Human Factors Engineering (HFE) Program Management Plan (PMP)

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Non-Proprietary

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ABSTRACT

NuScale Power, Inc., (NuScale) is the design developer of the NuScale nuclear power plant. This power plant design uses 12 independent modular reactor units to generate electric power.

This Human Factors Engineering (HFE) Program Management Plan (HFE PMP) describes the goals and scope of NuScale’s HFE Program. The plan explains how NuScale implements and integrates the HFE discipline into the analysis, design, verification and validation (V&V), implementation, and operation of the NuScale nuclear power plant. The method for tracking HFE issues is covered along with an overview of the implementation plans that address the HFE technical elements.

The HFE process begins with the Operating Experience Review (OER), which provides information to support multiple other HFE technical elements. Functional Requirements Analysis defines functions at the plant as well as the system level for safe operation. Function Allocation determines whether a human, machine, or a combination of both human and machine should complete actions to perform those functions.

A Human Reliability Analysis (HRA) methodology supports other HFE technical elements and the Probabilistic Risk Assessment (PRA). One source of human actions considered in the HRA analysis is the HFE Issues Tracking System (HFEITS), which tracks any identified HFE issues and human engineering discrepancies (HEDs) throughout the project life cycle.

Information and control needs established from the Task Analysis will provide the input for the design of Human-System Interfaces (HSIs) and standard plant procedures and training. Desktop and full-scope simulators will serve as the focal point for integration of the HSI design and development work. A comprehensive V&V plan will be developed and integrated into the overall NuScale nuclear power plant V&V plan. The HFE Program provides recommendations or support, as applicable, to ensure design implementation and human performance monitoring of the results of the HFE process.

The HSI design will employ modern digital technology to implement the monitoring, control, and protection functions for the NuScale reactor with the goal of reducing the need for a larger staff, where practical, using state-of-the-art support.

1.0 DEFINITIONS / ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALARA</td>
<td>As low as is reasonably achievable</td>
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<tr>
<td>CAR</td>
<td>Corrective Action Request</td>
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<tr>
<td>CBP</td>
<td>Computer-based procedure</td>
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<tr>
<td>CFR</td>
<td>U.S. Code of Federal Regulations</td>
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<td>COL</td>
<td>Combined License</td>
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<td>COLA</td>
<td>Combined License Application</td>
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<td>CRDT</td>
<td>Control Room Design Team</td>
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<td>DCD</td>
<td>Design Control Document</td>
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<tr>
<td>DI&amp;C</td>
<td>Digital Instrumentation and Controls</td>
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<tr>
<td>EOF</td>
<td>Emergency Operations Facility</td>
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<td>HED</td>
<td>Human Engineering Discrepancy</td>
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<td>HFE</td>
<td>Human Factors Engineering</td>
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<td>HFEITS</td>
<td>Human Factors Engineering Issues Tracking System</td>
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<td>HRA</td>
<td>Human Reliability Analysis</td>
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NUSCALE POWER, INC.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>HSI</td>
<td>Human-System Interface</td>
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<tr>
<td>I&amp;C</td>
<td>Instrumentation and Control</td>
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<td>ITAAC</td>
<td>Inspections, Tests, Analyses, and Acceptance Criteria</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<td>INPO</td>
<td>Institute of Nuclear Power Operations</td>
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<td>ISG</td>
<td>Interim Staff Guidance</td>
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<td>LCS</td>
<td>Local Control Station</td>
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<td>LTR</td>
<td>Licensing Topical Report</td>
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<td>MCR</td>
<td>Main Control Room</td>
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<td>NRC</td>
<td>Nuclear Regulatory Commission</td>
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<td>NUREG</td>
<td>Technical Report of the United States Nuclear Regulatory Commission</td>
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<tr>
<td>OER</td>
<td>Operating Experience Reviews</td>
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<td>OSU</td>
<td>Oregon State University</td>
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<td>PMP</td>
<td>Program Management Plan</td>
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<td>PRA</td>
<td>Probabilistic Risk Assessment</td>
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<td>QMP</td>
<td>Quality Management Plan</td>
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<td>Rad</td>
<td>Radioactive</td>
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<td>RG</td>
<td>Regulatory Guide</td>
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<td>RSS</td>
<td>Remote Shutdown System</td>
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<td>SPDS</td>
<td>Safety Parameter Display System</td>
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<td>TSC</td>
<td>Technical Support Center</td>
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<tr>
<td>V&amp;V</td>
<td>Verification and Validation</td>
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2.0 HUMAN FACTORS ENGINEERING PROGRAM MANAGEMENT PLAN

The Human Factors Engineering (HFE) Program described within this plan and the supporting HFE implementation plans represent a living program that extends throughout the life cycle of the facilities constructed from the standard plant design. The plans provide guidance for analysis, design, verification and validation, implementation, and operation of the NuScale nuclear power plant. The purpose of this HFE Program Management Plan (HFE PMP) is to describe the following:

- NuScale HFE analysis, design, and development
- Implementation of HFE analysis and design development processes
- Integration of HFE discipline into the design of the NuScale nuclear power plant
- HFE process and procedures
- HFE Issues Tracking System
- Supporting implementation plans for HFE technical elements

This plan also describes how this HFE PMP and supporting HFE technical implementation plans comply with regulatory requirements and HFE guidelines, and reflects state-of-the-art human factors principles.

2.1 Human Factors Engineering Program Goals and Scope

The primary goal of the NuScale HFE Program is to provide a systematic method for integrating HFE into plant analysis, design, evaluation, and implementation to achieve safe, efficient, and reliable operation, maintenance, testing, inspection, and surveillance of the plant. Other goals include the following:

- Providing design criteria to guide HFE implementation
- Integrating an HFE process that can be practically implemented
- Ensuring personnel can perform tasks within the established safety, time, and performance criteria with the Human-System Interfaces (HSIs) provided
- Supporting a design that maintains operator vigilance
- Providing acceptable workload levels for operators
- Providing a design that helps prevent operator error and provides for error prevention, detection, and recovery capability
- Providing a high quality interface between operators and plant systems that ensures safe plant operation, shutdown, and emergency core cooling and alerts operators to off-normal conditions

These goals include coordinating and integrating HFE activities with relevant engineering activities and ensuring the application of HFE principles in the design and verification of the following:

- Physical control room structures
- Main Control Room (MCR) equipment and furnishings
- All environments and structures where human tasks must be performed
- Control panels and instruments throughout the plant
- Controls and tools
- Operating procedures
- Operator training
- Staffing planning

The NuScale nuclear power plant’s HFE design goals are achieved by following an integrated HFE process that includes review of inputs, system documentation, work verification, procurement and manufacturing follow-up, and acceptance testing. Provisions are made in all processes for necessary iteration, review, and verification.
This integrated HFE process enables early and consistent input of HFE requirements into system design specifications and automation decisions as a matter of policy, thereby ensuring that the design never dictates the human task. The HFE process is implemented and enforced throughout the project life cycle primarily through the HFE Program and the Engineering Design Change Process. The overall HFE program appropriately considers and addresses the deterministic aspects of the design, as discussed in RG 1.174 (Reference 1).

The scope of the NuScale HFE Program includes planning and analysis to support the HSI design process, including design of hardware interfaces and Computer-Based Procedures (CBPs) as part of an overall computerized operator support function. The program also covers V&V of the HSI design, procedure development, and support for the training program. The HFE process and procedures, as well as planned design activities, are in conformance with the NuScale Quality Management Program and are discussed further in this document.

In addition, the following are included in the scope of the NuScale HFE Program:

- Assumptions and Constraints - The HSI component of the NuScale nuclear power plant design permits reduction of staff where practical using state-of-the-art support. This includes a multi-module control room that allows one operator to be responsible for monitoring and control of more than one reactor module.
- Applicable Facilities - Facilities addressed by the NuScale HFE Program include the MCR, Refueling Station, Radioactive (Rad) Waste Control Room, Remote Shutdown System (RSS), Technical Support Center (TSC), Emergency Operations Facility (EOF) displays, and Local Control Stations (LCSs) with a safety related function. Additional facilities may be identified by task analysis.
- Applicable HSIs - The HFE Program provides HSIs and inputs to a systematic approach to Procedures and Training Development for the NuScale nuclear power plant functions and systems that have safety significance. The HSIs will be developed for applicable plant situations such as operations, accident management, maintenance, testing, inspection, and surveillance. This effort also includes monitoring the designs provided by NuScale suppliers to ensure that the designs are consistent with the HFE requirements of the NuScale HFE Program.
- Applicable Plant Personnel - Plant personnel addressed under the HFE Program include licensed control room operators, as defined in 10 CFR 55 (Reference 2), as well as the following personnel categories defined by 10 CFR 50.120 (Reference 3):
  - non-licensed operators
  - shift supervisors
  - shift technical advisors
  - Instrumentation and Control (I&C) technicians
  - electrical maintenance personnel
  - mechanical maintenance personnel
  - radiological protection technicians
  - chemistry technicians
  - engineering support personnel

NuScale’s HFE implementation plans will conform to regulatory guidance unless otherwise noted within this HFE PMP or other supporting plans, in which case a documented rationale for nonconformance will be provided.

Emerging technology used in the NuScale nuclear power plant affecting the HFE Program will be reviewed for issues and NUREG/CR-6947 (Reference 4) will be used as a reference for the review.

NuScale plans to file an Exemption Request from the Nuclear Power Plant Licensed Operator Staffing Requirements specified in 10 CFR 50.54(m) (Reference 5). This exemption request will address multi-
module control room and operator staffing, based on HFE analysis and evaluation results, and conform to
guidance provided in NUREG 1791 (Reference 6) and NUREG/CR-6838 (Reference 7).

2.2 Human Factors Engineering Team and Organization

The HFE team, with the support of other engineering staff, prepares the various implementation plans
required to support HSI design activities and manages those activities through final validation of the
implemented design. A team of experienced individuals is maintained for the HFE team throughout the
process. The HFE team’s collective expertise covers a broad range of disciplines that are relevant to
both the design and implementation activities.

The following comprise the HFE team’s responsibilities:

- Development of all HFE plans and procedures
- Analysis to support the HFE Program and HSI design process
- HSI design, development, testing, and evaluation activities
- Identification of HFE issues
- Recommendation of solutions to problems identified during HFE activities
- Tracking of HFE issues
- Verification that solutions to problems and recommendations have been implemented
- Assurance that HFE activities comply with the HFE plans and procedures
- Scheduling of HFE activities and milestones

Identification, resolution, tracking, and closure of HFE issues will be done using the HFE Issues Tracking
System process.

The HFE team falls within the I&C Systems group that reports to the Engineering Manager. However, the
HFE team lead has the authority to report directly to the Chief Operations Officer (COO) to provide
reasonable assurance that HFE areas of responsibility are accomplished. This authority provides an
avenue to identify problems in the implementation of the overall plant design.

The HFE team, together with other subject matter experts, includes the following appropriately qualified
members (members representing non-HFE disciplines are not permanent and participate as needed):

- HFE Team Lead - manages the HFE Program process and schedule and requests resources
- Human Factors Engineer - integrates HFE into plant design, verification, and implementation
- Human Factors Design Engineer - provides analysis and development of design
  requirements
- Technical Project Management - provides schedules and interfaces with other disciplines
- Systems/Design Engineers - provides input to the HFE Program regarding plant design
  (detailed characteristics and layout)
- Nuclear Safety Engineer - provides input to the HFE Program regarding reactivity control,
  safety assessment and classification, Probabilistic Risk Assessment (PRA), safety analyses
  and initiating events, the “as low as is reasonably achievable” (ALARA) philosophy, dose
  rates, zoning of the plant, task safety, and radiological aspects
- Plant Operations - provides input regarding operational activities and task characteristics
- Training Specialists - provides input regarding requirements for development and evaluation
  of training
- I&C Engineers - provides input design and integration of operational control functions, as well
  as design and evaluation of displays/controls and system software/hardware
- Structural Design Engineer - provides input regarding the layout, constructability, and
  inspectability of the plant design

Qualification requirements for HFE team members follow the guidelines in Appendix A of NUREG-0711
(Reference 8) unless specifically noted. Further support will be added to the HFE team as the program
requires. Examples of areas that will be addressed as the design progresses include maintenance tasks and personnel interactions during maintenance of the NuScale nuclear power plant.

As a part of the HFE team, a Control Room Design Team (CRDT) coordinates the design of the MCR, Refueling Facility Control Area, Remote Shutdown panels, and Local Control Stations. This CRDT is composed of members from the HFE team and may include involvement by Combined License (COL) applicant staff that is familiar with plant engineering, operations, and maintenance requirements.

The duties of the HFE team are to establish, perform, or ensure the execution of the activities defined in this plan and supporting plans. The HFE team’s specific duties are to guide and oversee the design implementation activity and to ensure that execution and documentation of each step in the activity is carried out in accordance with the established program and procedures. The HFE team has the authority to ensure that all its areas of responsibility are properly managed and to identify problems in the implementation of the HSI design. The HFE team also has the authority to determine where its inputs are required and to access work areas and design documentation. The HFE team is authorized to control further HFE processes until nonconformance, deficiency, or unsatisfactory conditions have been resolved.

2.3 Human Factors Engineering Process and Procedures

2.3.1 Human Factors Engineering Process

The engineering activities described in this plan are conducted in accordance with the NuScale Project Procedures and Engineering Procedures, which implement the NuScale Quality Management Plan (QMP). The process through which the HFE team executes its responsibilities is established in project policies that implement the NuScale QMP, which addresses the requirements of 10 CFR 50, Appendix B (Reference 9). Part of the HFE team’s responsibility is to support the safety culture by applying the principles called out in the QMP. Support of a safety culture includes attributes such as a questioning attitude, preventing complacency, commitment to excellence, appropriate conservatism, regular design reviews, and personal accountability in all nuclear safety matters.

The HFE process is accomplished by integrating the HFE Program into the NuScale engineering organization. The HFE Program includes the HFE PMP and HFE technical elements outlined in NUREG-0711 (Reference 8) and shown below in Figure 2–1.
The HFE process addresses the elements outlined in NUREG-0711 (Reference 8) using supporting plans that, in turn, dictate inputs and deliverables for different parts of the HFE Program. The first supporting plan is the HFE Implementation Plan, which addresses the following elements:

- Operating Experience Review
- Functional Requirements Analysis and Function Allocation
- Task Analysis
- Staffing and Qualification
- Human Reliability Analysis

The remaining elements will have standalone plans. This includes the HSI Design and Procedure Development plans. The remaining HFE technical elements of the NuScale HFE Program address activities that support Combined License Application (COLA) activity.

The HFE process begins with the Operating Experience Review (OER), which provides information used to support multiple other HFE technical elements. Functional Requirements Analysis defines functions at the plant, as well as system levels for the safe operation of the plant. Function Allocation determines whether a human, machine, or a combination of both human and machine should complete actions required to perform those functions.

A Human Reliability Analysis (HRA) methodology supports other HFE technical elements and the PRA. One source of human actions considered in the HRA analysis is from HFEITS, which tracks any identified
HFE issues and human engineering discrepancies (HEDs) throughout the project lifecycle. Information and control needs established from the Task Analysis provide the input needed for design of HSIs and standard plant procedures and training. Desktop and full scope simulators serve as the focal point for integration of the HSI design and development work. HSI design activity is coordinated through accomplishment of periodic milestones for development of the simulators.

A comprehensive V&V plan will be developed and integrated into the overall NuScale nuclear power plant V&V plan. The HFE Program provides recommendations or support, as applicable, to ensure design implementation and human performance monitoring of the results of the HFE process.

### 2.3.2 Human Factors Engineering Procedures

The HFE team works within the scope of the NuScale QMP. The design control procedure, along with applicable project plans provides direction under the QMP using a tiered document approach. The project plans and design control procedure address the following areas:

- Assigning activities to individual team members
- Governing the internal management of the team
- Making design decisions
- Governing equipment design changes
- Design team review of products

The QMP, specific project plan (which takes into consideration RG 1.206 [Reference 10]), and specific project quality plan provide further detailed guidance. Some of the details are addressed below.

- This HFE PMP and its subordinate implementation plans are controlled documents under configuration control in accordance with the QMP and applicable project plans. When deficiencies are identified, a Corrective Action Request (CAR) is issued to document the condition, track activities, and ensure that corrective and preventive actions are implemented and are effective in eliminating the deficiency.
- Change or revision of this document and its subordinate plans is controlled in accordance with the QMP and applicable project procedures.
- A work breakdown structure (WBS) will be developed on a project basis to define the project scope, activities, and deliverables. Activities and deliverables for each implementation plan described in Section 2.5 of this document will be incorporated into the project WBS, which will be updated as changes occur in the work scope, design inputs, and outputs.
- Process management tools include tools and techniques (e.g., review forms) to be utilized by the team to verify that application of HFE efforts are identified in the HFE implementation plans described in the HFE technical element section of this plan or in respective supporting HFE plans.
- Integration of HFE and other plant design activities is established in the applicable project plan and this plan, both of which are in accordance with the NuScale QMP.
- Following completion of HFE activities by NuScale, the licensee will be responsible for addressing the following issues that may arise from implementation of the NuScale HFE PMP:
  - Disposition of any items remaining in the HFEITS
  - Completion of any HFE V&V activities that could not be evaluated at the time of the results summary report and communication of the results to the U.S. Nuclear Regulatory Commission (NRC)
  - The process for keeping the Functional Requirements Analysis and Function Allocation current over the plant’s lifecycle so that it can be used as part of the design basis when modifications are considered
  - The process by which HSIs are modified and updated and temporary HSI changes are made
The process for maintaining procedures, controlling updates, and integrating procedure modifications across the full set of procedures, as well as for ensuring that alterations in particular parts of the procedures are consistent with other parts of the full set of procedures.

- The process for retraining plant personnel to support the training program requirements.

Specific HFE procedures will be developed as necessary to support applicable HFE technical elements.

Guidance for how the HFE process will be accomplished is provided in the HFE Implementation Plan, standalone technical plans, and plans supporting COLA activities. Specific details will be provided, as needed, in the results summary reports for the appropriate activities.

In accordance with the NuScale QMP, the HSI design process provides for independent verification of appropriate aspects of the HSI design throughout the process. The independent verification process includes verification that individual stages of the process are correct and that transfer of information from stage to stage has been properly accomplished. The independent verification process also validates that the HSI enables the intended user/operator to perform specific tasks in a defined context with effectiveness, efficiency, safety, and satisfaction and verifies that the individual steps in the design process have been properly carried out.

2.4 Human Factors Engineering Issue Tracking System

HFE issues and HEDs are tracked within HFEITS, which facilitates resolution of problems, issues, and HEDs by providing a means to record and track issues throughout the process of design, development, and evaluation. Tracking by the HFE team ends when design implementation activity is completed and tracking is transferred to the licensee.

HFEITS assures that problems, issues, and HEDs identified throughout the development and evaluations of the HSI implementation are addressed. The HFEITS procedure describes the

- process for identifying problems, issues, and discrepancies and entering them into the log with a unique tracking number.
- administrative responsibility for maintaining the tracking system and tracking logs.
- process for evaluating and documenting proposed resolutions and the residual effects of the implemented resolutions for the issue. (This process follows the methodology described in NUREG-0800 and applies the content and process contained in the HFE V&V Plan.)
- responsibilities for HFE team members and CRDT members regarding issue identification, resolution, and closeout.
- format of the HFEITS reports that can be used by the design team.

Resolution verification is the element of the process that verifies that HFEITS issues are evaluated and documented. Identified HEDs are justified, analyzed, prioritized, and documented so that design solutions can be developed and evaluated. In this way, modifications can be adequately addressed in the design. Use of a “desktop simulator” may allow issues to be addressed before the plant full-scope simulator is available.

Issues that cannot be resolved until the plant full-scope simulator is available are specifically identified and incorporated into the design verifications of the HFE V&V activities. Those issues that cannot be resolved until the plant facility is available will be addressed in the design implementation activities. The final resolution of remaining HEDs and open issues, as well as the transfer of HFEITS are accomplished as part of the Design Implementation activity.
2.5 HFE Technical Elements

The remaining 11 HFE elements from NUREG-0711 (Reference 8) have plans that will be addressed in Licensing Topical Reports (LTRs). Design criteria identified for input into or provided as output from the HFE Program will be developed as part of these supporting plans or within the scope described in the process and procedures section of this plan. Five of the elements are contained in the HFE Implementation Plan (OER, Functional Requirements Analysis and Function Allocation, Task Analysis, Staffing and Qualifications, and HRA). The Procedures Development element is a standalone LTR, as is the HSI Design element, which addresses an HSI Style Guide. The remaining four elements (Training, Human Factors V&V, Design Implementation, and Human Performance Monitoring) are provided as plans supporting COLA activity.

The 11 HFE technical elements are as follows:

- Operating Experience Review (OER) (part of the HFE Implementation Plan)
- Functional Requirements Analysis and Function Allocation (part of the HFE Implementation Plan)
- Task Analysis (part of the HFE Implementation Plan)
- Staffing and Qualifications (part of the HFE Implementation Plan)
- Human Reliability Analysis (HRA) (part of the HFE Implementation Plan)
- HSI Design (standalone plan)
- Procedure Development (standalone plan)
- Training Design (supporting COLA activity)
- Human Factors Verification and Validation (V&V) (supporting COLA activity)
- Design Implementation (supporting COLA activity)
- Human Performance Monitoring (supporting COLA activity)

The following sections provide a general overview of the supporting plans.

2.5.1 Human Factors Engineering Implementation Plan

The following subsections define the HFE element plans contained within the HFE Implementation Plan.

2.5.1.1 Operating Experience Review

The HFE Implementation Plan describes how OERs will be conducted, documented, and used for input into other HFE element plans to apply lessons learned. OERs are based on the nuclear industry, military, and other industries. The choice is based on whether there are similarities with the NuScale MCR design, similar technologies, or similar concepts of operations. The concept of operations for the NuScale plant includes the use of advanced automation to support the anticipated changing role of the operator in the MCR.

The objective of the OER is to inform and enhance the plant design processes, plant layout, plant support systems, operator training, operational procedures, and operations. The OER process includes screening, data processing, data analysis, corrective action setting and prioritization, action tracking, trending and trend review, identification of significant issues, review of external operating experience, and reporting.

OER includes reviews of related systems (including Oregon State University’s (OSU’s) NuScale test facility), application of NUREG/CR-6400 (Reference 11), review of issues concerning the technology proposed for the NuScale HSIs, input from interviews with appropriate plant personnel, and issues associated with any identified risk-important human actions.
2.5.1.2 Functional Requirements Analysis and Function Allocation

The Functional Requirements Analysis and Function Allocation element of the HFE Implementation Plan identifies the process for defining the plant's safety functional requirements, allocating those requirements that take advantage of human strengths to human operators, and avoiding allocation of functions that would be negatively affected by human limitations. Functions and the operator's role are examined in two steps: functional requirements analysis and function allocation.

Functional Requirements Analysis is the identification of those functions that must be performed to satisfy the plant's safety objectives (i.e., to prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public). This analysis develops the objectives, performance requirements, and constraints of the design and sets a framework for understanding the role of controllers (whether personnel or system) in regulating plant processes. High-level functions and plant systems and components are addressed, as necessary, along with parameters appropriate for the function level.

Input for Functional Requirements Analysis is provided by the OER Results Summary Report(s). Output from the Functional Allocation is provided in the Functional Requirements Analysis and Function Allocation Results Summary Report(s).

Function Allocation is the analysis of the functional requirements for plant control and the assignment of control functions to plant personnel, automation (including passive), or shared control between operator and automation. Selection of shared control requires further analysis based on the nature of the sharing, ranging from automation assisted decisions to personnel approved actions. Guidance for allocation will be drawn from NUREG/CR-3331 [Reference 12]).

Plant safety and reliability are enhanced by exploiting the strengths of both personnel and system elements, including improvements that can be achieved by assigning control to these elements with overlapping and redundant responsibilities. Function Allocation should be based on HFE principles and use a structured, well-documented methodology that provides personnel with logical, coherent, meaningful tasks.

2.5.1.3 Task Analysis

Task Analysis is the identification of task requirements for accomplishing the functions allocated to plant personnel. The Task Analysis process is iterative in nature and supports the plant design as it matures. The Task Analysis method has not yet been chosen, but will be selected from an industry accepted method. The HFE Implementation Plan describes how Task Analysis is used to provide the following:

- One of the bases for making decisions about HSI design
- Basic input for developing procedures
- Basic information for developing the staffing, qualifications, training, and communication requirements of the plant
- A basis for specifying the design requirements for the displays, data processing, and controls needed to carry out tasks

Task Analysis addresses the following topics, as appropriate, for each task:

- information requirements
- decision making requirements
- response requirements
- communication requirements
- workload
- task support requirements
- workplace factors
- situational and performance shaping factors
• hazard identification

Task Analysis includes a range of plant operating modes, including startup, normal operations, abnormal operations, transient conditions, low power, shutdown, and refueling conditions. The Task Analysis process also extends to the tasks required for maintenance of the plant.

The output of the Task Analysis will be Task Analysis Results Summary Report(s) for use as input by several of the other HFE technical elements. The Task Analysis results are also used to define a minimum inventory of alarms, displays, and controls. In addition, Task Analysis supports changes over the life cycle of the NuScale nuclear power plant design and implementation, including a process for addressing tasks resulting from or required for modification of the plant.

2.5.1.4 Staffing and Qualifications

Plant staffing and their qualifications are important considerations throughout the design process that provide input to many of the HFE technical elements. Initial staffing levels have been established based on staffing of existing operating plants, staffing goals (such as staffing reductions), initial analyses, government regulations, and the NuScale philosophy of plant operation. However, the acceptability of the staffing goals and assumptions will be examined as the design of the plant proceeds.

NUREG-0800, Sections 13.1.1 through 13.1.3 (Reference 13), and 10 CFR 50.54(m) (Reference 5) are used as inputs in developing the Staffing and Qualifications Plan, as are other applicable references from Sections 6.4 and 6.5 of NUREG-0711 (Reference 8). Applicable plant personnel are listed in Section 2.1 of this document.

The HFE Implementation Plan describes the methodology for systematically analyzing the requirements for the number and qualifications of personnel. This analysis includes a thorough understanding of task requirements and regulatory requirements. This analysis will be provided in the form of Staffing and Qualifications Results Summary Report(s) and will be iteratively reviewed based on changes in other HFE technical elements that affect Staffing and Qualifications.

2.5.1.5 Human Reliability Analysis

HRA seeks to evaluate both the potential for and the mechanisms of human error that may affect plant safety. Thus, HRA is an essential element in achieving the HFE goal of providing operator interfaces that minimize personnel errors, allow their detection, and provide recovery capability.

HRA is conducted as an integrated activity to support both the HSI design and PRA. PRA and HRA are performed early in the design process to provide insights and guidance for both systems design and HFE purposes.

The robustness of the HRA largely depends on the analysts’ understanding of personnel tasks, the information related to them, and the factors that influence human performance. Accordingly, HRA is an iterative process throughout the design process. By developing an understanding of the causes, modes, and probabilities of human error, HRA can provide valuable insights into the desirable characteristics of the HSI design. Consequently, special attention should be paid to those scenarios, critical human actions, and HSI components that were identified by HRA and PRA analyses as important to the plant’s safety and reliability. The effect of advanced technology on human performance is considered when performing the HRA.

The HFE Implementation Plan describes the detailed methodology for implementing HRA. IEEE Standard 1082 (Reference 14) will be used in selecting the method by which HRA is performed. The HRA is intended to ensure the following:

• The NuScale design has addressed human-error mechanisms in the design of the HFE aspects of the plant to minimize the likelihood of personnel error.
• The NuScale design has addressed human-error mechanisms in the design of the HFE aspects of the plant to ensure that, should errors occur, they are detected and recovery is ensured.
• The HRA activity effectively integrates the HFE Program with the PRA and risk analysis.

HRA Results Summary Report(s) will be among the outputs of this plan and will be used by applicable HFE technical elements. The analysis and HRA Results Summary Report(s) will be updated to support the iterative nature of the HSIs and plant design.

2.5.2 Human-System Interface Design

The objective of the HSI Design Plan is to define the process by which HSI design requirements are developed and how HSI designs are identified and refined. The plan describes how functional and task requirements are translated to the detailed design of alarms, displays, controls, and other aspects of the HSI.

HSI is designed using a structured methodology that guides designers in identifying and selecting candidate HSI approaches, defining the detailed design, and performing HSI tests and evaluations. The HSI Design Plan will cover development and use of HSI guidelines that are tailored to the unique aspects of the NuScale design; it will also provide an HSI Style Guide to define the design-specific conventions.

The HSI design process addresses the following:

• HSI design elements covered in NUREG-0711 (Reference 8)
• An HSI Style Guide addressing items found in NUREG-0700 (Reference 15)
• Constraints imposed by the I&C system
• Applicable regulatory requirements identified as inputs
• Use of the NuScale Concept of Operations
• HSI design process support for development of Functional Requirements Specifications for HSI types (e.g., alarms, displays, and controls), including a Safety Parameter Display System (SPDS) console, automatic indication of bypassed and inoperable status of safety systems, and a monitoring capability in the MCR for applicable system parameters
• Surveys of state-of-the-art HSI technologies
• Development of HSI design concepts alternatives, including evaluation methods
• Translation of functional and task requirements into HSI design performance requirements
• Support for reduction of the probability that errors will occur for risk-important human actions
• Support for personnel and task performance at different staffing levels and considering shift duration issues, as well as support for maintenance, test, repair, or inspection
• Consideration of both normal and extreme conditions for the HSI locations

The HSI design process uses applicable guidance from NUREG-0700 when considering advanced information systems design (Reference 15).

HSIs rely mainly on proven technology. Due to the advantages that currently available technology offers over some of the technology found at operating reactors, modern technology is used wherever possible to improve existing designs. Criteria for use of proven and unproven technologies are described below.

• Criteria for Proven Technology - Proposed I&C and HSI systems must utilize successfully proven, up-to-date technology and must be available for installation as scheduled in the COL applicant activities. For safety related systems, proven systems, equipment, subsystems, components, design and services are those that have been evidenced by at least one (1) year of successful operation experience in existing light water reactors. For non-safety
related systems, proven systems are those that have at least one (1) year of successful operation experience in existing light water reactors, fossil plants, or industry process plants prior to the startup date.

- **Criteria for Unproven Technology** - NuScale may make use of up-to-date modern technology and design and understands that some proposed designs, systems, subsystems, equipment, or components may not have received the required one (1) year of satisfactory service prior to the startup date. For these designs, systems, subsystems, equipment, or components, NuScale may develop a documented methodology to evaluate equivalent operating experience. Such an approach will be evaluated and considered acceptable if one of the following is true:
  
  - A defined program of prototype testing that has been designed to verify performance in the project HSI application has been completed, and a detailed plan has been developed for collection of one (1) year of operation.
  
  - Specific proven designs, systems, subsystems, equipment, or components have been evidenced by at least one (1) year of successful operation experience and can meet the basic functional requirements.
  
  - The needed experience data collection can be completed and assessed prior to issuance of an Operating License, and a determination can be made prior to issuance of the Operating License concerning whether the base approach (up-to-date modern technology and design) is acceptable. If the base approach is not acceptable, the backup approach must be utilized without either of these two approaches impacting the overall project schedule.

HSI design will employ modern digital technology to implement the monitoring, control, and protection functions for the NuScale reactor. A description of the technology will be contained in the NuScale system documentation prepared for the NuScale Design Control Document (DCD). Any development of soft controls will use applicable guidance from NUREG-0700 (Reference 15). Static mockups and a dynamic simulator will be used as tools for HSI design, and V&V of the HSI elements will be conducted.

The HSI design implementation activity includes development of dynamic models (including the different phases of simulator development) that will be used to evaluate the overall plant response, individual control systems, and operator actions. These models are

- suitable for analyzing operator actions during both steady state and transient plant behavior
- capable of confirming the design of the advanced alarm system concepts
- capable of confirming the adequacy of control schemes
- capable of confirming allocation of control to an operator or automatic system
- useful for developing and validating plant operating procedures
- capable of being incorporated as directly as possible into plant general purpose or limited use simulators

HSI evaluations and tests of designs are addressed in the HSI Design Plan and will use various levels of mockups for performance-based V&V. Test and evaluation outcomes will be documented in test reports.

### 2.5.3 Procedure Development

Procedures are essential to plant safety because they support and guide personnel interactions with plant systems and their response to plant-related events. HFE inputs to procedures are developed from the same design process and analyses as the HSIs and training. This results in a well-integrated design with a high degree of consistency that supports a systematic approach to procedure development.

The objective of the Procedure Development Plan is to describe the methods used to apply human engineering principles and guidance, along with other design requirements, to develop procedures that are technically accurate, comprehensive, explicit, easy to use, and verified and validated. The plan addresses the following:
- Development of Emergency Operating Procedures (EOPs) (should include consideration of generic technical guidelines as well as being symptom-based)
- Analysis supporting the proposed use of CBPs and documentation of this analysis (The proposed use of CBPs is based on applicable guidance from NUREG-0700 [Reference 15], where applicable.)
- Review of procedure use for different locations, including the MCR, remote shutdown facility, and any applicable local control stations
- Maintenance procedures
- Applicable requirements of NUREG-0800, Sections 13.5.1 and 13.5.2 (Reference 13)
- Procedure maintenance and transfer of a NuScale nuclear power plant to licensees
- How input to a procedure writer's guide is handled, including content requirements in NUREG-0711, Section 9.4(4) (Reference 8)

Input to the procedure development process is provided by the OER results, Task Analysis, HSI Design, and any other applicable HFE technical elements.

2.5.4 Plans Supporting Combined License Application Activity

The following four elements (Training, Human Factors V&V, Design Implementation, and Human Performance Monitoring) are developed as plans to support COLA activity.

The Training Program Design and Human Performance Monitoring Plans will include inputs for and oversight during the creation of the programs. Both plans will use NuScale’s criteria and recommendations for successful programs. NuScale either will implement HFE V&V and the Design Implementation Plans or provide support and oversight. NuScale also will conduct a final review of the reports produced by these activities.

2.5.4.1 Training Program Design

The Training Program Design Plan is developed to conform to or support the customer’s training program. Typically, the training program is based on the Institute of Nuclear Power Operations (INPO) systematic approach to training. The plan also addresses applicable requirements from 10 CFR 50.120 (Reference 3).

The OER, Function Allocation, Task Analysis, HRA, HSI Design, and Staffing and Qualifications HFE technical elements are used to support training development. Input for the training program design will include information from other HFE analyses and address categories of personnel (both licensed and non-licensed) that affect plant safety, specific plant conditions, specific operational activities, and HSIIs.

2.5.4.2 Human Factors Engineering Verification and Validation

HFE V&V evaluations comprehensively determine whether the final design conforms to HFE design principles and enables personnel to perform their tasks successfully and safely to achieve operational goals. This element involves the following three evaluations:

- HSI Task Support Verification - An evaluation to verify that the HSI supports personnel task requirements as defined by task analyses
- HSI Design Verification - An evaluation to verify that the HSI is designed to accommodate human capabilities and limitations as reflected in HFE guidelines (such as those provided in NUREG-0700 [Reference 15] and the NuScale HSI Style Guide)
- Integrated System Validation - An evaluation that uses performance-based tests to determine whether an integrated system design (i.e., hardware, software, and personnel elements) meets performance requirements and acceptably supports safe operation of the plant

The V&V planning and execution effort includes operating procedures, operations, and I&C in integrated testing. These tests are designed to verify that execution of procedures has the desired outcome and that
operators can make effective transitions between the HSIs and the procedures to accomplish their tasks and transition to interface management tasks such as display configuration and navigation. V&V will also test the usability of the HSIs and procedures. Any HEDs found during HFE V&V will be documented and resolved using the HFEITS procedure.

Operational condition sampling is addressed in the plan and

1. will include conditions that are representative of the range of events that could be encountered during operation of the plant,

2. reflects the characteristics that are expected to contribute to system performance variation, and

3. considers the safety significance of HSI components.

Aspects of operational conditions sampling criteria listed in Section 11.4.12 of NUREG-0711 (Reference 8) will be addressed further in the V&V Plan.

The HFE V&V Plan addresses other issues such as the integrated system validation review criteria listed in Section 11.4.3.2 of NUREG-0711 (Reference 8) and will use NUREG/CR-6393 (Reference 16) for further guidance.

2.5.4.3 Human Factors Engineering Design Implementation

This element addresses verification of the implementation of the HFE aspects of the design. The objectives of the HFE Design Implementation Plan are to verify that the HFE process as-built design conforms to the verified and validated design developed during the HFE design process.

The following elements are addressed in the HFE Design Implementation Plan:

- Displays for plant-specific design features
- Operator performance under actual operating conditions
- MCR features such as lighting and noise
- Final HSIs, procedures, and training effectiveness
- Maintenance, inspection equipment, and special tools
- Verification that all HEDs in HFEITS have been adequately addressed

One possible method of verifying implementation of the HFE aspects of the design is to compare these as-built design aspects with the detailed design description and specifications to verify that they conform to the design resulting from the HFE design process and V&V activities.

2.5.4.4 Human Performance Monitoring

A Human Performance Monitoring strategy helps verify that the confidence developed by the completion of the integrated system validation is maintained over time. There is no intent to periodically repeat the full, integrated system validation. The Human Performance Monitoring Plan describes a process for providing reasonable confidence that personnel have maintained the skills necessary to accomplish the assumed actions. The Human Performance Monitoring Plan will include inputs for and describe oversight of the program. The plan will use NuScale’s criteria and recommendations for a successful program. The objectives of this plan are to describe the human performance monitoring strategy for ensuring no safety degradation occurs because of any changes made in the plant and to verify that the conclusions drawn from the evaluation remain valid over time.
3.0 REFERENCES


