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

NRC Workshop on Human Factors Considerations for Remote Operation of Nuclear Facilities

January 31 & February 1, 2024

HYBRID MEETING

U.S. NRC HQ Auditorium & Microsoft Teams

Rockville, MD

Workshop Goals

1) Understand concepts of operations the nuclear industry is considering that may include elements of remote operation, and

2) Gain insights regarding how well-suited NRC's current guidance is for the human factors review of these concepts.

More Information

- Public meeting notice: https://www.nrc.gov/pmns/mtg?do=details&Code=20240019

Participating Organizations

- U.S. NRC
- Idaho National Laboratory
- Aalo Atomics
- ARC Clean Technology
- Boston Atomics
- Brookhaven National Laboratory
- BWX Technologies, Inc
- Curtiss-Wright
- Electric Power Research Institute (EPRI)
- Flibe Energy, Inc
- Framatome, Inc
- General Electric Vernova
- Institute of Energy Technology (Halden HTO)
- Kairos
- NextEra Energy
- Nuclear Energy Institute (NEI)
- Nuclear Promise X
- Nuclear ROSE Consulting, LLC
- NuScale Power, LLC
- Oklo
- Radiant Nuclear
- Sargent & Lundy
- Tecnatom
- TerraPower
- UK Office for Nuclear Regulation (ONR)
- Ultra Safe Nuclear Corporation
- United Engineers & Constructors
- University of Toronto
- Westinghouse
- X-energy

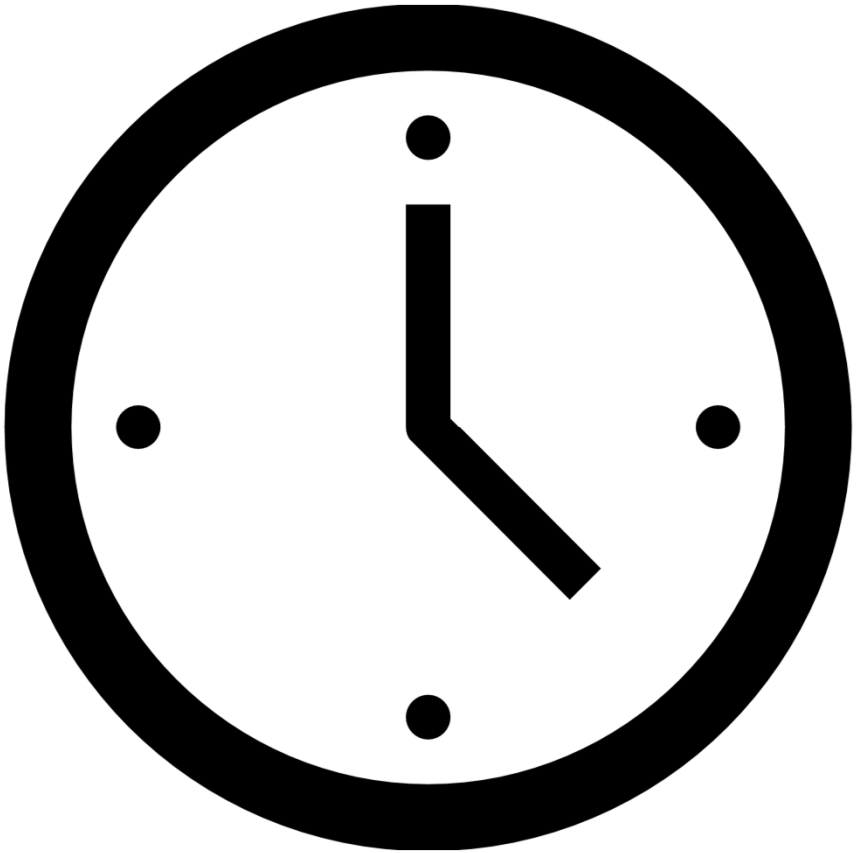
AGENDA
DAY 1

JAN 31, 2024
9:00 AM – 4:30 PM

TIME	TOPIC	SPEAKERS
9:00 AM – 10:00 AM	Workshop Opening and Introductions	• Niav Hughes Green & Stephanie Morrow, Workshop Coordinators, NRC • Ray Furstenau, Acting Executive Director for Operations, NRC
10:00 AM – 10:15 AM	**BREAK**	
10:15 AM – 11:30 AM	Overview of NRC Ongoing Regulatory Development Areas • Development of Ground Rules for Regulatory Feasibility of Remote Operations • Ground Rules through a Human Factors Lens • Proposed Part 53 Rulemaking • Key Questions for Workshop	• David Desaulniers, NRC • Tom Ulrich, INL • Theresa Buchanan, NRC
11:30 AM – 1:00 PM	**LUNCH (On Own)**	
1:00 PM – 2:30 PM	Session 1: Industry Presentations on Remote Operation Concepts & Discussion*	• Nuria Bernal Cortes, Westinghouse eVinci • Chanson Yang, Radiant Nuclear • Christopher Poresky, Kairos
2:30 PM – 2:45 PM	**BREAK**	
2:45 PM – 4:15 PM	Session 2: Industry Presentations on Remote Operations Concepts & Discussion*	• Dan Laughman, GE Vernova • DJ Hanson, Flibe Energy • Annie Paskavitch, NextEra
4:15 PM – 4:30 PM	Public Comments (Open to All)	• NRC/Public
4:30 PM	**Day 1 Adjourn**	

**Includes open discussion for questions from in-person and virtual participants.*

15 Minute Break



Overview of NRC Ongoing Regulatory Development Areas

Presenters:

- David Desaulniers, Senior Technical Advisor for Human Factors, NRC Office of Nuclear Reactor Regulation
- Thomas Ulrich, Associate Scientist, Human Factors and Reliability Analysis, Idaho National Laboratory
- Theresa Buchanan, Senior Reactor Engineer (Operator Licensing), NRC Office of Nuclear Reactor Regulation

Developing Ground Rules for Regulatory Feasibility of Remote Operations of Nuclear Power Plants

AN NRC FUTURE FOCUSED RESEARCH INITIATIVE
JANUARY 31, 2024

DAVID DESAULNIERS, SENIOR TECHNICAL ADVISOR FOR HUMAN FACTORS
NRC, OFFICE OF NUCLEAR REACTOR REGULATION

Disclaimer

The contents of this presentation are the views of the individual presenter and do not necessarily represent those of the Nuclear Regulatory Commission.

BACKGROUND

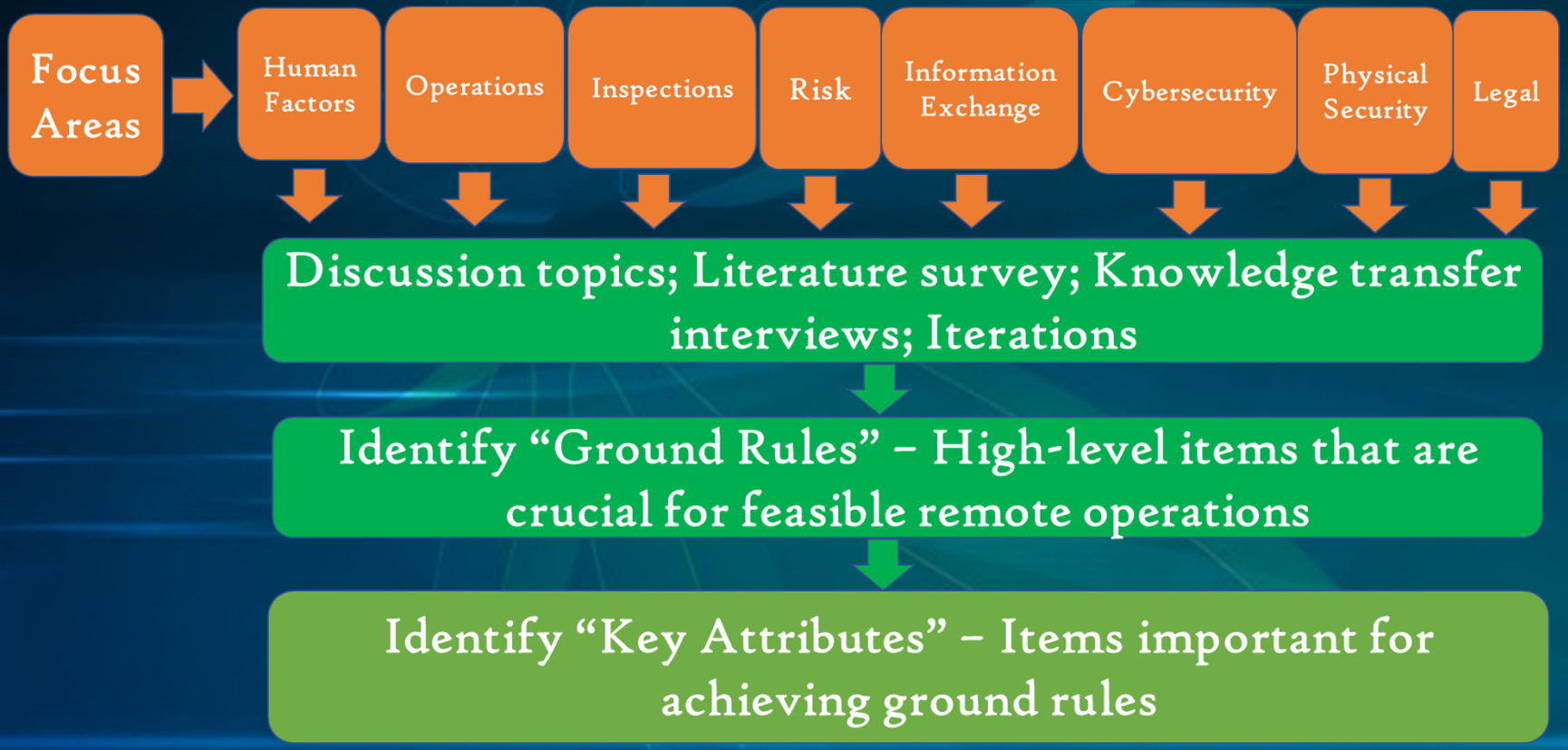
- Objective - lay the groundwork for identifying and addressing future regulatory needs pertaining to remote operation of nuclear power plants
- Timeline - conducted over an 8-month period starting in December 2020 and a report issued on November 9, 2021 (ADAMS Accession no. ML21291A024)
- Team - NRC staff with collective expertise and experience spanning different areas of NRC's mission

ML21291A024

Method of Work

- Iterative team discussions (approximately bi-weekly)
- Literature reviews
- Knowledge transfer interviews with subject matter experts from two different federal agencies to understand infrastructure and operational requirements, best practices, and lessons learned from industries that currently use remote operations

Method Overview



Foundational Terms

- Remote operation
- Autonomous systems
- Automatic

Foundational Terms

Remote operation

"command and control of the plant from a location outside the nuclear reactor site boundary"

Source: Ground Rules for Regulatory Feasibility of Remote Operations of Nuclear Power Plants (ML21291A024)

Foundational Terms

Autonomous systems

"able to perform their task and achieve their functions independently (of the human operator), perform well under significant uncertainties for extended periods of time with limited or nonexistent communication, with the ability to compensate for failures, all without external intervention"

Source: Preliminary White Paper – Micro-Reactor Licensing and Deployment Considerations: Fuel Loading and Operational Testing at a Factory (September 2023) (ML23264A802)

Foundational Terms

Automatic

Pertaining to a function, operation, process, or device that, under specified conditions, functions without intervention by a human operator.

Source: IEEE 100 - The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition

Outcomes

- 11Ground rules
  - Most reflect human factors consideration or have human factors engineering implications
  - The ground rules are not formal NRC positions, guidelines, or requirements
- Multiple attributes for each ground rule (except Ground Rule #1)

Ground Rules (abridged)

1. Remote operations criteria should be part of the design and development process from the beginning
2. The public's risk perception of remote operations will likely be an important consideration for the NRC staff and reactor vendors
3. Changes to regulations, if needed, should be based on (1) how well existing regulations accommodate the remote operations paradigm and (2) safety and security issues

Ground Rules (abridged)

4. Guidance on acceptable approaches to meet regulations is unavoidable
   - Should use technology-neutral and performance-based acceptance criteria
   - Demonstrated achievement of such criteria is expected to be more effective in assuring safety than prescriptive guidance or regulations.
5. The concept of "minimal risk conditions" is essential to the identification of safe plant configurations for any credible scenario
6. Data and voice communication infrastructure as well as security, including cybersecurity, are crucial

Ground Rules (abridged)

7. The responsibilities of the remote operator(s) (i.e., operators in the remote control room (CR)) should be based on:
   - the level of automation,
   - the reliance on human actions in meeting both the acceptance criteria for remote operation and the technology's "minimal risk conditions"
   - the time in which such human actions need to be completed
8. Licensing and training of operators in the remote CR is necessary, with flexibility in the licensing and training regimen depending on the technology, the level of automation, and the responsibilities of the operators in the remote CR

Ground Rules (abridged)

9. A crew that is based on-site or in the vicinity of the site is unavoidable within the remote operations paradigm
10. Inspections of the site and remote control room, including physical and cybersecurity inspections, are necessary
11. Physical security of both the site and the remote CR is necessary

Thank You!

Ground Rules for Remote Operations Through a Human Factors Lens

Dr. Thomas Ulrich, Associate Scientist
Human Factors and Reliability Analysis

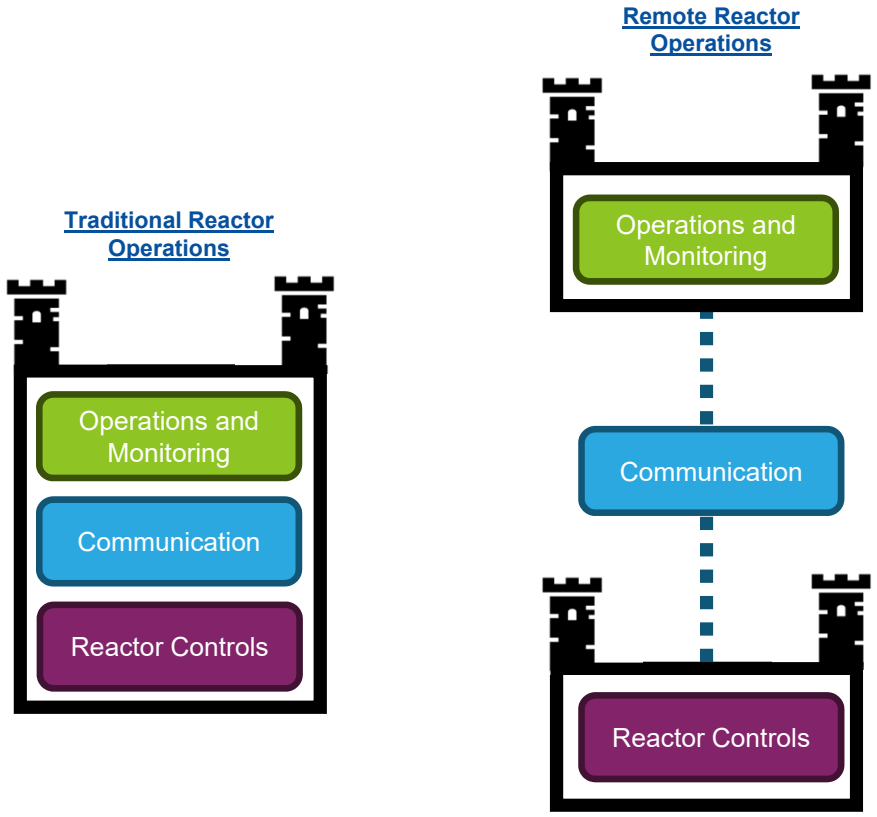
Idaho National Laboratory

Overview

- **Introduce** the **types of human factors issues** associated with remote operations
  - Based on a recent INL LDRD Project developing a remote concept of operations
  - Aimed to identify a generic and representative use-case to consider HF issues
    - Surveyed proposed designs as available (identified potential technologies and HF impacts)
    - Reviewed existing nuclear regulations and nuclear and other domain practices
      - Developed within the context of the NRC Ground Rules
- **Provide human factors implications** related to the ground rules to set the stage for subsequent discussions in the workshop
  - Focuses on the following subset of ground rules
    6. Data and voice communication infrastructure as well as security, including cybersecurity, are crucial.
    7. The responsibilities of the remote operator(s) (i.e., operators in the remote control room (CR)) should be based on:
       - the level of automation,
       - the reliance on human actions in meeting both the acceptance criteria for remote operation and the technology's "minimal risk conditions"
       - the time in which such human actions need to be completed
    9. A crew that is based on-site or in the vicinity of the site is unavoidable within the remote operations paradigm
    11. Physical security of both the site and the remote CR is necessary

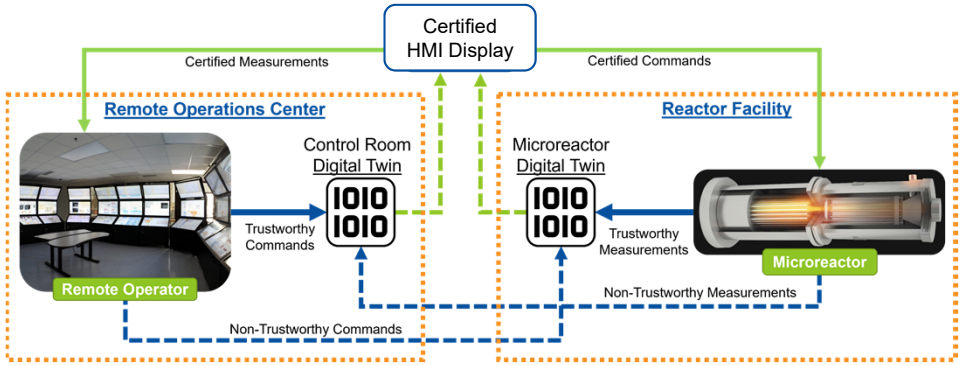
Communication Implications – Key Considerations

- Operations can no longer function within a protected and isolated environment
  - Operations must extend outside of protected boundary and span multiple geographically separated sites
  - Remote, on-site, and in-the-vicinity personnel must all be coordinated
  - Necessity for robust communication leads to increased vulnerabilities and attack surfaces.
- Potential use cases entail reactor siting in locations with limited communication infrastructure and physical accessibility
  - Response time and planning must account for remote location logistics
- Even dedicated communications systems are subject to failure or compromise
  - Communications monitoring needed to identify communication failures
  - Communication interruptions should be anticipated
    - During an interruption how do operators make informed decisions?
  - Vendor provided solutions using existing telecom industry my require additional coordination



Communication Implications – How do you reasonably ensure remote monitoring and control?

- Communication issues introduce new uncertainties outside of existing operational paradigms
  - New technologies and methods to interpret additional uncertainties provide impose new tasks and challenges
    - Physics-based and machine learning based systems modelling and evaluating reactor behavior
      - Requires operators to evaluate and potentially curate models of the systems in addition to traditional monitoring and control tasks
    - Example - Digital twins and advanced HMIs based concept of operations system to provide remote operators with information assurance and enhanced diagnostics



  - How do remote operators maintain oversight of the reactor during communication failures?
    - Diverse causes and spectrum of implications that could require different responses.
  - During communication failures, what types of normal and abnormal operations occur?

Advanced plant designs and technologies – Considerations

- What will be the role/function of an operator at the local and remote site(s) and how should those roles/functions be allocated?
  - Based on the requirements for human actions
- Division of responsibilities and level of expertise changes depending on reactor level of autonomy
  - Lower levels (1-2) should be considered, but the cost-benefit and scalability appear to limit the business case for remote operations
- Self-reliant-mitigation facility (~levels 3-5)
  - Passive safety/simplicity of design/automation associated with some designs *could* reduce the types of remote interactions
    - May eliminate many previously required safety critical functions imposed on operators
    - Benefits of remote operations more apparent at this higher level of automation
    - Serves as a barrier for human error/malicious actions
  - Associated with operator role changes and raises associated HF issues

Table 9.1 Levels Of Automation For NPP Applications

Level	Automation Tasks	Human Tasks
(1) Manual Operation	No automation	Operators manually perform all tasks.
(2) Shared Operation	Automatic performance of some tasks	Operators perform some tasks manually.
(3) Operation by Consent	Automatic performance when directed by operators to do so, under close monitoring and supervision	Operators monitor closely, approve actions, and may intervene to provide supervisory commands that automation follows.
(4) Operation by Exception	Essentially autonomous operation unless specific situations or circumstances are encountered	Operators must approve of critical decisions and may intervene.
(5) Autonomous Operation	Fully autonomous operation. System cannot normally be disabled but may be started manually	Operators monitor performance and perform backup if necessary, feasible, and permitted.

Advanced Plant Designs and Technologies – Implications

- Remote operations can potentially support cost saving expertise centralization and realize economy of scale benefits from multiple reactor oversight
- However, this must be balanced with human factors safety issues associated with the increased requirement for multi-site coordination while maintaining high safety

Higher level self-reliant-mitigation facility (~levels 3-5)					
Remote Operations Center			On-site or in-the-vicinity		
Normal	Abnormal	Emergency	Normal	Abnormal	Emergency
• Startup • Shutdown • Surveillance • Online Testing • Reactivity • Thermal dispatch • Communications monitoring	• Malfunction • Maintenance scheduling • Quick response team deployment	• Security	• Initial configuration • Startup testing/validation	• Communications malfunction	• Security

What level of experience and training is required for operators at each site?

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Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

Human-System Integration Requirements of Draft Proposed Part 53

David R. Desaulniers
Theresa Buchanan
U.S. Nuclear Regulatory Commission
January 31, 2024

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Nuclear Energy Innovation and Modernization Act (NEIMA)

Key Criteria of the NEIMA mandate:

- Risk-informed
- Performance-based
- Technology Inclusive

Rulemaking Status, Process, & Implications

- Staff provided draft proposed rule to Commission December 2022
- Staff requirements memorandum in development
- Public comment period to occur later this year
- Proposed rule issued for comment can be expected to differ from draft
- The following slides are based on draft proposed rule
- Individuals interested in commenting on the proposed rule should submit comment in response to the solicitation for comment

Concept of Operations

OL and COL applicants must address:

1. Plant goals
2. The roles and responsibilities of operating personnel and automation (or any combination thereof) that are responsible for completing plant functions
3. Staffing, qualifications, and training
4. The management of normal operations
5. The management of off-normal conditions and emergencies
6. The management of maintenance and modifications
7. The management of tests, inspections, and surveillances

Functional Requirements Analysis and Function Allocation

OL and COL applicants must:

- Address how safety functions and functional safety criteria are satisfied
- Describe how the safety functions will be assigned to human action, automation, active safety features, passive safety features, and/or inherent safety characteristics

Human Factors Engineering

- Current (Part 50 and 52) regulatory framework focuses HFE on the main control room
- Proposed Part 53 framework focuses HFE on safe and reliable performance in all locations that human activities are expected for performing or supporting the continued availability of plant safety or emergency response functions

Facilities and Operators

- Two classes of facilities
  - Interaction-dependent-mitigation facilities
  - Self-reliant-mitigation facilities
- Two classes of operators
  - Licensed Reactor Operators
  - Generally Licensed Reactor Operators

Self-Reliant Mitigation Facilities

The plant design must:

- Meet safety performance criteria *without reliance on human action for credited event mitigation*
- Rely on safety features and characteristics that will neither *be rendered unavailable by human errors of commission or omission nor credibly require manual human operation in response to equipment failures*
- Provide for a layered defense-in-depth approach that is not dependent upon any single barrier *or credited human action*

Self-Reliant Mitigation Facilities
Additional Human-System Interface Requirements

Must provide the generally licensed reactor operators with the capability to do the following:

- Receive plant operating data, including reactor parameters and information needed for the evaluation of emergency conditions
- Immediately initiate a reactor shutdown from their location
- Promptly dispatch operations and maintenance personnel
- Immediately implement responsibilities under the facility emergency plan, as applicable

Generally Licensed Reactor Operators (GLROs)

GLROs:

- can manipulate the controls of a self-reliant-mitigation facility and direct the licensed activities of generally licensed reactor operators
- do not have a role in fulfilling and maintaining safety functions

Staffing Plans

- **Interaction-dependent-mitigation facilities**: description of how the proposed numbers, positions, and qualifications of operators and senior operators across all modes of plant operations will be sufficient to ensure that plant safety functions will be maintained. This description must be supported by human factors engineering analyses and assessments.
- **Self-reliant-mitigation facilities**: description of how generally licensed reactor operator staffing that is both sufficient to continually monitor the operations of fueled reactors and to provide for a continuity of responsibility for facility operations at all times during the operating phase will be maintained.

Staffing Plans

Must describe:

- how the numbers, positions, and responsibilities of personnel contained within those plans will adequately support all necessary functions within areas such as plant operations, equipment surveillance and maintenance radiological protection, chemistry control, fire brigades, engineering, security, and emergency response.
- how engineering expertise will be available to the on-shift operating personnel during all plant conditions, to assist if they encounter a situation not covered by procedures or training.

Simulation Facilities

Simulation facility means an interface designed to provide a realistic imitation of the operation of a commercial nuclear plant used for the administration of examinations, for training, and/or to demonstrate compliance with experience requirements for applicants or licensees. A simulation facility may rely, in whole or part, upon the physical utilization of the reference plant itself.

Load Following

Permitted if at least one of the following is immediately capable of refusing demands when they could challenge the safe operation of the plant or when precluded by the plant equipment conditions:

- The actuation of an automatic protection system that utilizes setpoints more conservative than those otherwise credited for the purposes of reactor protection; or
- An automated control system; or
- An operator or senior operator or a generally licensed reactor operator, as appropriate.

Remote Operations Implications

- Performance-based approach to HFE and staffing
  - Driven by what is necessary to fulfill safety functions
- No requirement on location of the operators or HSIs
  - Focus on demonstrating the adequacy of the proposed approach considering design-specific considerations
- Requirements pertaining to self-reliant-mitigation facilities and load following may be particularly relevant
- Future remote operations concepts supported by this approach
- Other considerations (e.g., cybersecurity) remain

Questions?

Points of contact:

Theresa.Buchanan@nrc.gov

David.Desaulniers@nrc.gov

Questions for Understanding Remote Operation of Nuclear Facilities

David R. Desaulniers
U.S. Nuclear Regulatory Commission
January 31, 2024

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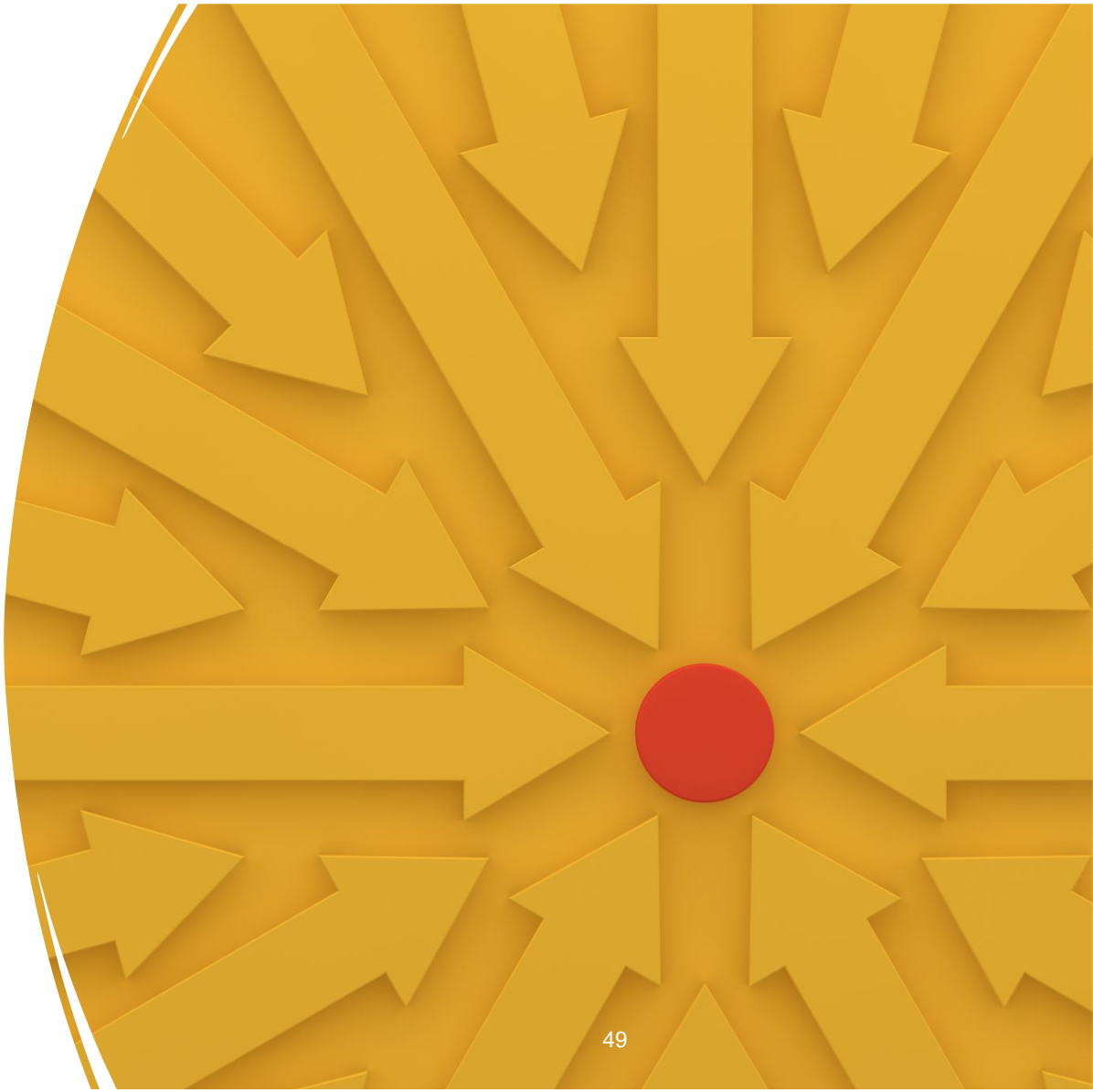
Plant Mission/Goals

- What will be the primary mission(s) of the reactor facility?
- What are the facility's safety and emergency response functions?



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Roles and Responsibilities of Personnel and Automation

- What will be the role of personnel in performing and ensuring the achievement of plant safety and emergency response functions?
- What role will plant personnel have in other facility mission functions?
- From where will the personnel role in each of these functions be achieved?

Staffing, Qualifications, and Training

- What are the planned number and qualifications of onsite staff and remote staff?
- What staffing plan changes are anticipated, if any, over the course of a facility license?
- Where will personnel be trained and qualified (e.g., at the reactor facility, at a remote operations facility, other)?

Management of Normal Operations

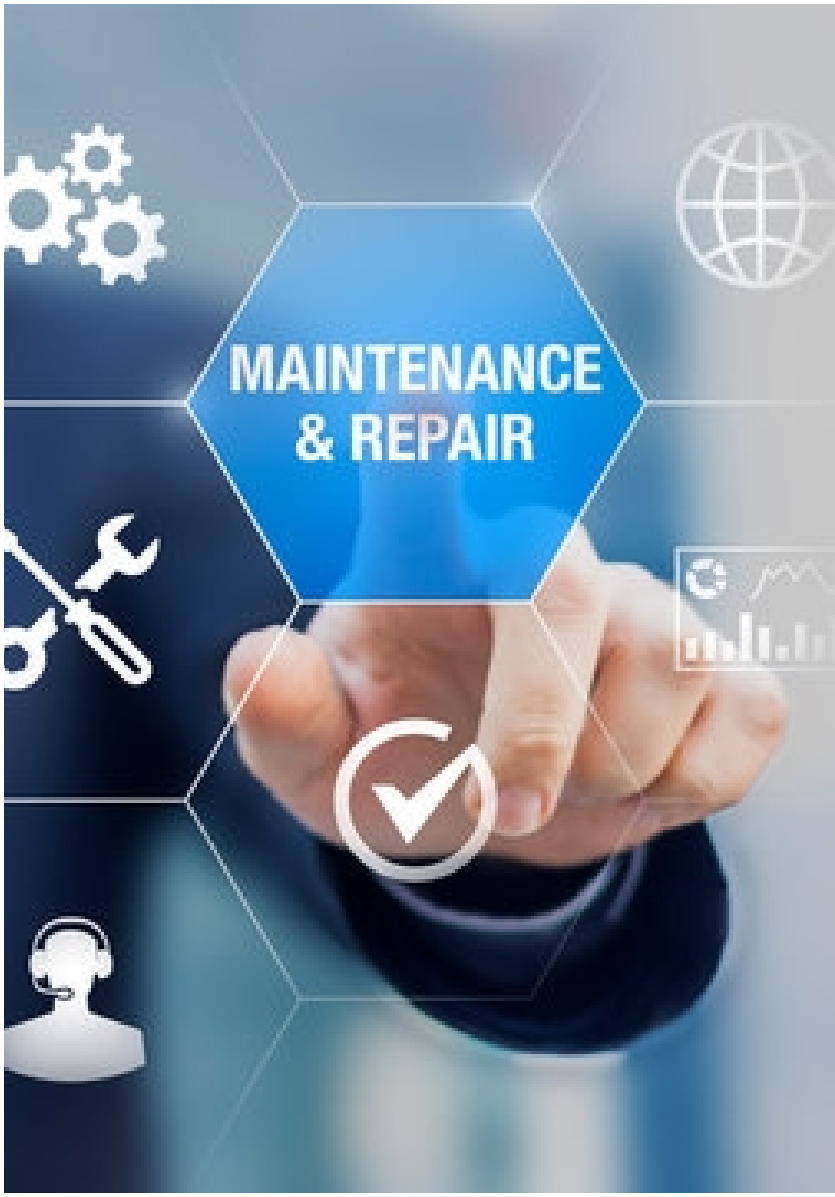
- What will be the roles of personnel in the monitoring and control of normal operations (e.g., start-up, power level control, shutdown, refueling)?
- Where will personnel perform the duties to fulfill these roles?

Management of Off-Normal Conditions and Emergencies

- What will be the roles of personnel in responding to off-normal and emergency conditions?
- Where will personnel perform the duties to fulfill these roles?
- Will response to off-normal or emergency conditions require personnel to be dispatched to the reactor site? If so, from where?
- How will a loss or degradation of communications (e.g., control signals, safety parameters) between the reactor facility and remote operations facility be managed?

Management of Maintenance and Modifications

- What will be the roles of personnel in performing maintenance and modifications?
- Where will personnel perform the duties to fulfill these roles?



Management of Tests, Inspections, and Surveillances

- What will be the roles of personnel in tests, inspections, and surveillances?
- Where will personnel perform the duties to fulfill these roles?

Questions???

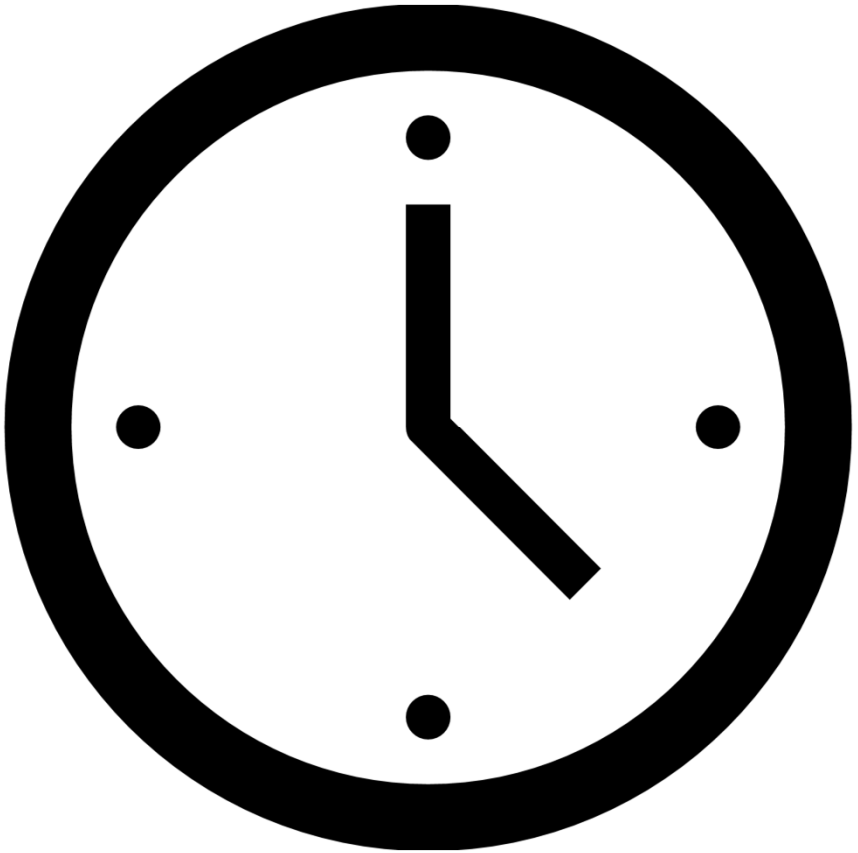
Session 1:
Industry Presentations on Remote Operation Concepts

Session Chair: Casey Kovesdi, INL

Presenters:

- Nuria Bernal Cortés, Human Factors Engineering Senior Engineer, Westinghouse eVinci
- Chanson Yang, Systems Engineer, Radiant Nuclear
- Christopher Poresky, Manager of Cyber-Physical Systems, Kairos

15 Minute Break



Session 2:
Industry Presentations on Remote Operation Concepts

Session Chair: Zachary Spielman, INL

Presenters:

- Dan Laughman, Senior Engineer, Human Factors Engineering, General Electric Vernova
- DJ Hanson, Chief Operating Officer, Flibe Energy
- Annie Paskavitch, General Manager Central Operations, NextEra

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U.S. NRC HQ Auditorium & Microsoft Teams

Rockville, MD

Workshop Goals

1) Understand concepts of operations the nuclear industry is considering that may include elements of remote operation, and

2) Gain insights regarding how well-suited NRC's current guidance is for the human factors review of these concepts.

AGENDA
DAY 2

FEB 1, 2024
9:00 AM – 4:15 PM

TIME	TOPIC	SPEAKERS
9:00 AM – 9:15 AM	Day 2 Opening	• Niav Hughes Green & Stephanie Morrow, Workshop Coordinators, NRC
9:15 AM – 10:15 AM	Stakeholder Presentations & Discussion*	• Rick Paese, Sargent and Lundy • Cristina Corrales, EPRI • Daniel Odéen & Per Øivind Braarud, Institute for Energy Technology (Halden)
10:15 AM – 10:30 AM	**BREAK**	
10:30AM – 11:00 AM	NRC Human Factors Reviews: Current Practices and Preparing for the Future & Discussion*	• Brian Green, NRC
11:00 AM – 11:30 AM	Development of Scalable HFE Review Plans for Advanced Reactors & Discussion*	• David Desaulniers, NRC
11:30 AM – 1:00 PM	**LUNCH (On Own)**	
1:00 PM – 1:30 PM	Summary of Range of Concepts of Operations Discussed on Day 1	• Casey Kovesdi, INL
1:30 PM – 2:45 PM	Breakout Discussions of Concepts of Operations for Remote Operation**	• All In-Person Participants
2:45 PM – 3:00 PM	**BREAK**	
3:00 PM – 3:45 PM	Summary of Breakout Discussions & Key Takeaways	• NRC/INL
3:45 PM – 4:00 PM	Public Comments (Open to All)	• NRC/Public
4:00 PM – 4:15 PM	Day 2 Closing – End of Workshop and Next Steps	• Niav Hughes Green & Stephanie Morrow, Workshop Coordinators, NRC

**Includes open discussion for questions from in-person and virtual participants.*

***Breakout discussion activity from 1:30-2:45pm for in-person participants. Virtual participants will break until 3:00pm.*

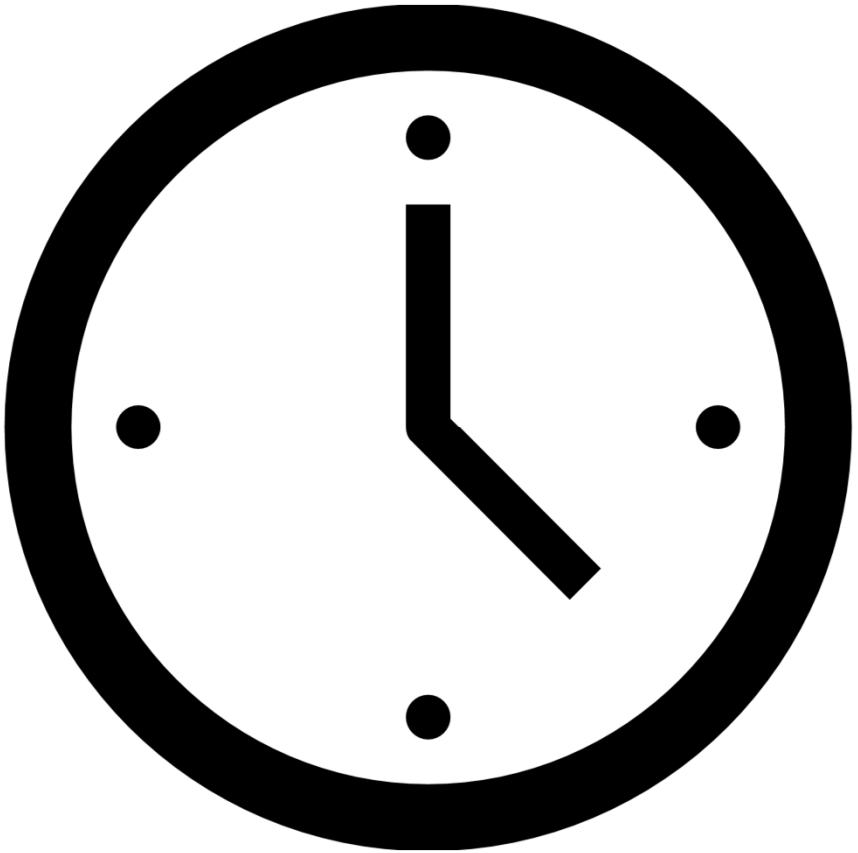
Stakeholder Presentations

Session Chair: Rachael Hill

Presenters:

- Richard Paese, Digital I&C and Human Factors Engineering Consultant, Sargent and Lundy
- Cristina Corrales, Principal Technical Leader – Nuclear I&C, Electric Power Research Institute (EPRI)
- Daniel Odéen, Control Room and Interaction Design, & Per Øivind Braarud, Senior Scientist, Institute for Energy Technology

15 Minute Break



NRC Human Factors Reviews

Presenters:

- Brian Green, Senior Technical Advisor for Human Factors and Team Lead, NRC Office of Nuclear Reactor Regulation
- David Desaulniers, Senior Technical Advisor for Human Factors, NRC Office of Nuclear Reactor Regulation

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NRC Human Factors Reviews
Current Practices & Preparing for the Future

Brian Green
Senior Technical Advisor for Human Factors & Team Lead
Office of Nuclear Reactor Regulation

February 1, 2024

Disclaimer

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Scope of Human Factors Reviews

- Consider the design of the control room and some aspects of operator actions elsewhere in the plant to verify that important actions can be completed as described.
  1. Existing reviews focus on main control room with limited consideration elsewhere
  2. Advanced reactor reviews no longer presume main control room is the focus of activities
     - Operation from a local panels
     - Operation from an offsite Remote Operations Center

NRC Technical Reviews

- Goals:
  1. Verify that technical claims about the safety of the facility are true.
     - Human Factors Reviews: Ensure that operators have the knowledge, tools, and ability to safely control the plant.
     - Not just designing the Human-System Interfaces
  2. Conduct efficient, risk-informed reviews.

Technical Review Process Overview

- Pre-application interactions
  - **Optional, but highly recommended**
  - Ensure a quality application that considers topics in this presentation
  - Opportunity identify and align on key issues and applicable regulatory basis
- Acceptance Review
  - Correct scope and depth of information
  - Resources and schedule
- Technical Review
  1. Requests for Additional Information
  2. Draft Safety Evaluation Report (SER)
  3. Final Safety Evaluation
- Advisory Committee for Reactor Safeguards (ACRS) review

NRC Staff need:

- Enough technical information to convince them the plant can be operated safely.
- Information on the docket that can be sited in the safety evaluation.
- Positions must be defensible.

What might pre-application discussions look like for advanced reactors?

- Understanding key design features and operating concept (FRA/FA & ConOps)
- Understanding regulatory basis
  - Part 50/52/53
  - Applicable guidance
- Understanding licensing approach & schedule
  - E.g., ITAAC? When will information be available for staff review?

Regulatory Basis and Key Guidance for Advanced Reactors

- 10 CFR Part 53 Subpart F

- § 53.440(n): The design would need to reflect state-of-the-art human factors principles for safe and reliable performance in all settings that human activities are expected for performing or supporting the continued availability of plant safety or emergency response functions.

- § 53.730 Defining, fulfilling, and maintaining the role of personnel in ensuring safe operations.
  - § 53.730(a): HFE Design Requirements
  - § 53.730(b): HSI Design Requirements
  - § 53.730(c): Concept of Operations
  - § 53.730(d): Functional Requirements Analysis and Function Allocation
  - § 53.730(e): Operating Experience Review Program
  - § 53.730(f): Staffing Plan

Interim Staff Guidance (ISGs)

- DRO-ISG-2023-01, "Operator Licensing Programs" (ML22266A066)

- DRO-ISG-2023-02, "Interim Staff Guidance Augmenting NUREG-1791, 'Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m),' for Licensing Commercial Nuclear Plants under 10 CFR Part 53" (ML22266A068)

- DRO-ISG-2023-03, "Development of Scalable Human Factors Engineering Review Plans" (ML22266A072)

- TICAP/ARCAP for 10 CFR Part 50/52

NUREG-0800 Chapter 18 & NUREG-0711

HFE Submittals & Licensing Strategy:

Part 53 preserves features of Part 50 (i.e., CPs and OLs) and Part 52 (i.e., ITAAC)

- Implementation Plans (IP) describe a methodology for future HFE work
- Results Summary Report (RSR) summarize results of HFE work and include a summary of the methodology used
- Not "either/or" –
  - If an IP is submitted, it should be followed by an RSR
  - An RSR can be submitted without an IP preceding it

NRC may audit or inspect these activities

NRC staff must have adequate information available to support writing a safety evaluation report (SER). An IP alone is not sufficient basis for a staff determination. NRC staff need information to be available to review before they can write an SER.

Inspections & Audits

- Audits occur during licensing reviews to verify information and may request certain information be submitted on the docket.
  - Can sometimes be done in an electronic reading room
- Inspections occur after licensing is complete
  - Such as for ITAAC
- Traditionally staff find HFE Verification and Validation inspections/audits to be necessary.
  - Other HFE activities may also be inspected/audited

Key Points

- Chosen licensing pathway may influence applicable HFE guidance
- Joint understanding between the applicant and NRC supports an efficient review
- **Pre-application activities, although optional, are highly recommended** to identify challenging issues associated with design features, schedules, and regulatory challenges to resolve them efficiently.
  - Unique design features and concepts of operation should be discussed during preapplication.
  - May consider aspects of design outside of control room
  - Allows for strategies to conduct reviews, audits, & inspections, that work with facility timelines.
- NRC is developing key guidance for Part 53
  - Additional guidance may be desirable.
  - We'd like to know what would be most useful.

Questions?

Development of Scalable HFE Review Plans for Advanced Reactors DRO-ISG-2023-03

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Disclaimer

The contents of this presentation are the views of the individual presenter and do not necessarily represent those of the Nuclear Regulatory Commission.

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Outline

Motivation for developing guidance to scale HFE reviews

Overview of the process for scaling HFE reviews

Overview of draft DRO-ISG-2023-03

Background: Current Practice

Current 10 CFR 50 HFE requirement (i.e., 50.34(f)(2)(iii)) is focused on the main control room

NRC's HFE reviews for large light-water reactors have been conducted using NUREG-0711, Human Factors Engineering Program Review Model

- Systems engineering based approach
- 12 program elements and 300+ criteria

Lessons-learnt from recent Part 52 reviews indicated a need for a new approach to regulation and review of HFE for advanced reactor technologies

Background: Proposed Part 53 Approach to HFE

HFE to be required where necessary to support important human actions

HFE reviews to be application specific (i.e., scaled) considering the characteristics of the facility design and its operation

Background: Proposed Part 53 HFE Requirement

The plant design must reflect state-of-the-art human factors principles for safe and reliable performance in all locations that human activities are expected for performing or supporting the continued availability of plant safety or emergency response functions.

[proposed (§ 53.730(a)]

Draft Guidance

Objective is to guide reviewer through the process of:

- Developing an application specific review plan
- Identifying appropriate HFE review guidance

To be used in place of NUREG-0800, Chapter 18, Human Factors Engineering

Developed as an Interim Staff Guide (ISG)*

Following experience with using the ISG the staff plans to make the guidance a NUREG

*A publicly available draft of DRO-ISG-2023-03 is available at (ML22272A051)

Scaling Process: Timeline

Begins - during pre-application engagements (if conducted)

Concludes - with completion of application acceptance review

Conducted - in 5 steps leading to the staff assembling the review plan

Scaling Process: 5 Steps

1. Characterization – establishing a documented understanding of the design and its operation from an HFE perspective
2. Targeting – identifying aspects of the design and operation for HFE review
3. Screening – selecting HFE program elements / activities for review in conjunction with each target
4. Grading – selecting specific standards and guidance documents to be applied to the review
5. Assembling the review plan – integrating results of prior steps to produce a plan that supports an efficient, risk-informed, reasonable assurance determination

Scaling Guidance: Overview

Main body (22 pages) – provides essential guidance for developing the review plan

Appendices (88 pages) – provide supporting guidance for implementing each step of the process

Scaling Guidance: Main Body – Key Features

- Applicability:
  - Standard Design Approvals (SDAs), Certifications (DCs), Combined Licenses (COLs) and Operating Licenses (OLs)
- Rationale for scaling reviews
- Regulatory basis / acceptance criteria
- Guidance for each step of scaling process
  - Objective
  - Process
  - Reviewer Responsibilities
- Focus is on “what to do / accomplish” when scaling reviews

Scaling Guidance: Appendices – Key Features

Focus is on “how to”

Recommended methods for each step of scaling process

Pointers to sources of additional guidance

Scaling Guidance: Appendix A

Characterization:

What to include in the characterization – essential elements

How to organize and document the characterization

Use of the characterization to aid coordination with related reviews (e.g., staffing, operator licensing, I&C)

- Establishes an integrated understanding of the facility and its operation
- Reduces the potential for large, light-water reactor assumptions

Elements of a Concept of Operations

- plant goals
- the roles and responsibilities of operating personnel and automation (or any combination thereof) that are responsible for completing plant functions
- staffing, qualifications, and training
- management of normal operations
- management of off-normal conditions and emergencies
- management of maintenance and modifications
- management of tests, inspections, and surveillance tasks

Scaling Guidance: Appendix B

Targeting:

- General principles for target selection
  - Application of risk insights
  - Qualitative consideration of uncertainty
    - *Limited operating experience*
    - *Limited design development*
- Descriptions of 38 prospective (example) characteristics of advanced reactor designs and operations
  - Human performance implications
  - Availability of guidance to support reviews

Table B-1. Example Design and Operational Characteristics with Human Performance Implications

ConOps Dimension	Characteristic of Design or Operation
Plant Mission/Goals	New Missions
	Novel Designs and Limited Operating Experience from Predecessor Systems
Roles and Responsibilities of Personnel and Automation	High Levels of Automation for All Operations
	Autonomous Operations
	Multiunit Operations and Teamwork
Staffing, Qualifications, and Training	New Tasks and Jobs
	New Staffing Positions
	Decentralization of Duties
	Operator Licensing Options
	New Plant Staffing Models
	Staffing Levels
	Alternative Training Methods/Programs
Management of Normal Operations	Managing Non-LWR Processes and Reactivity Effects
	Load-Following Operations
	Novel Refueling Methods
	HSIs for New Missions (e.g., steam production, hydrogen)
	No Traditional Control Room
	Remote Operations
	Different Unit States of Operation

Scaling Guidance: Appendix C

Screening:

General strategies and specific considerations for selecting which HFE activities to review or screen out

Implications / challenges of advanced reactor design characteristics for certain HFE activities or their review

Table 2-1 NUREG-0711 Elements Impacted by Potential SMR Issues

	NUREG 0711 Element	OER	FRA/FA	TA	S&Q	IHA	HSI	PD	TPD	V&V
ConOps Model Dimension	**SMR Issue**									
Plant Mission	New Mission	x	x	x	x	x	x	x	x	
	Novel Design and limited OE	x								
Agent's Roles and Responsibilities	Multi-Unit Operations and Teamwork	x			x		x	x		x
	High Levels of Automation		x	x			x			x
	Function Allocation Methodology		x							
Staffing, Qualifications and Training	New Staffing Positions				x				x	
	Staffing Models				x					x
	Staffing Levels				x					x
Management of Normal Operations	Different Unit States of Operation				x		x	x	x	
	Unit Design Differences						x	x	x	
	Control System for Shared Aspects of SMRs						x	x		
	Impact of Adding New Units on Operations						x	x		
	Non-LWR Processes and Reactivity Effects		x				x	x	x	x
	Load-following Operations		x		x	x	x	x	x	x
	Novel Refuleing Methods		x		x	x	x	x	x	x
	Control Room Configuration and Workstation Design						x			x
	HSI Design for Multi-unit Monitoring and Control						x			x
	HSIs for new missions						x			x
Management of Off-normal Conditions and Emergencies	Safety Function Monitoring						x	x		x
	Unplanned Shutdowns and Degraded Conditions				x		x	x	x	x
	Handling Off-normal Conditions at Multiple Sites				x		x	x	x	x
	Design of EOPsfor Multi-unit Disturbances							x		x
	New Hazards			x			x	x	x	x
	Passive Safety Systems			x			x	x	x	x
	Loss of HSIs and Control Room						x	x	x	x
	PRA evaluation of Site-wide Risk					x				
	Identification of RIHAs					x	x	x	x	x
Management of Maintenance and Modifications	Modular Concturctions and Replacement								x	
	New Maintenance Operations					x	x	x	x	x
	Managing Novel Maintenance Hazards									

Excerpted from

NUREG/CR-7202, NRC Reviewer Aid for Evaluating Human Performance Aspects Related to the Design and Operation of Small Modular Reactors

Scaling Guidance: Appendix D

Grading:

- Guidance for selection of standards and guidance documents to support the review
  - Considerations for use of documents that lack prior NRC endorsement
- Reference table of HFE standards and guidance documents in both nuclear and non-nuclear domains

Use of documents that lack NRC endorsement can be both an opportunity and a challenge

Table D-1. Additional Consensus Standards and Guidance Documents

Publication	Keywords	Domain
NUREG/CR-3331, "A Methodology for Allocating Nuclear Power Plant Control Functions to Human or Automatic Control"	evaluation; functional analysis and assignment	Nuclear
IEEE-2411, "IEEE Guide for Human Factors Engineering for the Validation of System Designs and Integrated System Operations at Nuclear Facilities"	nuclear power plant; integrated systems; verification & validation (V&V); performance-based validation; human factors engineering (HFE); operation; multistage validation; integrated system validation	Nuclear
IEEE Std 1023-2004, "IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities"	nuclear power plant; human-system interface (HSI)	Nuclear
NUREG/CR-2623, "The Allocation of Functions in Man-Machine Systems: A Perspective and Literature Review"	human-system interface (HSI); automation; computer-based procedure (CBP); computer-based aids; functional analysis and assignment	Nuclear

Scaling Guidance: Appendix E

Assembling the Review Plan:

Strategies for integrating the results of Steps 1-4 to develop a plan that is efficient yet sufficient to support a reasonable assurance determination

Guidance for documenting the review plan and gaining management approval

Summary

Staff has developed a framework for generating application-specific plans for the HFE review of advanced reactor license applications

Guidance is “interim” and will be refined with lessons-learnt through application

Ensuring suitability of human factors guidelines for advanced reactor technologies and concepts of operation will be critical to effective, efficient, and timely conduct of NRC’s HFE reviews

Thank you for your attention!

Acronyms Used

CFR – Code of Federal Regulations
COL – combined license
DC – design certification
DRO – Division of Reactor Oversight
FA – function allocation
FRA – functional requirements analysis
HFE – human factors engineering
HSI – human system interface
I&C – instrumentation and control
IHA – important human action
ISG – interim staff guide
OL – operating license
OER – operating experience review
PD – procedure development
S&Q – staffing and qualifications
SDA – standard design approval
TA – task analysis
TPD – training program development
V&V – verification and validation

Summary of Range of Concepts of Operations

Presenter:

- Casey Kovesdi, Human Factors Scientist, Idaho National Laboratory

Breakout Discussion Process

- Three 20-minute rounds of discussion
- Select an open seat at one of the designated tables to begin
- Participants will rotate to a different table for each round

Discussion Objective: To understand the implications that remote operations has for each dimension of a concept of operations, including areas that might be challenging or have unique implications for human performance.

Breakout Table Topics

Table 1

- Plant Mission/Goals
- Roles and Responsibilities of Personnel and Automation

Table 2

- Operator Staffing, Training and Licensing

Table 3

- Normal Operations

Table 4

- Off-Normal Operations

Table 5

- Maintenance and Modifications
- Tests, Inspections, and Surveillance

Use this QR code to access a copy of the draft interim staff guidance: Development of Scalable HFE Review Plans

DRO-ISG-2023-03

TABLE 1 Concept of Operations

1: Plant Mission/Goals
2: Roles and Responsibilities of Personnel and Automation

TABLE 2
Concept of
Operations

3: Operator Staffing, Training and Licensing

TABLE 3
Concept of
Operations

4: Normal Operations

TABLE 4
Concept of
Operations

5: Off-Normal Operations

TABLE 5 Concept of Operations

6: Maintenance and Modifications
7: Tests, Inspections and Surveillance


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CHANGING LANDSCAPE
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WEDNESDAY, MARCH 13, 1:30 PM – 3:00 PM

W11 Human in the Loop: The Changing Role of Humans in New and Advanced Reactor Designs

Sponsored by the Office of Nuclear Regulatory Research and the Office of Nuclear Reactor Regulation

The next generation of reactor designs features a variety of nontraditional operational concepts like remote operation, multiunit operation, and highly automated systems. These new concepts can fundamentally change the role of the human in ensuring the safe operation of nuclear reactors.

This session features a diverse panel of experts who will discuss important considerations for human-system interactions in different operational design contexts. Panelists will present their views on the top human performance challenges and opportunities with new and advanced reactor designs and the associated safety and regulatory implications.

WEDNESDAY, MARCH 13, 3:45 PM – 5:15 PM

W16 The Future of Nuclear: Adapting to AI-Enabled Autonomy

Sponsored by the Office of Nuclear Regulatory Research and the Office of Nuclear Reactor Regulation

Artificial intelligence (AI) is rapidly transforming the nuclear industry, and AI-enabled autonomy is one of the most promising areas of innovation. While AI-autonomous systems have the potential to enhance safety, efficiency, and reliability, they also raise important regulatory considerations.

This session will explore the future of AI-enabled autonomy in the nuclear industry, featuring perspectives from a diverse panel of experts to discuss the latest AI technological developments, the potential benefits and risks of AI and autonomy, and the regulatory considerations and opportunities that lie ahead.