reliable fossil fuel supply chain may not be feasible or where costs are prohibitive. Mobile micro-reactors may also be quickly and temporarily deployed to areas where traditional power distribution is disrupted, such as following natural disasters.

These small-scale reactors are being designed to employ more accident tolerant fuels and passive safety systems that promise to increase plant safety. They also may incorporate high levels of automation and artificial intelligence (AI) with the aim of significantly reducing staffing relative to existing commercial reactors. The move towards more automation also has the goal of enabling a future of remote and autonomous reactor operations in which many reactors across a region may be operated from a single control center. In addition, new large light-water reactors are being commissioned that employ advanced technologies such as highly automated control rooms. In short, new reactor designs have the potential to be safe, reliable, and flexible sources of low carbon energy, but their realization will come with significant changes in the role of humans in their operation and maintenance.[1]

The importance of designing nuclear power plant control rooms that are compatible with the needs and capabilities of human operators was demonstrated by the 1979 Three Mile Island nuclear accident, the worst accident in U.S. history. Inadequate training and attention to how plant information was displayed to the operators were direct causes of the failure of operators to detect and understand the loss-of-coolant in the system.[2] Poor display design, the use of multiple similar alarms that were not disambiguated, and a failure of the equipment to indicate either the coolant-inventory level or the position of a stuck relief valve were major design failures. These design shortcomings did not provide operators with sufficient awareness about the state of the system, which undermined their ability to make accurate decisions.

Following the Three Mile Island accident, the Nuclear Regulatory Commission engaged the Human Factors Society to conduct a large-scale investigation into system design shortcomings at U.S. commercial nuclear reactors.[3] Human factors is a discipline and profession that uses knowledge about human abilities, characteristics, and limitations to better design equipment and work environments to support operator performance."[4; 5] This pioneering work led to significant improvements in nuclear power plant control rooms and nuclear power safety, both within the U.S.[4; 6] and internationally.[7]

Other major nuclear accidents, such as those at Chernobyl and Fukushima, similarly were at least partially due to the insufficient application of human factors and attention to related considerations, particularly the safety culture of these organizations.[8-10] Safety culture refers to the broad sets of attitudes, values, policies, prioritization and management of safety in an organization that influences the actions and practices of the organization and its members to proactively maintain safe operations. While significant improvements in the design of nuclear power plants have been carried out over the past 40 years, a continued emphasis on the

application of human factors in the design of systems and the maintenance of a healthy safety culture in the operation of nuclear plants are critical for ensuring that they provide a safe, reliable source of energy, both for the existing fleet and for proposed new reactors.

Application of human factors principles to the design and operation of new nuclear power technologies will be critical to their commercial success and safe operation, as well as the continued diversification of the nation's energy supply. In particular, advances in the use of automation will fundamentally change the role of humans in the operation, oversight, and maintenance of nuclear power plants. Such changes present substantial opportunities for advancements, but will not come without risk. The application of human factors in system design and operation will be crucial for managing that risk. Even plants that have the potential for fully automated operation will be dependent on humans to diagnose problems during operation and manage safe shutdowns in response to events that may not have been foreseen in the design process. Human factors principles and methods support the effective integration of humans and systems, including those that are highly automated, to help ensure their safe oversight.

Policy Recommendations

1) **Current Regulations**. Since the Three Mile Island nuclear plant accident, the U.S. Nuclear Regulatory Commission has, through the development of regulations, policy, and guidelines, served a vital role in ensuring that the application of human factors has been addressed in the design and operation of our nation's nuclear power plants. The continuation of these efforts will be essential to the safe and effective deployment of new nuclear power plant technologies. At a minimum, current human factors regulations and guidelines should be maintained to preserve the safe operation of nuclear power plants, including:
    - 10 CFR 50.34(f), Additional TMI-related requirements;
    - NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, Chapter 18, Human Factors Engineering;
    - 10 CFR Part 26, Fitness for Duty Programs;
    - 10 CFR Part 55, Operators' Licenses;
    - 10 CFR 50.120, Training and Qualification of Nuclear Power Plant Personnel;
    - 76 FR 34773, Safety Culture Policy Statement.

2) **Improved Regulations.** Support the proposed 10 CFR Part 53, which would address human factors in the design and operation of new nuclear power plants by adopting a framework that is informed by risk assessment and considers the unique concepts of operations for advanced reactors, including potential remote operations envisioned in new micro-reactor designs.

3) **Small Scale Reactors**. Human factors design considerations unique to small and micro-reactors should be included in future regulations (e.g., 10 CFR Part 57) for these facilities.[1] The regulations should specifically consider a number of critical issues associated with these operations that will significantly affect human performance including new minimal staffing concepts, increased reliance on automation and AI, remote operations allowing oversight of multiple reactors, and the increased importance of surveillance and maintenance of passive safety systems. Clear human factors design guidance will benefit industry who may have limited expertise in this area and will help to streamline the regulatory licensing process.

4) **Managing Older Nuclear Power Plants**. Current human factors regulations and guidelines need to be applied when decommissioned nuclear power plants are restarted. Likewise, application of human factors can be critical for extension of licenses for older reactors since such plants may require modernization of outdated control room equipment. This is needed to ensure that the potential for

future accidents is avoided, which would endanger both local populations as well as newly developing nuclear power efforts.

5) **Oversight at Military Facilities.** Nuclear Regulatory Commission review and oversight of facilities deployed at military bases is strongly recommended. The NRC is highly experienced at understanding the many issues associated with the safe operation of nuclear power, has a strong body of expertise, and well-established processes for ensuring the safe design, operation, and maintenance of nuclear power facilities.

6) **Adopt New Human Factors Standard.** Enhance decision maker insight into the incorporation of human factors in the design and testing of future power plant systems by employing the ANSI/HFES 400 Human Readiness Level Standard.[11] This will support the need for early integration of human factors design and testing that is critical to successful system development.[12]

7) **Ensure the Safe Use of AI in Future Regulations.** In facilities that employ AI,[13] the careful testing and evaluation of these systems is critical to ensure that they support effective use and oversight by human operators. The design of systems incorporating AI should be guided by overarching safety principles for the use of AI, including guidelines for human-system interaction,[14] as well as new standards for human-AI test and evaluation.[15]

Research Recommendations

The existence of a vast body of human factors research and data on the design, operation, and maintenance of nuclear power plants can be leveraged to guide the development of safe and effective future reactors. Additional research is also needed to address novel aspects of new advanced reactors. Research and development supporting the following objectives will support both agility in the development of new facilities and safety in their operation.

1) **Human-System Design for New Concepts of Operation.** Develop human-system interaction solutions for advanced nuclear power plants that support the new concepts of operations (e.g., remote and highly automated operations) planned for these facilities. Where feasible, leverage technical expertise at national laboratories and other agencies to provide common design solutions, thus minimizing the standalone development activities required of each vendor. This process will help to accelerate deployment activities, while ensuring the safety and efficiency of operations and providing a U.S. competitive advantage in nuclear power.

2) **Human-AI Design Guidance**. Establish guidelines for the appropriate use of AI in nuclear power plant design, operation, maintenance, testing, and surveillance tasks that are consistent with the protection of public health and safety.

3) **Risk Analysis**. Enhance risk analysis tools, including human reliability analysis, as well as digital twin technologies to better support real-time risk monitoring and operational decision-making capabilities. Improve current capabilities to assess the risks associated with the operation and maintenance of advanced reactors technologies and passive safety systems, including human-system interaction issues. Enhance human reliability analysis methods to address considerations unique to small modular reactors and micro-reactors, including remote operations and reduced staffing concepts.

4) **Early Integration of Human Factors.** Develop new human factors tools, methods, and processes that support early integration of human factors, rapid evolution of nuclear power plant designs from conceptual to detailed, and human factors validation of the constituent systems and integrated system designs within the new concepts of operation.

5) **Safety Culture.** Develop effective methods and materials for the development, institutionalization, and maintenance of nuclear safety cultures in organizations engaged in the design, development, certification, and operation of advanced reactor technologies, including new small-scale reactors.[10]

6) **Mobile Reactors.** Conduct research on the specific human factors issues associated with new mobile nuclear reactor designs.

About the Human Factors and Ergonomics Society (HFES)

With over 3,400 members, HFES is the world's largest nonprofit association for human factors and ergonomics professionals. HFES members include psychologists, engineers and other professionals who have a common interest in working to develop safe, effective, and practical human use of technology, particularly in challenging, safety-critical settings.

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