Human-System Interaction in NRC's Risk-Informed Framework for Advanced Reactors

NPIC HMIT 2025

14th International Topical Meeting on Nuclear Plant Instrumentation, Control & Human-Machine Interface Technologies

An Overview of 10 CFR Part 53 and Self-Reliant Mitigation Facilities (SRMFs)

Brian Green, Theresa Buchanan, Amy D'Agostino

Presented by: Dr. Niav Hughes Green
U.S. Nuclear Regulatory Commission

June 16, 2025

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

EMBEDDED TOPICAL CONFERENCE AT THE
ANS® 2025 ANNUAL CONFERENCE

Acknowledgements

The authors would like to acknowledge the technical contributions of Mr. Jesse Seymour to the formation of this paper, input and reviews of Dr. David Desaulniers, Mr. William Reckley, Ms. Lauren Nist, Ms. Maurin Scheetz, Dr. Niav Hughes Green, Mr. Stephen Fleger, Dr. Stephanie Morrow, and Mr. Ian Jung of the U.S. Nuclear Regulatory Commission, as well as the work of Dr. John O'Hara of the Brookhaven National Laboratory, in the development of material discussed within the paper.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

ANS®

Disclaimer

The views expressed in this presentation are those of the presenters and do not necessarily represent an official position of the U.S. Nuclear Regulatory Commission (NRC). This presentation material is declared as a work of the U.S. Government and is not subject to copyright protection in the United States.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

ANS

Advanced Reactor Designs and 10 CFR 53 (Draft)

- 10 CFR Part 53 for Advanced Reactors considers the changing role of operators
- Developed to be risk informed, performance-based, and technology inclusive
- Considers a wide variety of human factors design possibilities:
  - New concepts of operation
  - Safer designs that credit inherent and passive safety features
  - Increased levels of automation
  - Desire for reduced staffing levels

Part 53 Introduces a New Classification: Self-Reliant Mitigation Facility (SRMF)

- Design ensures safety without operator actions.
- Eligible for relaxed regulatory treatment.
  - Can use Generally Licensed Reactor Operator (GLRO) instead of SRO/RO
    - No medical fitness requirements
    - Facility creates and implements licensing program
    - NRC does not need to be present for exams
  - Minimal staffing requirements - potential remote/autonomous operation

Self-Reliant Mitigation Facility Criteria (10 CFR 53.800)

NRC staff will need to confirm that facilities qualify for the regulatory relaxations:

1. **No human action** needed to satisfy radiological consequence criteria.
2. **No human action** for licensing events.
3. No safety functions assigned to **human action**.
4. Uses robust, highly-reliable safety features.
5. Adequate defense-in-depth achieved **without human action**.

FRA and FA Requirements Help Clarify Role of Operator

- Section 53.730(d) mandates:
  - Functional Requirements Analysis (FRA)

"A functional requirements analysis (FRA) identifies those plant functions that must be performed to satisfy the plant's overall operating and safety objectives and goals: To ensure the health and safety of the public by preventing or mitigating the consequences of postulated accidents. This analysis determines the objectives, performance requirements, and constraints of the design, and sets a framework for understanding the role of controllers (personnel or system) in regulating plant processes." (NUREG-0711)

  - Function Allocation (FA)

"Function allocation is the assignment of functions to (1) personnel (e.g., manual control), (2) automatic systems, and (3) combinations of both. Exploiting the strengths of personnel and system elements enhances the plant's safety and reliability, including improvements achievable through assigning control to these elements with overlapping and redundant responsibilities." (NUREG-0711)

- FRA helps NRC verify if all safety functions are achieved using inherent or highly-reliably passive features.
- FA helps NRC understand which functions need a human to backup automation.

Other Considerations

- **Human roles remain relevant**, even if not explicitly credited, due to:
  - Backup functions
  - System misalignments
  - Defense-in-depth strategies
  - Potential for **errors of commission** (inappropriate human actions)
  - Notifications to the NRC
- Two key issues in applying FA to advanced systems:
  - Even if functions are allocated to machines, **human involvement often persists**, requiring rethinking traditional FA paradigms (like those in NUREG-0711).
  - Terms like **"inherent"** and **"passive"** are used inconsistently in the industry, complicating regulatory clarity.

Limitations of Traditional FA Approaches

- Traditional FA methods may not suit SRMFs.
- Need new methods to assess:
  - Resilience to human error
  - Performance under human failure

Conclusion

- Part 53 modernizes reactor regulation.
- Accounts for diverse human roles in safety.
- SRMFs offer a new paradigm for self-reliant designs.
- Guidance to be refined to support this evolution.

References

Nuclear Energy Innovation and Modernization Act, Public Law No: 115-439 (available via https://www.congress.gov/bill/115th-congress/senate-bill/512).

U.S. Nuclear Regulatory Commission (U.S. NRC), "Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors" [proposed 10 CFR Part 53 rule], Federal Register, 89 FR 86918- 87128, October 31, 2024.

U.S. NRC, "Micro-Reactor Licensing and Deployment Considerations: Fuel Loading and Operational Testing at a Factory" (SECY-24-0008), Enclosure 1 pp. 10-11, U.S. NRC, Washington DC, United States (2024) (available via U.S. NRC ADAMS library at ML23207A251).

U.S. NRC, *Human Factors Engineering Program Review Model* (NUREG-0711, Revision 3), pp. 23-25, U.S. NRC, Washington DC, United States (2012) (available via U.S. NRC Agencywide Document Access and Management System (ADAMS) library at ML12324A013).

U.S. NRC, *Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors* (Regulatory Guide 1.233, Revision 0), p. 24, U.S. NRC, Washington DC, United States (2020) (available via U.S. NRC ADAMS library at ML20091L698).

J. Seymour, D. Desaulniers, B. Green, "Technology-Inclusive Human-System Considerations for Advanced Reactors" (paper no. 84), International Atomic Energy Agency International Conference on Topical Issues in Nuclear Installation Safety, Vienna, Austria, October 18-21, 2022, pp. 3-4 (available via U.S. NRC ADAMS library at ML22136A209).

J. O'Hara, S. Fleger, D. Desaulniers, B. Green, J. Seymour, & A. D'Agostino, *Development of HFE Review Guidance for Advanced Reactors* (Report No. F0028-04), pp. 108–111, Brookhaven National Laboratory, Upton NY, United States (2021) (available via U.S. NRC ADAMS library at ML21287A088).

U.S. NRC, *Risk-Informed and Performance-Based Human-System Considerations for Advanced Reactors* (staff white paper), pp. 8-10, U.S. NRC, Washington DC, United States (2021) (available via U.S. NRC ADAMS library at ML21069A003).

Sandia National Laboratory, *Human Factors Considerations for Automating Microreactors* (Sandia Report SAND2020-5635), p. 10, Sandia National Laboratory, Albuquerque NM, United States (2020), (available via U.S. NRC ADAMS library at ML20175A117).

International Atomic Energy Agency, *Safety Related Terms for Advanced Nuclear Plants* (IAEA-TECDOC-626), pp. 7-13, International Atomic Energy Agency, Vienna, Austria, (1991) (available via https://www.iaea.org/publications/882/safety-related-terms-for-advanced-nuclear-plants-report-of-a-technical-committee-meeting-vaesteras-sweden-30-may-2-june-1988).

U.S. NRC, *Guidance for Evaluation of Defense in Depth and Diversity to Address Common-Cause Failure Due to Latent Design Defects in Digital Instrumentation and Control Systems* (Branch Technical Position 7-19, Revision 9), pp. 9-10, U.S. NRC, Washington DC, United States (2024) (available via U.S. NRC ADAMS library at ML24005A077).

U.S. NRC, *Standard Review Plan for Fuel Cycle Facilities License Applications* (NUREG-1520, Revision 2), pp. 3-B-5, 14-1, and 14-2, U.S. NRC, Washington DC, United States (2024) (available via U.S. NRC ADAMS library at ML15176A258).