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TECHNOLOGY-INCLUSIVE HUMAN-SYSTEM CONSIDERATIONS FOR ADVANCED REACTORS

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Presented by Jesse Seymour
Senior Reactor Engineer (Examiner)
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Authors

Jesse Seymour

Senior Reactor Engineer (Examiner)

Dr. David Desaulniers

Senior Technical Advisor for Human Factors and Human Performance Evaluation

Dr. Brian Green

Senior Human Factors Engineer

All authors are employed by the U.S. NRC in the Office of Nuclear Reactor Regulation's Division of Reactor Oversight

Introduction

- New reactor technologies provide opportunities and challenges for developers, utilities, and regulators
- NRC staff recognized the need for a new regulatory framework to address considerations such as:
  - high degrees of automation
  - reduced reliance on human action for assuring safety
  - new facility missions (e.g., hydrogen production)
- Path forward should incorporate risk-informed, performance-based, and technology-inclusive regulations that appropriately consider the role of humans and human-system integration in the operational safety of advanced reactors

Implications of Advanced Reactor Technologies

- Attributes of advanced technologies shape the approach to human-system interactions under the new framework
- These include elements such as passive safety features, modular reactor units, and non-light-water reactors
- Of particular significance are smaller source terms and the incorporation of inherent safety characteristics
- Technology tends to shape the human role in safety
- Inherent characteristics are more reliable than passive features; both are more reliable than active features
- Autonomous operations are possible, but operators would continue to fulfill important administrative functions

Regulatory Framework Needs

- A framework covering human-system interactions needs to appropriately consider how human actions factor into the overall context of safe facility operations
- Central premise is that contexts where interactions between humans and plant systems have a nexus to plant safety should be focused on in the new approach
- There is also a need for an integrated approach to the various areas involving humans and systems
  - Advanced reactors have attributes that warrant a cohesive treatment of human-system interactions that can adapt to such interdependencies
- An integrated approach is taken for staffing, operator qualifications, and human factors engineering (HFE)

Design-Specific Safety Functions

- Any dependence of safety on humans must be identified
- Design-specific safety functions can serve to accomplish this because they have shared utility within both the systems design and HFE processes
- Safety functions identified during the design process can vary from one type of advanced reactor to another
  - The need to maintain and fulfill safety functions can serve as a technology-inclusive foundation for other performance-based requirements
- HFE methods of Functional Requirements Analysis and Function Allocation provide a method for defining the human actions needed to fulfill safety functions

Approach to Human Factors Engineering

- HFE must be adequate to ensure that operators can understand plant status, take actions to ensure safety, and perform any other required technical and administrative functions
- For advanced reactors, operators fulfilling safety functions may not only occur from a control room
- The new framework aims to require advanced reactor applications to address the incorporation of state-of-the-art human factors principles in all settings and locations where humans will act to maintain plant safety functions
  - This performance-based HFE requirement will be evaluated using an HFE review process that is scalable in nature

Approach to Operator Staffing

- The variety of design considerations and operational approaches associated with advanced reactors means that the prescriptive staffing requirements historically used would not be appropriate within the new framework
- Instead, applicants should propose staffing plans in which the numbers and qualifications of operators are determined based upon design-specific needs
- Staffing plans need to be supported by HFE-based analyses and assessments; these generally require the use of a simulator to conduct performance-based testing
- A central consideration in the evaluation of staffing plans will be whether the plan provides assurance that design-specific safety functions can be reliably fulfilled

Approach to Operator Qualification

- In the U.S., operations staff at commercial nuclear power plants include both licensed and non-licensed operators
- Advanced reactor designs and operational concepts may not align well with existing operator licensing framework
- Flexibilities that may be appropriate include accommodating variations in design-specific technologies and concepts of operations, modifying examination structure on a facility-specific basis, and alternatives to full-scope, plant-referenced simulators
- Primary objective remains ensuring that licensed operators possess knowledge and abilities to reliably carry out tasks needed to fulfill safety functions

Summary and Conclusion

- The paper outlines key attributes and features of a proposed regulatory framework for addressing human-system considerations at advanced reactor facilities
- Approach uses an applied understanding of design-specific safety functions to provide requirements that are technology-inclusive in nature
- Requirements associated with human-system interactions are integrated to reflect the interdependent and interrelated nature of operator staffing, operator qualifications, and HFE at advanced reactor facilities
- Lastly, flexibilities are provided by means of requirements that are performance-based in nature

The authors wish to express their sincerest appreciation for this opportunity to present on these topics.

A version of the full paper (including reference citations) is also available via the NRC's Agencywide Document Access and Management System (ADAMS) under Accession No. ML22136A209 at https://www.nrc.gov/reading-rm/adams.html

Point of contact for paper:

Jesse Seymour

Jesse.Seymour@nrc.gov

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