Using NRC Regulatory Guidance for Human Factors Reviews of Nuclear Reactors

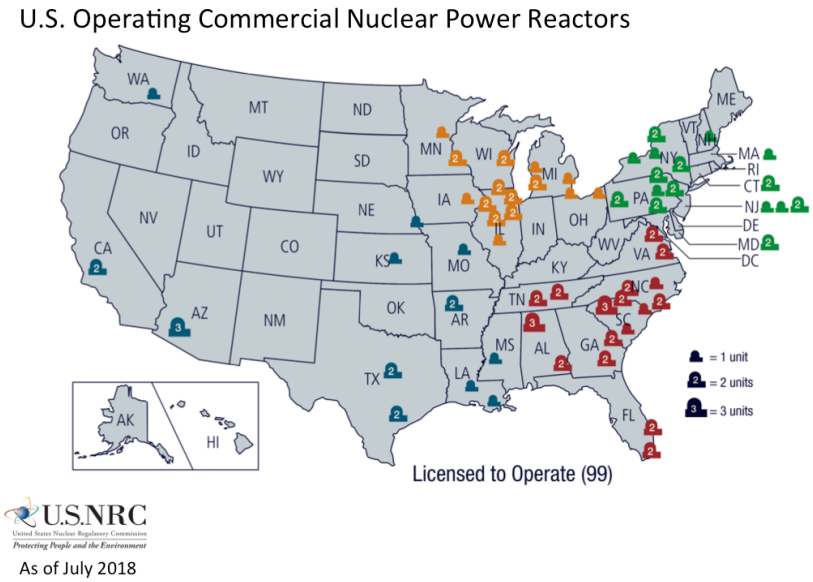
Brian Green, Ph.D.
Sr. Technical Advisor for Human Factors
U.S. Nuclear Regulatory Commission
April 21, 2026

NRC Mission

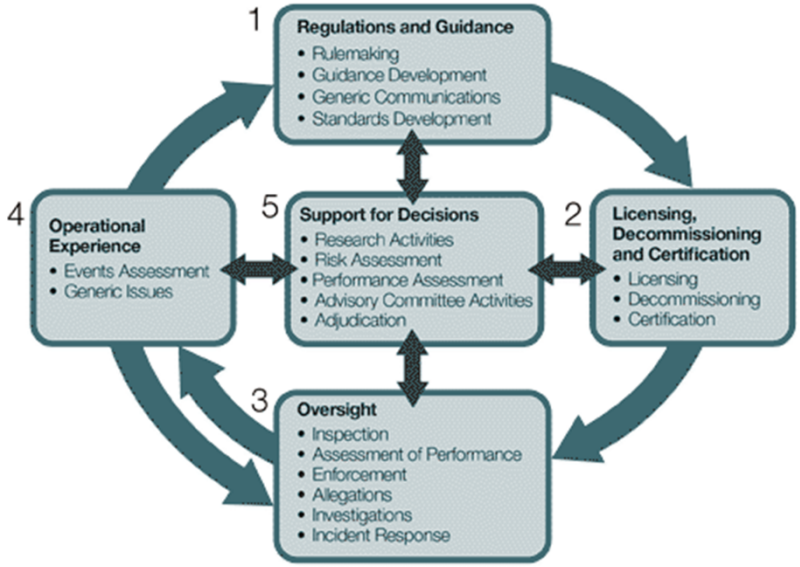
The NRC protects public health and safety and advances the nation's common defense and security by enabling the **safe and secure** use and deployment of **civilian nuclear energy technologies** and radioactive materials through efficient and reliable licensing, oversight, and regulation for the benefit of society and the environment.

Nuclear Reactor Overview

- Pressurized Water Reactors (PWR)
- Boiling Water Reactors (BWR)
- Several Advanced Reactor designs being developed



Key Regulatory Activities for Safety



1. *Developing regulations and guidance for applicants and licensees.*
2. *Licensing or certifying applicants to use nuclear materials, operate nuclear facilities, and decommission facilities.*
3. *Inspecting and assessing licensee operations and facilities to ensure licensees comply with NRC requirements, responding to incidents, investigating allegations of wrongdoing, and taking appropriate followup or enforcement actions when necessary.*
4. *Evaluating operational experience of licensed facilities and activities.*
5. *Conducting research, holding hearings, and obtaining independent reviews to support regulatory decisions.*

As of June 2017

- **Licensing**
  - Ensure the plant and organization are designed for safe operation
  - Use Deterministic/Risk-Informed Approaches
- Operations & Construction Oversight: **Inspections**
  - Ensure plant is constructed as licensed: ITAAC
  - Ensure plant is operated as licensed: tech specs, license conditions
- **Enforcement**
  - Penalties for operating outside of the terms of the license

https://www.nrc.gov/about-nrc/regulatory.html#providing

Regulatory Basis & Key Guidance for Human Factors

"Like" a Recipe

Taste Test

Regulatory Basis

- 10 CFR 50.34(f)(2)(iii) – "state-of-the-art human factors principles"
- 10 CFR 52.47 (DCA) & 52.79 (COLA) refers to 10 CFR 50.34
- General Design Criterion 19 – a control room to safely operate the plant
- *In reality:* ***Current Licensing Basis*** *for each licensee is different due to nuanced differences in response to TMI action items.*

Key Regulatory Guidanc

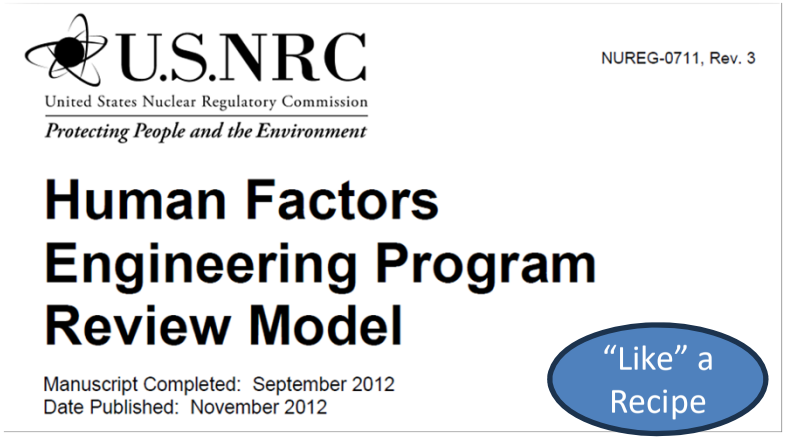
- **NUREG-0800**; "
  Chapter 18 -
- **NUREG-07**
  Program R
- **NUREG-070**
  Design Review
- Supporting Guida

Great general guidance –but don't address issues unique to special designs like SMR

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

"Human Factors Engineering Program Review Model" NUREG-0711 Philosophy

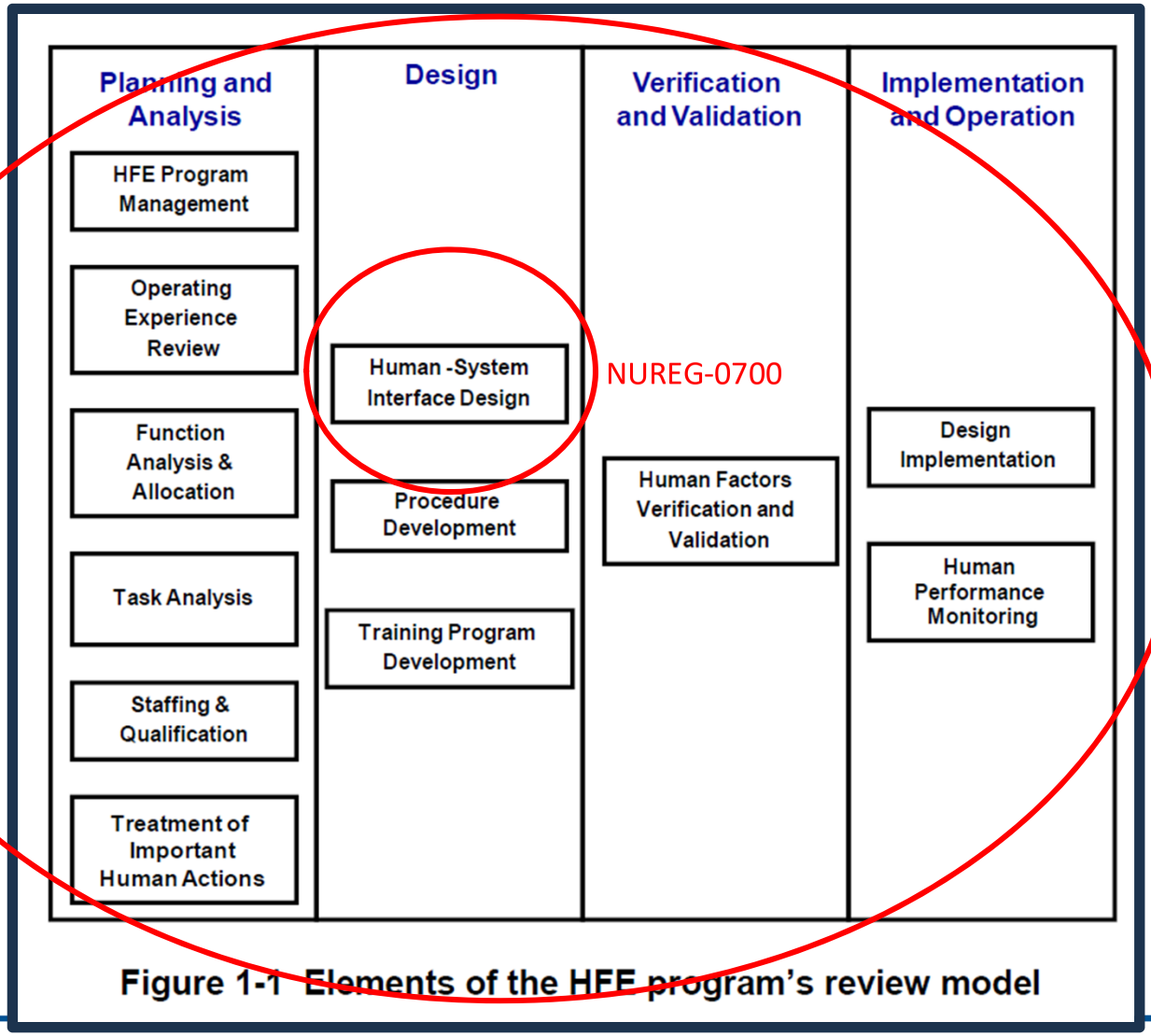
- NRC staff guidance to review an applicant's HFE design program
  - NOT an instruction manual on how to set up an HFE program, although it is sometimes used as such.
- Systems engineering & human information processing model
- Allows 2 types of submittals:
  - Implementation Plans (IP) & Results Summary Reports (RSR)
  - IPs usually followed by RSRs



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

"Like" a Recipe

NUREG-0711



NUREG-0700

Figure 1-1 Elements of the HFE program's review model

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

Taste Test

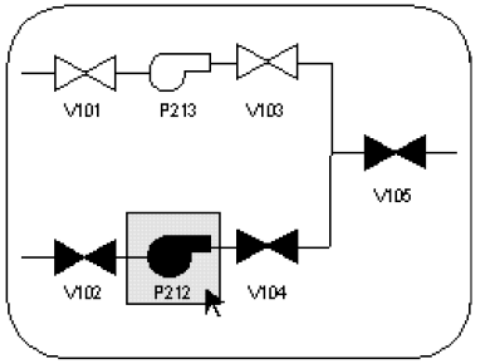
Example from NUREG-0700 "HSI Design guidelines"

Menu display—This is a display format that shows a list of alternatives. Selection may be made using a pointing device, a function key, or a keyboard to enter an identification code. The bottom part of Figure 7.1 depicts a cursor selecting a component from a menu display.

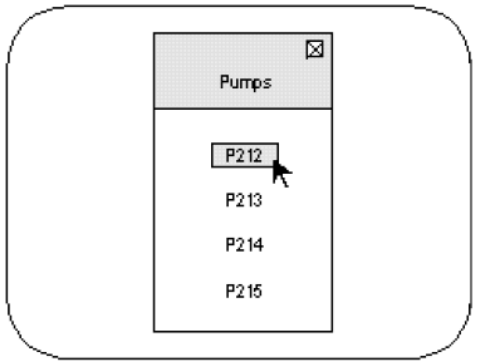
Dedicated button—This is a button whose activation will cause a particular control or display to be retrieved. It may be dedicated to a particular soft control. A dedicated button may be a physical "hard" button located on a keyboard or console or a "soft" button presented on a computer-based display device.

The following interaction methods generally require the user to identify a choice from memory: command language, natural language, query language, and question-and-answer dialogues. These methods may be augmented with online forms and other aids to help the operator compose entries. Although alphanumeric keyboards typically provide input, other input media, such as voice, are also possible.

- Applicants usually commit using NUREG-0700 as a style guide as part of the design process controlled by NUREG-0711.



a. Mimic



b. Menu

Figure 7.1 Two Typical Displays for Selecting Parameters or Components (With Onscreen Cursor)

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

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

USE OF REGULATORY GUIDANCE IN TECHNICAL REVIEWS

EXAMPLE: NUSCALE DESIGN CERTIFICATION REVIEW

- Requested a design certification (DC) – (allows a standardized design that can be built on other sites)
- 12 units from a single control room*
  - Integrated PWR, fully submersed in water (ultimate heat sink)
  - Unique refueling strategy
- Highly automated, passive and inherent safety features
- Initial staffing levels at 6 operators, subsequent topical report set staffing to 3 operators, no Shift Technical Advisor (STA)

*There is a more recent license application that has just 6 units instead of 12. That will **not** be addressed in this discussion.

Key Regulatory Documents

- **Laws – Passed by Congress** (e.g. Atomic Energy Act)
- **Regulations**
  - 10 CFR 52 – Design Certifications and Combined Operating Licenses
  - 10 CFR 50.34 – Conformance with SRP or justify deviations (via 52.47)
- **SRP (NUREG-0800) –** Tells NRC staff how to conduct safety reviews
  - **Chapter 18** – Provides specific guidance regarding human fa
- **Key Guidance –** (e.g. NUREG-0711& NUREG-0700)
  - Incorporated by reference in Ch 18
  - Provides explicit <u>acceptance criteria</u>
- **Supporting Guidance** – (e.g. NUREG/CR-7202 & NUREG/CR-7126)
  - May or may not be incorporated by reference in Chapter 18 or documents
  - Provide research-based positions that can support staff licensees
  - Does not usually consider public feedback before publica
  - **<u>Does not</u>** <u>provide explicit acceptance criteria</u>
    - Instead both have "questions" to be considered by reviewers

Great general guidance –but don't address issues unique to special designs like SMR

Discuss how we integrate Supporting Guidance into Reviews

Regulatory Strength

Applicant Submittals & NRC Documentation

- NRC staff consider all the documents on the previous slide, as well as **all submittals provided by an applicant**
  - e.g. license application (DCA, implementation plan (IP)/results summary reports(RSR)), supplements, responses to requests for additional information (RAIs), etc.
- Staff document regulatory findings in a **Safety Evaluation Report (SER).**

Example Regulatory Basis: NuScale DC

Design Certifications (DC)

Chapter 18 SER for NuScale (DC)

NUREG-0800 – Chapter 18

NUREG-0711

NUREG-0700

NUREG/CR-7202

Excerpt from the Staff SER

18.1.3 Regulatory Basis

The following NRC regulations cont
for this review:

10 CFR 52.47(a)(8), as it r
demonstrate compliance wi
the Three Mile Island (TMI
50.34(f), except 10 CFR 5

10 CFR 50.34(f)(2)(iii), wh
for Commission review, a co
the-art human factor principles
or revision of fabricated control roo
Chapter 18, Section III, "Acceptance Crite
criteria adequate to meet the above requirements, as well as review interfaces with other SRP sections. Acceptance criteria for HFE design methodology are provided in NUREG-0711, Revision 3, Section 2.4, "Review Criteria." (NUREG-0711 references NUREG-0700, which provides detailed acceptance criteria for HFE design attributes.)

The following documents also provide additional criteria or guidance in support of the SRP acceptance criteria to meet the above requirements:

NUREG-0696, "Functional Criteria for Emergency Response Facilities," issued February 1981

NUREG-0700, "Human-System Interface Design Review Guidelines," Revision 2, issued May 2002

NUREG/CR-7126, "Human-Performance Issues Related to the Design and Operation of Small Modular Reactors," issued June 2012

NUREG/CR-7202, "NRC Reviewer Aid for Evaluating the Human-Performance Aspects Related to the Design and Operation of Small Modular Reactors," issued June 2015

NRC staff identify applicable regulations and guidance and document in the SER. This slide shows the regulatory basis for the full review

NUREG-0711 – Element 2 Operating Experience Review

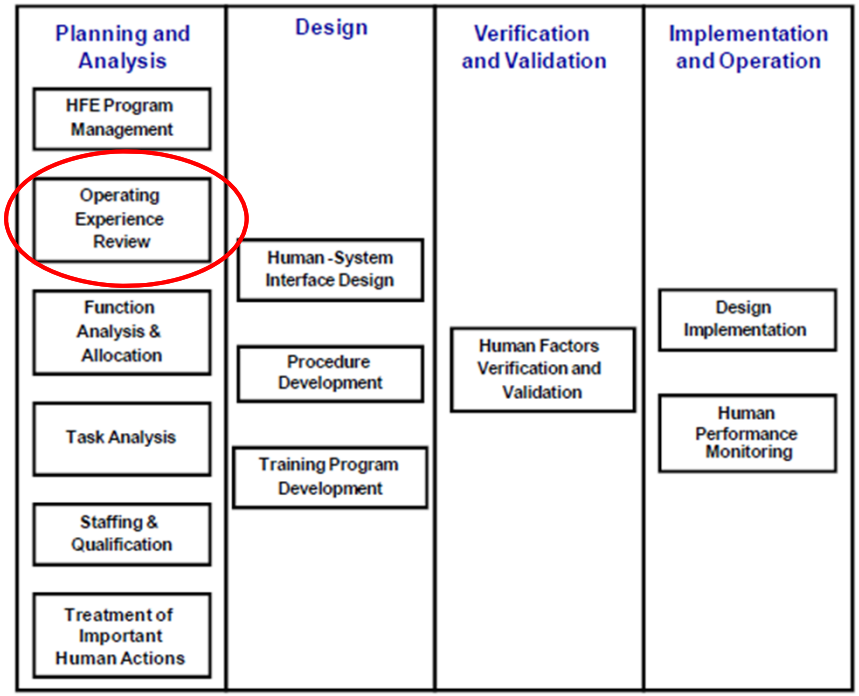


Figure 1-1 Elements of the HFE program's review model

Section 3.1 "Backgrou

Applicants should pr
administrative proc
evaluating operati
experience (refer
experience"), and
industry experienc
manner to those de
plant [10 CFR 50.34(f)

The main reason an applic
operating experience review (OER)
HFE program is to identify HFE-related safety issues. The OER provides information on the past performance of predecessor designs. For new plants, these predecessors may be earlier designs upon which the new design is based. For modifications to plants, they may be the design of the systems being changed. The issues and lessons learned from operating experience offer a timely basis for improving the plant's design (i.e., at the beginning of the design process).

Considering an applicant's submittal for a new NPP, its predecessor designs are those plants, systems, HSIs, and operational approaches that are the basis for the new plant's design. It may be based on multiple predecessors and encompass both non-nuclear and nuclear industry sources…

This is an example of one "element" of a NUREG-0711 review. This tells NRC staff what to look for when conducting the review.

Specific Example: Excerpt from SER Section for OER

Regulations

SRP

Acceptance Criteria

Supporting Guidance

Specific Justifications for Supporting Guidance

18.2.3 Regulatory Basis (OPERATING EXPERIENCE REVIEW)

The following NRC regulations contain the relevant requirements for this review:

10 CFR 52.47(a)(8), as it pertains to the information necessary to demonstrate compliance with any technically relevant portions of Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v)

10 CFR 50.34(f)(3)(i), as it addresses administrative procedures for evaluating operating, design, and construction experience

10 CFR 50.34(f)(2)(iii), which requires the applicant to provide, for Commission review, a control room design that reflects state-of-the-art human factor principles prior to committing to the fabrication or revision of fabricated control room panels and layouts

SRP Chapter 18, Section III, lists the acceptance criteria adequate to meet the above requirements, as well as review interfaces with other SRP [illegible]. Acceptance criteria for HFE design methodology are provided in NUREG-0711 (listed below). (NUREG-0711 references NUREG-0700, which provides acceptance criteria for HFE design attributes.)

NUREG-0711, Revision 3, Chapter 3, "Operating Experience Review," Section 3.4, "Review Criteria"

The following documents also provide additional guidance in support of the SRP acceptance criteria to meet the above requirements:

NUREG/CR-7202, "NRC Reviewer Aid for Evaluating the Human-Performance Aspects Related to the Design and [illegible]issued June 2015

NUREG/CR-7126, "Human-Performance Issues Related to the Design and Operation of Small Modular Reactors," issued June 2012

NUREG-0711 states, "The main reason an applicant conducts an OER as part of the HFE program is to identify HFE-related safety issues." The objective is to ensure that the applicant has reviewed previous designs and analyzed the results so that the design process can maintain positive features from predecessors and eliminate or minimize negative aspects of the design. The staff reviewed the RSR and applied the acceptance criteria in NUREG-0711,

Section 3.4, to ensure that this objective is met (Section 3.4.3, "Plant Modifications," applies only for plant modifications).

Some aspects of the design necessitate a modified version of an OER compared to those prepared for previous designs. Novel systems (e.g., unmanned aerial vehicles and teleoperative medicine) will play a much greater role in understanding the operating experience of techniques that are unique to NuScale.

NUREG/CR-7202 provides guidance to the staff to identify these new considerations with respect to SMR designs like NuScale. NUREG/CR-7126 provides additional detail that supports the criteria in NUREG/CR-7202.

The review criteria in NUREG-0711, Section 3.4, do not specifically mention the use of nonnuclear OER; however, the background section states, "It may be based on multiple predecessors and encompass both non-nuclear and nuclear industry sources." Additionally, NUREG/CR-7202, Section 2.2, "Novel Systems and Limited Operating Experience from Predecessor Systems," identifies questions the staff may consider when evaluating the ways the applicant has compensated for aspects of the design that may not have any or have only limited relevant predecessor plant operating experience.

The staff review verified that the applicant has a systematic and dedicated process for identifying, tracking, and addressing operating experience in the design in a manner similar to previous DC reviews. However, the staff focused this review using the guidance in NUREG/CR-7202 by verifying that the scope of the operating experience information reviewed includes appropriate surrogate industry information and by assessing whether a sufficient OER has been performed even when there may be limited or no relevant predecessor nuclear industry operating experience.

Acceptance Criteria
NUREG-0711: Criterion 3.4.1 "Scope" (1-5)

- 3.4.1 Scope

(1) Predecessor/Related Plants and Systems

(2) Recognized Industry HFE Issues

(3) Related HSI Technology

(4) Issues Identified by Plant Personnel

(5) Important Human Actions

Does NuScale have a predecessor? Yes and No

References NUREG-0933, NUREG-1275, NUREG/CR-6400. None relate directly to SMR. i.e. Multi-unit operation

"The applicant's OER should cover operating experience with the proposed HSI technology in the applicant's design." Surrogate industries have lots of experience with monitoring multiple devices

NUREG/CR-7202 – Appendix A

APPENDIX A QUESTIONS FOR SMR APPLICANTS ORGANIZED BY NUREG-0711 ELEMENT

In this appendix, the questions identified in Section 2 for each issue are reorganized by NUREG-0711 review element. Following each question, the Section 2 issue associated with the question is identified in parentheses. Reviewers needing additional information about the question should consult the originating issue in Section 2.

A.1 Operating Experience Review

What are the sources of operating experience contributing to the design of the SMR? Applicants should describe all relevant sources, even those that may come from non-nuclear systems. (Novel Designs and Limited Operating Experience from Predecessor Systems)

What operating experience is available for predecessor systems associated with the new missions? (New Missions)

What operating experience for multi-unit operations has been collected? (Multi-unit Operations and Teamwork)

What information will be used as a substitute for operating experience for those aspects of the design for which operating experience is unavailable? (Novel Designs and Limited Operating Experience from Predecessor Systems)

How has this operating experience been used in the design? (Novel Designs and Limited Operating Experience from Predecessor Systems)

Staff Assessment of NuScale OER Scope in SER Criteria 3.4.1 (1-5)

18.2.4.1.2 Staff Assessment

The staff compared the scope of the five methods used to assess relevant sources of operating experience described in the OER RSR to the associated NUREG-0711 criteria and considered the supplemental guidance in NUREG/CR-7202, which describes challenges related to OER methodologies that are unique to SMR technologies.

The staff found that the scope described in the OER RSR was consistent with the applicable NRC guidance described above with the following exceptions:

- The OER RSR submittal did not specifically identify some notable published examples of OERs that apply to SMRs (see NUREG/CR-7202, Appendix A: "Questions for SMR Applicants Organized by NUREG-0711 Element," Section A.1, "Operating Experience Review"). The December 12, 2017, response (ADAMS Accession No. ML17346A971) to RAI 9153, Question 18-5, describes the results obtained from the OER process when applied to certain nonnuclear technologies. Therefore, the staff was able to determine that the OER process had, in fact, included the appropriate scope including relevant nonnuclear industries.
- The bulleted list of considerations in the OER RSR, Section 3.3, was, for the most part, consistent with Criterion 3.4.1(3) and the supplemental guidance in NUREG/CR-7126; however, it was not apparent that multiunit considerations were included. The response to RAI 9153, Question 18-5, clarifies how multiunit operation and other issues described in NUREG/CR-7126 were considered in the OER process and used to improve the design. The response clarifies that NUREG/CR-7126 was used as an additional source of input to the OER analysis, and it summarizes a sample of results that are uniquely relevant to the NuScale design, such as the lessons learned from unmanned aircraft systems, oil refinery control systems, and teleoperative medicine experience.

During the June 2018 audit (ADAMS Accession No. ML18208A370), the staff confirmed that the sample of results presented in the OER RSR was representative of the full set of results contained in the OER database by reviewing a sample of OER items and ensuring that they were consistent with the applicable acceptance criteria.

Summary

- NRC staff assess documents submitted by applicants.
- Staff considers regulations, SRP, key guidance, supporting guidance
- Regulations must be met (or exemptions must be requested).
  - SRP helps the staff determine if a regulation is met – directs staff to acceptance criteria
    - HFE acceptance criteria are in key guidance documents like NUREG-0711 & 0700
  - Other guidance documents support interpretation of SRP and associated acceptance criteria
- Staff document how the acceptance criteria are met in SER. Includes:
  - The claims made by the applicant
  - What the staff considered while verifying claims made by an applicant
  - Conclusions about acceptability of actions taken by applicant

Questions

For Information about Careers at the NRC

NRC Careers
https://www.nrc.gov/about-nrc/employment.html

Brochure
https://www.nrc.gov/docs/ML2023/ML20238C035.pdf

www.USAJobs.gov

brian.green@nrc.gov

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

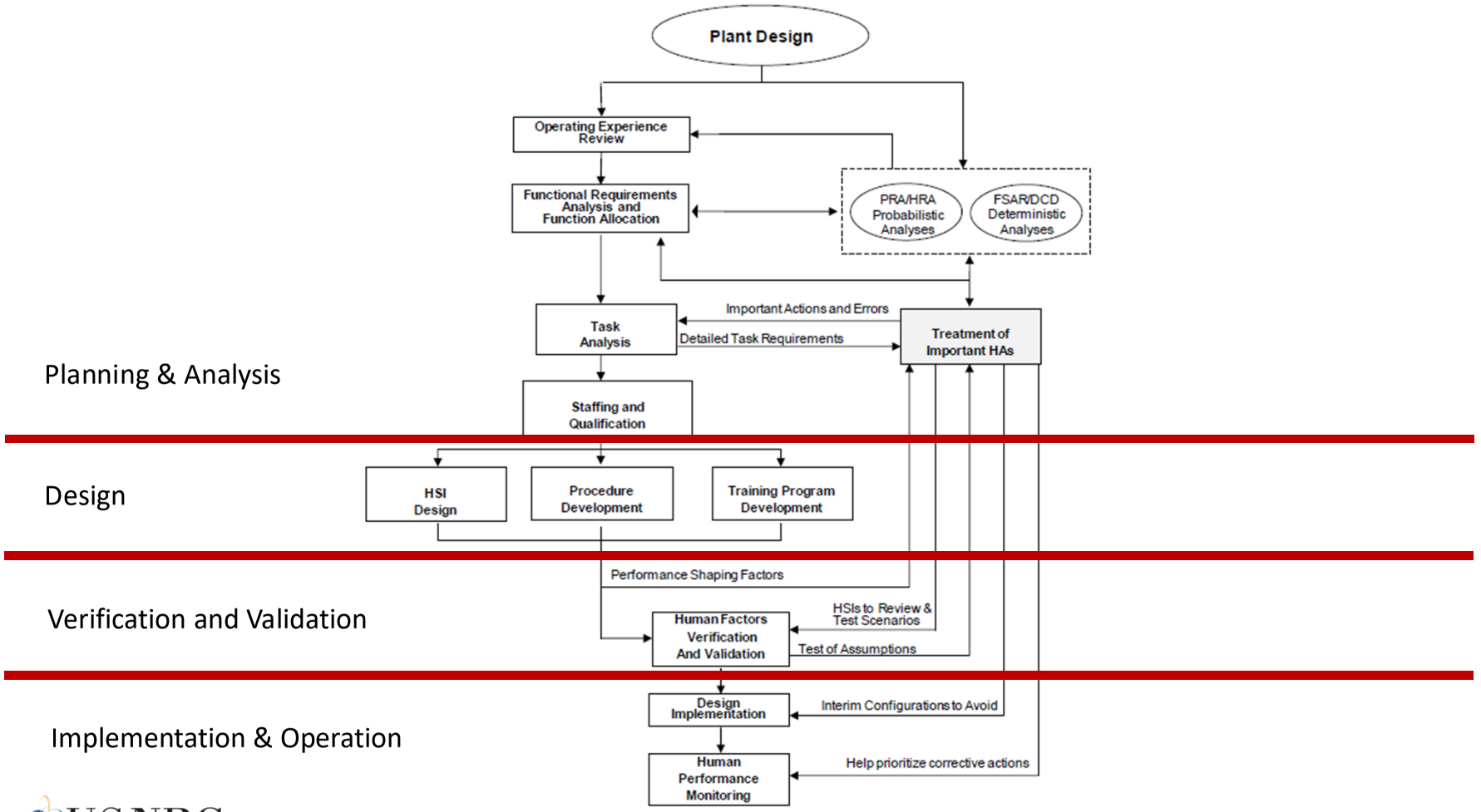


Figure 7-1 The role of important human actions in the HFE program

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

Operating Reactor Simulator

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

New Reactor - Simulator