Licensing Technical Report

Human Factors Engineering Human-System Interface Design Implementation Plan

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Abstract

This document provides the human-system interface (HSI) design implementation plan for the NuScale Power Plant. This implementation plan defines a structured methodology for the iterative design of the overall HSI, translating the functional and task requirements into the detailed HSI for the plant. The process produces a unique HSI Style Guide and a consistent state-of-the-art HSI design to be used by operators of the NuScale Power Plant to carry out the plant's goals under normal, abnormal, and emergency operating conditions. The process used is consistent with the applicable provisions of Section 8 of U.S. Nuclear Regulatory Commission, "Human Factors Engineering Program Review Model," NUREG-0711, Rev. 3 (Reference 4.1.2).

Executive Summary

The NuScale human-system interface (HSI) design is developed by a multi-faceted Human Factors Engineering (HFE) Design Team that brings unique skills and knowledge to the effort and works collaboratively and cohesively to reach the project goals. The NuScale HFE Design Team includes former nuclear plant operators and supervisors, plant system engineers, instrumentation and controls engineers, a simulator plant model, HSI software developers, and human factors engineers.

The plant functions, operator tasks, and concepts of use are incorporated into the NuScale HSI Style Guide for use by the HFE Design Team to produce a consistent state-of-the-art HSI design. The design team follows the NuScale HSI design and validation process to create and analyze the HSI the operators use to satisfy the plant's overall safety and operating objectives and goals.

The HSI is analyzed to verify that

- in-scope tasks can be performed in a consistent and timely manner.
- the design takes advantage of human and machine strengths to avoid human error and machine limitations.
- the HSI is consistent with the HSI Style Guide.
- the HSI satisfies the guidance in Section 8 of NUREG-0711 (Reference 4.1.2).

Staffing validation confirms the main control room layout and HSI design meet the needs of the staffing and qualification effort discussed in the Human Factors Engineering Staffing and Qualifications Results Summary Report (Reference 4.2.6).

This report is organized as follows. Section 1.0 and Section 2.0 provide an introduction to the HSI process and the HSI implementation process, respectively. Section 3.0 describes the methodology followed by the HFE Design Team during the development of the HSI. The source and referenced documents applicable to and used in the HSI effort are listed in Section 4.0.

1.0 Introduction

1.1 Purpose

The purpose of this implementation plan (IP) is to document the methodology of an iterative human-system interface (HSI) design process. This process translates the functional and task requirements to the HSI design requirements and to the detailed design of alarms, displays, controls, and other aspects of the HSI, which are based on systematically applying state-of-the-art Human Factors Engineering (HFE) principles and the criteria to support the safe and reliable operation of the NuScale Power Plant.

1.2 Scope

This IP includes a summary of the research, design, and testing efforts performed by the NuScale HFE Design Team that produced a coherent and consistent screen-based HSI design for the licensed operators located in the main control room (MCR) during normal, abnormal, and emergency operating conditions.

This IP encompasses the design activities for HSIs including those

- in the MCR.
- derived from the MCR-designed HSIs (including the Technical Support Center and Emergency Operations Facility.
- local control stations used by operators as described in the NuScale HFE Program Management Plan (Reference 4.2.9).

The HSIs include alarms, indications, controls, and embedded procedures. The HSI design also includes those systems used to communicate with personnel outside the MCR.

The NuScale HSI design and validation process addresses

- the guidance documents used for the HSI detailed design.
- the in-scope facilities and HSIs within those facilities covering form, function, and performance characteristics.
- required inputs to the HSI design process.
- the concept of how HSIs are used and an overview of the HSI design process.
- alarms, cautions, status indications, controls, and computer-based procedures.
- systems used to communicate with personnel outside the MCR.
- how the design minimizes the effects of degraded instrumentation & controls (I&C) and HSI conditions on the performance of personnel.
- the outcomes of tests and evaluations undertaken to support the HSI design.

1.3 Abbreviations and Definitions

Table 1-1 Abbreviations

Term	Definition
FRA/FA	functional requirements analysis and function allocation
HED	human engineering discrepancy
HFE	Human Factors Engineering
HSI	human-system interface
I&C	instrumentation & control
IHA	important human action
IP	implementation plan
MCR	main control room
NSE	non-safety enable
OER	operating experience review
S&Q	staffing and qualification
SA	situational awareness
TA	task analysis

Table 1-2 Definitions

Term	Definition
Embedded Procedure	A computer-based procedure that is part of the NuScale HSI system that allows the operators to safely monitor and control the plant. An embedded procedure has bidirectional connection to the control networks.
HFE Design Team	Generic term for the Plant Operations organization that consists of operators, human factor engineers, and simulator developers. The HFE Design Team does not include plant personnel. The HFE Design Team is responsible for the HFE associated with the NuScale design. The HFE team is also referred to as the design team.
Human-System Interface	The HSI is that part of the system that personnel interact with to perform their functions and tasks. In this document, "system" refers to a nuclear power plant. Major HSIs include alarms, information displays, controls, and procedures. Use of HSIs can be influenced directly by factors such as: (1) the organization of HSIs into workstations (e.g., consoles and panels): (2) the arrangement of workstations and supporting equipment into facilities such as: an MCR, local control station, Technical Support Center, and Emergency Operations Facility; and (3) the environmental conditions in which the HSIs are used, including temperature, humidity, ventilation, illumination, and noise. Human-system interface use can also be affected indirectly by other aspects of plant design and operation such as crew training, shift schedules, work practices, and management and organizational factors.
Module	A NuScale module consists of the containment vessel, reactor pressure vessel, and all components internal and external to each vessel, up to the disconnect flanges.
Process Library	NuScale HSI interface that allows plant operators to view embedded procedures and automated processes.
Screen-based HSI	A defined set of information that is intended to be displayed as a single unit. Typical nuclear power plant display pages may combine several different formats on a single display screen, such as putting bar charts and digital displays in a graphic piping and instrumentation diagram format. Display pages typically have a label and designation within the computer system so they can be assessed by operators as a single "display."
Unit	A NuScale unit consists of the components necessary to generate electricity. This includes a primary side containing a reactor power module and its specific supporting systems, and a secondary side containing a turbine generator and its specific supporting systems.
Video Display Unit	An electronic device for the display of visual information in the form of text or graphics.
FRA/FA & TA database	The functional requirements analysis and function allocation (FRA/FA) & task analysis (TA) database is a relational database that is used to store the FRA/FA, TA, staffing and qualifications (S&Q) analysis, development of HSIs, procedures, and training data. In this document it may be referred to as the "FRA/FA & TA database" or "database."

2.0 Implementation

2.1 Human-System Interface Design Process Overview

The analyses performed in the early stages of the HFE Program are important steps in establishing the inputs to the design requirements for the NuScale HSIs. The HSI design inputs that are analyzed and developed include the following:

- operating experience review (OER)
- functional requirements analysis and function allocation
- task analysis
- staffing and qualifications
- treatment of important human actions (IHAs)
- concept of operations
- I&C systems design
- alarm management
- system requirements
- HSI Style Guide

Once the inputs are established, the design effort follows the NuScale HSI process steps listed below when designing the MCR, conceptual workstations, and screen-based HSIs needed to complete the design effort.

1. Follow the appropriate chapters of the NuScale HSI Style Guide needed to establish a safe, user-friendly work location.
2. Follow the appropriate chapters of the NuScale HSI Style Guide needed to establish safe, user-friendly workstations.
3. Design and develop the HSI needed to accomplish safe and reliable operation of the plant.
4. Test and evaluate the HFE and HSI design of the simulator and products developed to support plant operations.

The HSI design products are the physical HSI screens, the embedded procedure functionality, and the plant notification functionality maintained within the MCR and simulator control room hardware and software.

2.2 Human-System Interface Design Team Composition and Responsibilities

2.2.1 Human-System Interface Design Team Composition

The NuScale HFE and HSI design process is instituted by a multi-faceted HFE Design Team that brings unique skills and knowledge to the effort and works collaboratively and cohesively to reach project goals. The HFE Design Team includes former nuclear plant operators and supervisors, plant system engineers, instrumentation and controls engineers, human factors engineers and software developers that work collaboratively and cohesively to reach project goals. This unique membership combination provides representation from both user and designer perspectives.

2.2.2 Simulator Development Responsibility

The HFE Design Team begins by designing an MCR simulator. An MCR simulator (also referred to as the simulator) is a computer-based, interactive work location that brings the operators as close as practicable to a true representation of the NuScale Power Plant responses and user interfaces located in the MCR. The simulator is where the HFE Design Team carries out rapid development, tests the evolving HSI design, and validates the NuScale MCR concepts and staffing goals. The simulator is also an effective tool for demonstrating plant operating and control concepts.

2.2.3 Human-System Interface Development Responsibility

The NuScale HSI design incorporates results of the OER, literature reviews, informal trade-off evaluations, informal consideration of multiple alternatives, and tests and evaluations. These aspects support the technical basis for demonstrating that the design supports personnel performance.

2.2.4 General Considerations

The following design goals are emphasized during the HSI design and evaluation process:

- high display-control compatibility (recognition)
- prompt feedback and accurate status indication for operator-initiated system actions
- selection of a data update rate that best meets the needs of operator tasks
- informative presentation of subsystem boundaries
- support for operator error detection and recovery
- informative, perceptually salient plant notifications that do not overwhelm the operator
- minimal interference of HSI maintenance and testing with operations (minimal distraction of operators)
- consistent application of styles, conventions, and information layout to support orientation and efficient navigation
- optimal balance between providing a flexible HSI that can be tuned to future operator needs while minimizing operator effort devoted to HSI management and possible confusion

2.2.5 Special Considerations for the Human-System Interface Design

The following special high-level design considerations identified as part of a preliminary analysis of the essential and desirable features of an HSI for the NuScale Power Plant are emphasized during the HSI design and evaluation process:

- improved situational awareness with a highly automated system
- acceptable workload levels with responsibility for control of multiple units assigned to a single operator
- at-a-glance top-level awareness with periodic lower-level active monitoring
    - information is presented in levels of detail based on task needs through an abstraction hierarchy (the work domain is modeled to determine what kinds of information should be displayed and how it should be arranged)
- process and information visualization techniques that take advantage of visual perception to offload demands from cognitive processing
- proper situational awareness with multiple units
    - interface and task design that seeks to avoid perceptual or cognitive tunneling on a particular condition or display at the expense of awareness of other systems or units
        - user-system interaction paradigm that avoids memorization and recall of codes and commands
        - interface that provides early detection of plant conditions that may lead to an alarm or caution condition
- integration of procedures with automated process control embedded into the HSI
- support for incident diagnosis after a plant trip

3.0 Methodology

3.1 Human-System Interface Design Inputs

3.1.1 Personnel Task Requirements

The analyses discussed below are performed in the early stages of the HFE Program and are used to establish design requirements for the NuScale HSIs.

During OER (Reference 4.2.3), issues from other plants and similar HSI designs are evaluated for inclusion or exclusion in the NuScale HSI design. The HSI design element confirms that the issues found during OER remain adequately addressed as the HSI design progresses. Discovered OER issues are resolved within the HSI design element or tracked in the Human Factors Engineering issues tracking system as applicable.

During FRA/FA (Reference 4.2.4), the NuScale Power Plant system functions that support safety are defined. Each system function is analyzed to determine the tasks, how each task is performed (manual, automated, or both), the technical basis, and the role of the operator. Safety functions are used as inputs to the design of the overview screens within the HSI inventory. The HSIs for lower level functions are further analyzed during TA. Automation criteria established during function allocation define the levels of automation anticipated for the HSI design. The HSI design issues initiated in FRA/FA are also resolved during HSI design.

The TA (Reference 4.2.5) provides the information needed to build a complete HSI inventory and the characteristics of that inventory needed to monitor and control critical functions during normal and abnormal operating conditions. Alarms, indications, procedures, and backup control for automated functions are also defined during TA. While building the HSI inventory during TA, characteristics such as alarm conditions, indication range and resolution, control function modes and accuracy, and procedure applicability conditions are established. Grouping of HSI elements in TA leads to HSIs designed for specific tasks and reduces both reliance on system-based HSIs and navigation between screens. Task support requirements are defined in TA and may be implemented during HSI design or as issues tracked for resolution by other engineering disciplines.

The HSI design considers IHAs identified in the Probabilistic Risk Assessment and from deterministic analyses to verify the assumptions regarding HSI characteristics for IHAs are implemented in the HSI. The following are examples of HSI characteristics that affect IHAs:

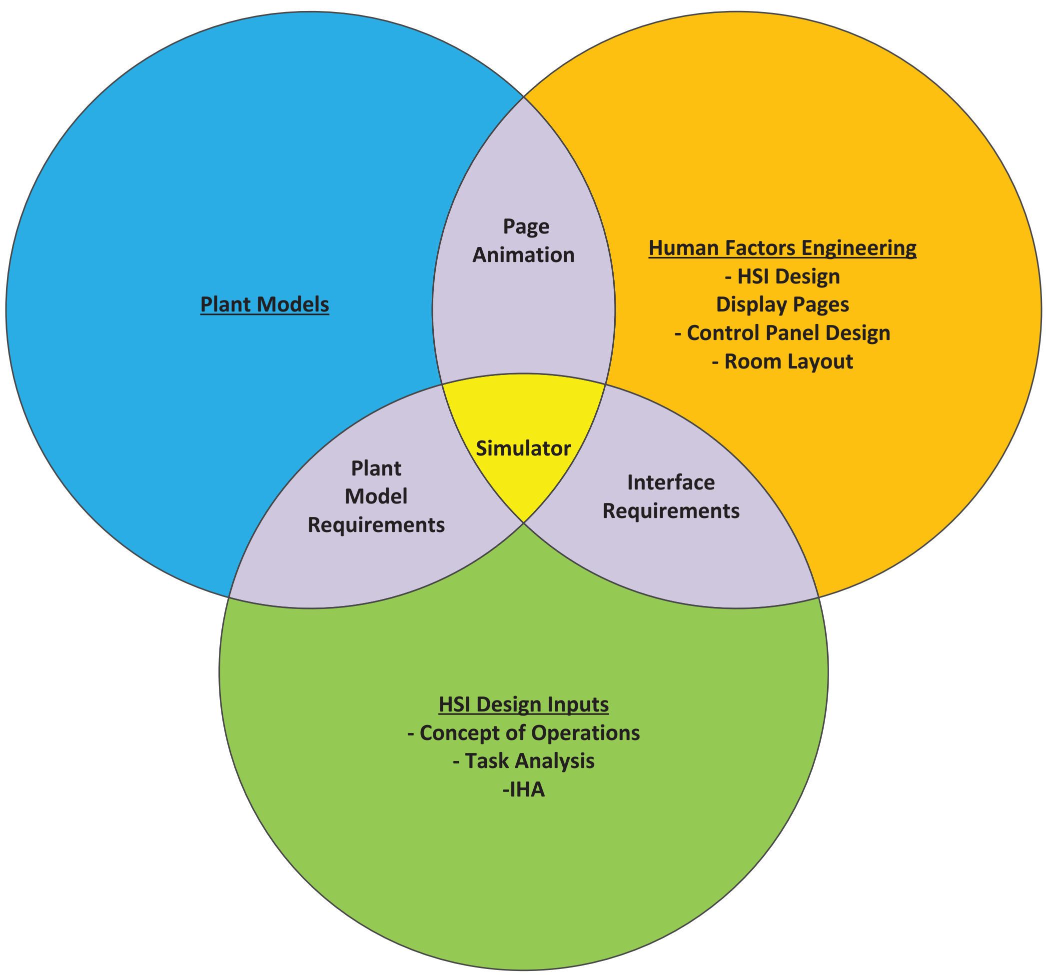
- reduction of time required for human actions via simplified or reduced navigation
- development of dedicated HSI
- developing alarms associated with IHAs

The MCR layout considers providing workstations and video display units needed for the monitoring and control of multiple units and the common systems associated with them. Staffing and qualification analyses (Reference 4.2.6) are used to provide input to the HSI design by influencing the HSI hierarchy and navigation concepts, allocation of controls and displays to individual visual display units, and overall MCR layout. The S&Q analyses also validate the MCR crew complement and responsibilities of each member of the crew.

3.2 Simulator Development

The development of the simulator is at the center of three major NuScale work efforts. The various aspects of the simulator design processes are interlinked as shown in Figure 3-1.

Figure 3-1 NuScale Main Control Room Simulator Development Venn Diagram



The elements shown are needed to design the simulator and are defined below:

- HSI design input - discussed in Section 3.1.
- Plant model requirements - functionality needed from the plant models to support the HSI and simulator design efforts. The appropriate HSI design inputs are used to help determine the needs.
- Plant models - set of models used to closely model and predicted behavior of the NuScale design.
- Page animation - HSI software that provides the operators an interface to the plant models.
- HFE - design effort discussed in this IP.
- Interface requirements - includes the NuScale HSI Style Guide as well as the input's information that drives HSI display page information (e.g., FRA/FA and TA).

The HSI process discussed in this IP is highlighted in orange in Figure 3-1. The other elements shown are discussed at a high level and are needed to develop the simulator and accomplish the goals discussed in Reference 4.2.9.

The HFE Design Team ensures that the partnerships among various NuScale plant design groups and the use of the appropriate guidance documents drive the simulator and HSI design to support:

- minimizing the probability that errors occur.
- maximizing the probability that any error made is detected.
- analyses of personnel roles (job analysis).
- systematic strategies for organization, such as arrangement by importance, and frequency and sequence of use.
- the inspection, maintenance, test, and repair of (1) plant equipment and (2) the HSIs.
- personnel task performance under identified staffing conditions (minimum, typical, and high-level or maximum).
- consistent design for the HSIs.
- philosophy for updating the HSIs.
- procedures.
- automation.

3.3 Human-System Interface Design Overview

An iterative methodology incorporating the HSI design inputs (Section 3.1), analysis of personnel task requirements, system and regulatory requirements, concept of use, and general requirements, is used to develop the HSI conceptual design. The iterative design and evaluation approach serves to

- guide the selection of one from multiple candidate designs.

- answer open HFE questions related to situational awareness (SA), workload, and staffing.
- identify and eliminate HFE issues from the design early in the process.

Feedback from users on HSI prototypes is incorporated before the detailed design effort.

The iterative design of the HSI is closely connected with other HFE activities. As a part of each design effort, the HFE team presents findings and solicits input from the following design disciplines:

- instrumentation and controls and computer systems - considers whether the design concepts are technically feasible, with a special emphasis on performance requirements
- human reliability analysis process - considers plant conditions, risk-important human actions and HSIs identified as being important to plant safety and reliability or operator actions credited for achieving plant stabilization when automatic actions are not triggered
- staffing and qualification plan efforts - determines deficiencies or features of the design that are incompatible with the proposed staffing model
- procedure development - HSI design supports clear, reasonable procedures and vice versa
- training program development - considers the feasibility of the operator skills, rules, and knowledge necessitated by the proposed design

3.3.1 Survey of State-of-the-Art in Human-System Interface Technologies

The state-of-the-art HSI technology is established with an emphasis on adaptability, principles, and design patterns that serve the needs of the NuScale Power Plant. Options are evaluated for human usability and technical feasibility. Specific software and hardware development is not in the scope of the survey; however, an understanding of the state-of-the-art software and hardware technologies provides insight for development of the functional and procurement specifications for the HSI platform.

3.3.2 Preparation of Human-System Interface Design Support Documentation

The Concept of Operations and HSI Style Guide documents have the potential to be updated during HSI conceptual design because of the iterative nature of the NuScale design process.

Note that these documents are revised as necessary throughout the design process as findings from testing and analyses are developed.

3.3.3 Conceptual Sketches

Conceptual screen sketches are aimed at creating a template page of a system or process that conforms to a subset of the HSI functional requirements. A template page is developed for each major portion of the HSI (e.g., task-based screens, computer-based procedures interfaces, overview displays). The level of detail of the template coincides with the maturity of the plant design for that type of interface. Representative screens and task sequences are selected for depiction, demonstrating key concepts, features and interactions, and for providing concrete grounds for analysis and feedback. Conceptual sketches incorporate the best understanding of design principles as outlined in the latest HSI Style Guide.

Screen designers produce multiple candidate approaches for the conceptual sketches. Major components that are initially investigated in this manner include:

- template for screen layout(s)
- navigation schema
- information visualization approaches
- advanced alarm system interface
- computer-based procedures integration

If elements of the conceptual sketches, once reviewed, bring positive features to the overall design, changes to the HSI Style Guide are made accordingly.

3.3.4 Rapid Prototyping

Based on the latest conceptual sketches and feedback from interfacing with other disciplines, mock-ups or prototype screens integrated with a software simulator of the system are developed for review and evaluation. While the prototype provides a realistic user experience with the system, the focus is on testing design concepts and soliciting feedback, rather than producing an engineering-quality software architecture and user interface.

3.3.5 Tests and Evaluations

The HSI design tests and evaluations are conducted and include trade-off evaluations and performance-based tests.

Trade-off evaluations pertain to comparing HSI design approaches and consideration of alternatives. In comparing HSI design approaches, consideration is given to ways to enhance human performance for performance of tasks, including IHAs.

Performance-based tests are performed to validate that the integrated system design (e.g., hardware, software, procedures, and personnel elements) supports the safe operation of the plant.

3.4 Human-System Interface Concept of Use

3.4.1 Operator Roles and Responsibilities

The MCR licensed operators and operating crews outside of the MCR are responsible for safe operation of the common plant, for each individual unit, and for maintaining power production. To achieve these objectives, the operators perform a variety of activities such as:

- monitoring the performance of structures, systems, and components
- operation of local and remote structures, systems, and components
- commanding automated sequences
- directing subordinate operators to perform procedures
- monitoring the performance of sequences and procedures
- interrupting and reprioritizing sequences or procedures
- summoning additional resources to expand capabilities
- monitoring and evaluating technical specification conditions
- surveillance testing
- reviewing trends
- responding to off-normal conditions
- responding to alerts and alarms
- establishing plant conditions to support preventative or corrective maintenance, testing, and inspections
- maneuvering the plant
- performing emergency response duties such as off-site notifications
- performing non-emergency off-site reporting
- maintaining a narrative log of events and activities that are relevant to the plant site
- communicating plant status, constraints, and planned actions to the appropriate stakeholders

Operators are guided in the performance of these activities by regulations, procedures, guidelines, training, and experience.

Operators follow procedures for equipment operation. Procedures direct the operation of components in the field, remote operation of components from the MCR, and the monitoring of automation to perform sub-steps, steps, and sequences to support the systems operation. Designing an integrated system for operation and monitoring roles at any location is a goal of the HFE Design Team.

3.4.2 Automation Roles

Automation plays a key role in the control of a NuScale Power Plant. Beyond controlling plant functions and systems, automation is applied to a wide range of other functions, including monitoring and notification, situational assessment, response planning, response implementation, and interface management. Automation is a critical component of the HSI design and supports operators in operation of the plant. The following are examples of automation as a function of the HSI design:

- placing equipment in service, conducting tests, and controlling processes
- automated notifications and recommended sequences
- performance of sequences not suited to manual operation (description of process control roles below)

3.4.2.1 Process Control Roles

The control system continuously monitors key plant parameters. When one of these parameters approaches a control limit, the process control responds automatically to adjust the process. Depending on the parameter, the associated automation (process control) may respond with or without operator consent depending on the task. The criteria used to develop the process control systems roles are discussed below:

- continuous monitoring - automation controls basic intermittent and continuous processes (such as hot well level control or turbine speed control) and provides continuous process parameter monitoring
- repetitive tasks - those that involve multiple identical component manipulations, which can be error-likely tasks for operators
- high cognizant burden functions - such as plant maneuvering, control rod exercising and valve testing, pressurizer level and coolant temperature control
- startup and shutdown support
- power maneuvering evolution support
- plant notifications - monitoring of plant parameters to provide visual and audible cues to the operator to maintain SA and support the need to take manual control
- data historian review - monitors parameters and evolutions to safely operate and report on the condition of the plant
- embedded procedures - a procedure system that assists control room operators by allowing control of plant components from within the procedure that is embedded into the HSI

3.4.3 Shared Roles

The HFE Design Team uses the following set of criteria to provide the information necessary to coordinate the shared activity when developing the HSI.

3.4.3.1 Parameter Monitoring

Automation performs functions associated with parameter and process monitoring, defined sequence functions, continuous process control, alert and alarm monitoring, safety limit monitoring, and automatic safety functions including monitoring. Operators monitor and evaluate automated functions, intervening as required.

Properly providing the operators with the ability to monitor process parameters that are controlled by automation supports SA and enables the operator to evaluate automated system performance and intervene, as necessary. Operators increase attention to system performance monitoring when

- transients are anticipated.
- sustained normal automated operation needs to be confirmed.
- degraded automation is suspected.

3.4.3.2 Operator Intervention

Operators intervene when the automation is asking for consent or when it becomes apparent that the automation has failed or is no longer appropriate for the current or planned plant conditions.

3.4.4 Document Review

When appropriate, operators access an information and records management system to review technical documents, reports, test results, and other work documents to confirm the readiness of structures, systems, and components for operations.

3.4.5 Main Control Room Layout

The list below outlines the MCR layout design concepts used to develop the HSI features discussed in this document. Original design concepts were based on OER from operating nuclear power plants and control rooms from various industries in which fewer operators operate multiple units.

The MCR concept includes the following attributes:

- a bank of visual display units configured with spatially dedicated continuously visible HSIs (e.g., post-accident monitoring variables, “manual” backups for protective functions)
- a minimum of four sit-down operator workstations, each providing access to HSIs for all units
- a dedicated unit stand-up workstation for each unit to allow focused operation
- a dedicated workstation for shared or common systems

- technologies to support teamwork and communications including individual and group plant notification techniques and non-wireless communication such as standard phone, verbal and e-mail protocols

3.5 Human Factors Engineering and Human-System Interface Design Guidance

3.5.1 Human-System Interface Style Guide

The NuScale HSI Style Guide applies to pertinent HSIs throughout the plant. The style guide includes a description of applicability for the included guidance. The HSI designers consider the environment in which the HSIs are to be used, for example, colors, brightness and contrast, and element spacing.

The NuScale HSI design employs an inclusive HSI Style Guide for various types and formats of HSIs. The design criteria listed below illustrate how the style guide is used during HSI design. The topics in the style guide address the scope of HSIs included in the design, and address their form, function, and operation.

The HFE guidance and the HSI design-related analyses are used to develop the guidance in the style guide. The style guide influences the design decisions that address specific goals of the HSI design. The style guide expresses precisely and describes easily observable HSI characteristics, such as “Alarms are shown in red.” The style guide contains sufficient detail so that design personnel deliver a consistent, verifiable design.

The style guide is maintained in a form that is readily accessible and usable by designers, and is easily modified and updated as needed. Each guidance statement includes a reference(s) to the source upon which it is based. The style guide is consistent with the guidance of NUREG-0700 (Reference 4.1.1)

3.5.2 Concept of Operations

The concept of operations provides an overview of the supporting processes, individual roles, overall staffing, organizational values, crew structure, and operating techniques used by the crews of a NuScale Power Plant to achieve a high level of safety and production.

The concept of operations is refined as the design, engineering and simulator evaluation associated with safety analysis, system design, control system automation, and HSI progresses.

3.5.3 Conduct of Operations

The conduct of operations provides a set of standards to influence operator behaviors to ensure high quality, consistent task performance that supports the safe and reliable operation of the NuScale Power Plant. The conduct of operations is applicable to on-shift operations staff.

The conduct of operations is refined as the design, engineering and simulator evaluation associated with safety analysis, system design, control system automation, and HSI progresses.

3.6 Human-System Interface Detailed Design and Integration

In addition to the input elements discussed in Section 3.1. the HFE Design Team also takes into consideration the design elements listed below during the HSI design process. The team addresses each area individually and applies the results to the overall HSI design:

- IHA
- HSI layout bases
- HSI support for inspection, maintenance, and testing
- support for staffing conditions
- human performance and fatigue
- environmental conditions
- HSI updates of plant modifications

3.7 Human-System Interface Tests and Evaluation Overview

This section describes the method NuScale uses to verify and document the review of the HSI displays, controls, and related equipment lying within the scope defined by the sampling of operational conditions discussed in the Control Room Staffing Plan Validation Methodology, RP-1215-20253 (Reference 4.2.8).

Detailed design is a stage of development for a certain portion of the HSI. Different portions of the overall HSI are in conceptual design or detailed design depending on their level of development. Detailed design applies to the information gained from the iterative conceptual design phases to the production of a comprehensive HSI design.

During detailed design, the limited HSI library is evaluated against the style guide to ensure interface predictability across the system. In addition, the HSI is evaluated against a limited portion of the system TA to verify the needs of the operator. The pertinent information within each screen during staffing validation sampling of operational conditions is verified during simulator based testing. The navigational structure and links that tie groups of related screens together is evaluated for usability during detailed design. The individual screens and their evaluations are archived in hard copy and electronic form.

Throughout the detailed design, the analysis of personnel task requirements is considered to ensure special attention to safety-related HSI elements (e.g., hard-wired backups for safety functions).

3.7.1 Internal Review of Design

Before performing tests on a hardware or software implementation, the design is subject to review. The review identifies HFE issues to be addressed before experimental evaluation and ensures that the design maturity is commensurate with the current design phase. Review of the design may also generate HFE questions or identify design trade-offs that cannot be resolved by static analysis, and should be considered for inclusion in subsequent tests.

The review steps include at least one of the following efforts for a particular iteration of the design:

- verification that design process inputs have been adequately considered and addressed in developing requirements and the design
- verification that the design conforms to the requirements
- inspection for close agreement between the design and the HSI Style Guide
- identification of usability issues based on human factors expert inspection and heuristic evaluation
- walk-through of representative tasks for ensuring compatibility of the design with the associated procedures and the I&C system

3.7.2 Testing and Evaluation of Design

Testing and evaluation consists of several stages.

Table 3-1 shows anticipated testing and evaluation efforts with respect to design phase.

Table 3-1 Iterative Human-System Interface Design and Evaluation Plan

	Design Phase		
	Conceptual Design	**Detailed Design**	**Detailed Design and Integration**
Desired Outcome	Identify best qualities of each approach Select either best candidate or hybrid approach Identify process information displays, alarm presentation, navigation, and computer-based procedure integration In particular, identify basic stylistic choices	Identify error-prone or counter-intuitive HSI elements Investigate workload, SA, and performance assessment with multiple units Ensure that the HSI design avoids confusability of units	Investigate crew communication and coordination under normal, abnormal, and emergency conditions Investigate workload and SA in simulated environment

Table 3-1 Iterative Human-System Interface Design and Evaluation Plan (Continued)

	Design Phase		
	Conceptual Design	**Detailed Design**	**Detailed Design and Integration**
Tasks Considered	Basic system related tasks (e.g., borating, diluting, pump operation) Start-up, shut down Incident detection and response Monitoring the balance-of-plant for multiple units	Complex integrated tasks across systems (e.g., alarm response) Start-up, shut down, Incident detection and response for individual module(s) Multiple challenging scenarios	System monitoring Start-up, shut down, incident detection and response, including plant-wide conditions (e.g., emergency operating procedures execution)
Test Configuration	Single operator Single unit Multiple operators Multiple units	Partial and full crews Variable number of modules Variable number of scenarios	Full crew with training in simulated MCR environment All units
Evaluation Metric(s)	Task observation Performance metrics (response time, accuracy) Design Team meetings	Inventory and characterization Performance metrics (response time, accuracy) Task support verification HFE design verification Design team meetings	Task observation Performance metrics (response time, accuracy) SA metrics Mental workload metric Post-test interviews and questionnaires

The following criteria are used to select the design approach. Once a design approach is advanced enough to be tested, these criteria are used to determine whether or not a design approach is part of detailed design.

- Are personnel-task requirements considered?
- Does the design approach take advantage of human-performance capabilities and limitations?
- Does the design approach enhance HSI system performance requirements?
- Does the design approach unduly increase inspection and testing needs or maintenance demands?
- Is proven technology used in the design approach?
- Has the design approach taken into account the OER findings?

3.7.3 Iteration Decision Point

The HFE team conducts a design review following completion of the testing and compilation of the results to determine the next steps. The HSI design tested may be accepted as is, re-designed, or tabled pending further development or testing.

3.7.4 Human Engineering Discrepancy Resolution

Human engineering discrepancies (HEDs) are identified throughout the HSI design process to ensure that HEDs are being discovered, documented, and resolved accordingly. NuScale begins to record HEDs after the completion of the staffing plan validation. At this point in the HSI design process, the HFE team can use the HSI used for staffing plan validation as a baseline to work from for recording HEDs.

The HEDs may not always be resolved; HEDs may be found acceptable after an evaluation in the context of the integrated design. The basis for a decision for accepting an HED without change in the integrated design is documented. This decision may be based on accepted HFE practices, currently published HFE literature, trade-off studies, tests, or engineering evaluations.

4.0 References

4.1 Source Documents

4.1.1. U.S. Nuclear Regulatory Commission, "Human-System Interface Design Review Guidelines," NUREG-0700, Rev. 3. July 2020.

4.1.2. U.S. Nuclear Regulatory Commission, "Human Factors Engineering Program Review Model," NUREG-0711, Rev. 3. November 2012.

4.2 Referenced Documents

4.2.1. Concept of Operations, TR-130408, Revision 0.

4.2.2. Human Factors Verification and Validation Implementation Plan, TR-130415, Revision 0.

4.2.3. Human Factors Engineering Operating Experience Review Implementation Plan TR-130409, Revision 0.

4.2.4. NuScale Human Factors Engineering Functional Requirements Analysis and Function Allocation Implementation Plan, TR-124333, Revision 0.

4.2.5. NuScale Human Factors Engineering Task Analysis Implementation Plan, TR-130413, Revision 0.

4.2.6. NuScale Human Factors Engineering Staffing and Qualifications Results Summary Report, TR-130412, Revision 0.

4.2.7. NuScale Human Factors Engineering Treatment of Important Human Actions Results Summary Report, TR-130416, Revision 0.

4.2.8. Control Room Staffing Plan Validation Methodology, RP-1215-20253, Revision 3.

4.2.9. Human Factors Engineering Program Management Plan, TR-130414, Revision 0.