Licensing Technical Report

Human Factors Engineering Operating Experience Review Implementation Plan

December 2022

Revision 0

Docket: 52-050

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Department of Energy Acknowledgement and Disclaimer

This material is based upon work supported by the Department of Energy under Award Number DE-NE0008928.

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Abstract

Operating experience review (OER) is a key element of the Human Factors Engineering (HFE) Program. As part of its HFE program, NuScale Power, LLC (NuScale) conducted an extensive OER effort to identify HFE-related safety issues, and incorporate lessons learned as appropriate from previous designs, in both nuclear and non-nuclear industries, that may be applicable to NuScale Power Plant design. This report documents methodology to be used in the reviews of operating experience to support the NuScale Power Plant US460 standard design. The process established in this OER implementation plan is consistent with the applicable provisions of Section 3 of Human Factors Engineering Program Review Model, NUREG-0711 (Reference 4.2.1).

Executive Summary

As part of the Human Factors Engineering (HFE) Program, NuScale performed an extensive review of operating experience (OE) in multiple industries and facilities. The reviewed industries and facilities included the operating nuclear power plants, nuclear facilities that do not produce power, non-nuclear power plants, a U.S. military platform, the petrochemical industry, automotive industry, railway industry, and the airline industry. The purpose of the review was to identify HFE-related safety issues and incorporate identified positive features in the NuScale Power Plant design while avoiding negative features. Human Factors Engineering Operating Experience Review Results Summary Report, RP-0316-17614 (Reference 4.2.11) documented the results of the operating experience review (OER) using OE up to the Design Certification Application submittal date. This implementation plan documents the methodology used in the reviews of OE in support of the NuScale Power Plant US460 standard design.

Consistent with the guidance of NUREG-0711, Section 3, the scope of the OER performed by NuScale included reviews of predecessor or related plants and systems, recognized industry HFE issues, related human-system interface technology, issues identified by plant personnel, and important human actions. The OER goals are met by reviews of related source documents and literature, nuclear industry websites and databases. The obtained data is documented in a database and evaluated for their applicability to the design. Applicable positive issues are also incorporated or tracked for incorporation into the design.

1.0 Introduction

1.1 Purpose

The NuScale operating experience review (OER) process conducts an extensive review of operating experience (OE). The purpose of the OER is to

- identify and document safety issues and lessons learned from the applicable OE.
- address applicable lessons learned in the design of systems in order to reduce human errors and their impact on risk and reliability of plant operation.
- apply the lessons learned to plant operations, operational procedures, training of plant operators, and human performance monitoring programs.
- avoid negative features in previous designs while retaining positive features.

The OER scope, methodology, and the results that supported the Design Certification Application (DCA) are documented in Reference 4.2.11 consistent with the applicable guidance of NUREG-0711 (Reference 4.2.1), Section 3, and have been accepted as part of the NuScale DCA. This document outlines the implementation plan for OER to support the NuScale Power Plant US460 standard design.

1.2 Scope

The OER scope includes reviews of the following:

- predecessor and related plants and systems
- recognized industry Human Factors Engineering (HFE) issues
- related human-system interface (HSI) technology
- issues identified by plant personnel
- important human actions (IHAs)

NuScale Power Plant’s unique design features include

- multi-module applications.
- use of digital control systems.
- heavy use of multiple levels of automation.
- use of computer-based procedures.

The combination of these design features and the extent of their use in the design is not found in the existing commercial nuclear reactors. Therefore, the OER effort focuses on multiple industry experience in

- monitoring and control of multiple units in one control room.
- construction and construction testing of one or more units coincident with operating units.

- initial plant testing (preoperational and start-up testing) coincident with operating units.
- refueling of a unit coincident with operating units.
- incident and accident management of a unit coincident with operating units.

The OER of nuclear industry experience is limited to activities performed by licensed control room operators during normal, abnormal, and emergency operating conditions. Maintenance or refueling activities, activities completed by craft or technical personnel (e.g., mechanical, electrical, or instrumentation and controls (I&C) maintenance; health physics; chemistry; engineering; or information technology), or activities associated with the Technical Support Center, Emergency Operations Facility, or other Emergency Response facilities are only considered when those activities are determined to impact licensed operator workload.

If licensed operator workload is impacted, then the area of concern is analyzed to a degree sufficient to quantify the impact to licensed operator workload and develop HSI required to address the specific task. Evaluation results for these HFE elements for the licensed control room operators provide assurance that the control room staffing is accommodated by the Control Building design with sufficient margin for additional staffing (Reference 4.2.2).

The results of the OER contribute to the basis for the determination of control room staffing and qualification levels for a future operator. Specifically, initial staffing goals for staffing and qualification levels are based, in part, on the staffing and qualification levels at the related plants and systems. Review of OE at related plants and systems includes investigation of operational problems and strengths and weaknesses resulting from staffing levels, and resulting changes to the initial staffing goals. The OER of recognized industry HFE issues included review of staffing considerations described in Nuclear Regulatory Commission (NRC) Information Notice 95-48: Results of Shift Staffing Study, October 10, 1995 (Reference 4.2.12), and work hour requirements of 10 CFR 26.205 and their impact on staffing. Use of OER in the determination of staffing and qualification levels is further discussed in Reference 4.2.2.

1.3 Abbreviations and Definitions

Table 1-1 Abbreviations

Abbreviation	Definition
AC	alternating current
CNV	containment vessel
DC	direct current
DCA	Design Certification Application
FRA/FA	functional requirements analysis and function allocation
HFE	Human Factors Engineering
HFEITS	Human Factors Engineering issue tracking system
HSI	human-system interface

Table 1-1 Abbreviations (Continued)

Abbreviation	Definition
I&C	instrumentation and controls
IHA	important human action
LWR	light water reactor
NRC	Nuclear Regulatory Commission
OE	operating experience
OER	operating experience review
PWR	pressurized water reactor
RSR	results summary report
TIHA	treatment of important human actions

Table 1-2 Definitions

Term	Definition
HFE issue	An HFE issue that has not been resolved in the NuScale HFE Program process. Issues are those items that need to be addressed at some later date and thus need to be tracked to provide reasonable assurance that they are not overlooked.
HFE team	A core group of human factors engineers with HFE training (or equivalent experience), experienced operators, and simulator engineers.
HFE issue tracking system database	An electronic database used for tracking HFE issues within the scope of the NuScale Power Plant HFE Program. The OER items are a subcategory within HFEITS.
Important human actions	The actions that meet either risk or deterministic criteria. The risk-important human actions are identified by the Probabilistic Risk Assessment and human reliability analysis processes. The deterministically important human actions are derived from the transient and accident analysis, and diversity and defense-in-depth coping analysis.
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.
OE item	Any operating experience issue identified by the OER that is potentially applicable to the NuScale design and that needs further evaluation.
OER team	Team performing the OER activities whose members are qualified representatives from the HFE, Systems Engineering, Safety Analysis, and Operations Organizations.
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.

2.0 Implementation

2.1 Operating Experience Review Process Overview

The OER process undertaken for the DCA established uniform practices for performing and documenting OER for the HFE Program. The process encompassed activities for OE screening and reviewing, providing recommendations, and documenting review results. The process to support the NuScale US460 design is built upon previous OER results.

The categories of sources for review includes

- U.S. Nuclear Regulatory Commission, “Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience,” NUREG/CR-6400, 1996 (Reference 4.2.6).
- similar technology from other industries.
- operator interviews.
- site visits.
- literature.
- nuclear industry databases.
- results from treatment of important human actions (TIHA).

The OER team lead identifies the specific OE items for initial screening in order to determine whether the item is applicable to the NuScale Power Plant. The items found to be applicable receive a full review. The purpose of the full review is to determine if a particular aspect of the NuScale design has already captured or provided a resolution of the issue described by the OE item.

If the full review concludes that the NuScale design must determine a mitigating design solution within the scope of the HFE Program, the OE item is forwarded to the Human Factors Engineering issue tracking system (HFEITS). If the full review concludes that NuScale must determine a mitigating design solution outside the scope of the HFE Program, the item is forwarded to the appropriate engineering discipline (Section 3.6).

The OER process includes four major decision points:

- Potential human performance issues are determined through review of the OER item causal factors. Where the OER item describes root or apparent cause, or human performance, key words such as time, stress, training, workload, management, and organization are indicative.
- Applicability to the NuScale design is established by review of available NuScale design documents for the system (or like system) in question. Other HFE team members or appropriate subject matter experts are consulted as appropriate. Applicability determination comprises the initial screening of the issues to determine whether a complete review is needed.

- Determination of HFE Program scope is conducted by review of applicable NuScale design documents or implementation documents for HFE Program elements such as program management plan, human performance monitoring, TIHA, and functional requirements analysis and function allocation (FRA/FA).
- The OER reviewer determines if the OER item is resolved by the current design by review of HSI design documents.

The OER team is involved in decisions regarding disposition of OE items. At OER team decision points, each HFE member involved in the OER is consulted after having reviewed the available OE item, design information, and qualifying explanation.

If an OE item is determined to be relevant and applicable to the NuScale HFE scope, but the current design documents do not address the item, the OE item becomes an HFE issue for tracking in the HFEITS database. The OE items tracked in the HFEITS are categorized to show which HFE elements they affect. This categorization facilitates future searches of the database by HFE element.

Applicable OE items identified are entered into the HFEITS database for evaluation and disposition.

The OER results are used as inputs in the analysis of other HFE elements, including FRA/FA, task analysis, staffing and qualifications, TIHA, and human factors verification and validation. Specifically, the OER results are used in supporting the determination of the requirements for and allocation of functions in the FRA/FA element. There are several experienced operators included as part of the HFE team (Section 2.2). These operators provide supplementary OE information related to any IHAs identified (Reference 4.2.4), which is incorporated in the task analysis, TIHA, and staffing and qualifications elements. Additionally, experienced operators provide valuable insights and lessons learned in selecting challenging and workload-intensive plant operating conditions performed on a simulator as part of staffing and qualifications analyses and in performing verification and validation.

2.2 Operating Experience Review Team Composition and Responsibilities

The OER is conducted and supported by an experienced team of members that includes representatives from the HFE and Operations organizations, who are supported by the Systems Engineering and Safety Analysis staff. The qualifications of the HFE team members are as stipulated in the NuScale Human Factors Engineering Program Management Plan (Reference 4.2.5), and are consistent with the guidance of NUREG-0711 Appendix.

The OER team lead and the remainder of the OER team are selected by the HFE supervisor from the HFE team members. As described in Reference 4.2.5, the HFE supervisor has the authority and organizational placement to ensure that the tasks assigned to the OER personnel who do not directly report to the HFE supervisor are completed.

The OER team includes an HFEITS database coordinator. Assigned by the team lead, the database coordinator is responsible for managing the integrity of the information that is recorded, screened, reviewed, and dispositioned in the HFEITS database.

Responsibilities of the OER team lead include

- organizing the OER team.
- assigning team member responsibilities.
- managing resources and schedule.
- ensuring that OER issues are completed with supporting documentation and entered into HFEITS as necessary.
- production of OER reports as needed.

Responsibilities of OER team members conducting the reviews and dispositioning the individual review items include

- reviewing OER issues for identification of human performance issues, sources of human error, and design elements that would support or enhance human performance.
- screening of OER issues for applicability to the NuScale design using criteria in accordance with established procedures and as discussed in Section 3.1 through Section 3.6.
- summarizing and documenting screening results with an explanation of the applicability to the NuScale design.
- identification of further sources and topics for OER.
- collection, preparation, and documentation of new sources of OE applicable to the NuScale design.
- conducting operator interviews using a questionnaire template.
- identifying need for NuScale design action on OER issues.
- entering actions resulting from OER into HFEITS.

Upon completion of the OER, the team lead performs the following functions:

- resolves and closes applicable OE items in the HFEITS database
- collects documentation for:
    - sources of OE data
    - screening methods
    - screening results
    - interview facilities
    - interview results including personal information for each interviewee
    - results of reviews

  - resolution of OE items tracked by HFEITS or engineering database
- ensures that the HFEITS operating experience database entries are complete and consistent and verify correct closure of OE items
- documents location of OER results to ensure availability of:
  - OE item-related systems
  - list of OE documents reviewed
  - results of reviewing relevant HSI technology
  - complete description and findings from interviews
  - list of OER-identified issues incorporated into the design
  - list of open issues still being tracked in the HFEITS

3.0 Operating Experience Review Methodology

The following sections describe the methodology used to address OE within the HFE Program. These sections address the applicable review criteria in NUREG-0711, Section 3, Operating Experience Review.

3.1 Review of Predecessor and Related Plants and Systems

The NuScale Power Plant design incorporates features such as passive safety systems, no reliance on safety-related alternating current (AC) or direct current (DC) power, and modular design that relies on automation and digital HSI technology. The combination of these design features and the extent to which they are utilized in the NuScale Power Plant design is not found in the existing commercial nuclear reactors; therefore, existing designs are not considered direct predecessors to the NuScale Power Plant design. However, many of the NuScale systems and components are found in existing designs. Therefore, operating commercial nuclear power plant experience is reviewed and used appropriately in the development of the NuScale Power Plant design.

The NPP has achieved improvements in safety over existing plants through simplicity of design, reliance on passive safety systems, small fuel inventory, and use of additional barriers to the release of fission products to the environment. The integrated design of the NuScale Power Module eliminates external reactor coolant loop piping and resulting large loss of coolant accidents, and the use of natural circulation as the prime driver for the reactor coolant system removes the operating challenges posed by reactor coolant pumps and associated seals.

The availability of passive safety systems for decay heat removal, emergency core cooling system, containment heat removal, and control room habitability eliminates the need for AC or DC power in a Fukushima-like event. This design removes the requirement for reliance on off-site power, safety-related AC or DC power systems, and emergency power sources, and technical specification-related issues that have caused significant OE items in the existing commercial fleet.

Each NuScale Power Module consists of a steel reactor pressure vessel within a steel containment vessel (CNV). ASME-rated pressure relief valves for the pressurizer relieve directly into the CNV, where it can be reutilized by the emergency core cooling system to allow flow back into the RPV to maintain core cooling. This innovative design provides a solution to overcome the loss of coolant accident suffered by the Three Mile Island Unit 2 as a result of a stuck open power operated relief valve.

The small CNV and evacuated annulus eliminate the need for thermal insulation around the reactor vessel, thereby reducing Generic Safety Issue 191 concerns.

The evacuated CNVs are partially immersed in an ultimate heat sink within the Reactor Building. The location of the ultimate heat sink eliminates the requirement for safety-related pumps and associated emergency power supplies, piping, valves, and coolers. This design feature removes the technical specifications requirements normally

associated with the above components, as well as limited conditions of operations for excessive sediment, algae, ice, and more.

The integration of the decay heat removal system with the steam generators, main steam, condensate and feedwater systems eliminates the requirement for an auxiliary or emergency feedwater system. This integration also alleviates the maintenance and technical specification requirements for such systems.

These design improvements over existing plants were in place before the formal OER Program was established. Considering this fact, NuScale's challenge is to improve the HSI, worker environments, and plant and equipment layout to reduce human error potential and worker injuries.

Table 3-1 provides a cross-reference among systems contained in operating commercial nuclear power plants and NuScale systems. Table 3-2 lists examples of systems and components in commercial nuclear power plants that are eliminated in the NuScale design, and the NuScale design features that allow their elimination. If the initial screening identifies no correlation between the OE related to these eliminated systems and components and the NuScale design, the OER record is closed as not applicable.

An initial screening is performed on each OE item to determine applicability to the NuScale design, and to determine whether further evaluation is necessary to identify potential HFE issues related to the NuScale design. Operating experience items identified from previous light water reactor (LWR) systems design with high relevance (greater than approximately 60 percent) to the NuScale design are candidates for detailed review, and are entered into the HFEITS database. Relevance is determined on the basis of comparison between the NuScale Power Plant and previous similar designs, and expressed in degrees of relevance. Table 3-3 provides such a comparison and the associated relevance expressed as HIGH, MEDIUM, or LOW, where MEDIUM relevance would be considered 40-60 percent relevant, and LOW would be less than 40 percent relevant.

The need for further screening is established by the following criteria:

- similarity of designed systems, technology, and concept of operations
- designs with multi-modular monitoring and control
- designs with multiple identical systems monitoring in same control room
- designs with highly automated control
- designs that use digital I&C and video display units
- HFE issues that can affect NuScale design
- lessons learned that apply to NuScale

The OER boundaries for this technology are extended beyond the experience of these existing plants because of the limited use and experience of the digital HSI technology in the current U.S. operating commercial nuclear power plants. Section 3.3 discusses the OER of the new HSI technology in other industries.

Table 3-1 Comparison of Commercial Pressurized Water Reactor Systems to NuScale Systems

System Category	Commercial PWR Systems	Corresponding NuScale System
Primary Systems	containment system	containment vessel (part of reactor module)
	chemical and volume control system	chemical and volume control system
	reactor coolant system	reactor coolant system (part of reactor module)
		pressurizer (part of reactor module)
		steam generator (part of reactor module)
		reactor pressure vessel (part of reactor module)
		reactor vessel internals (part of reactor module)
	steam generator system	steam generator (part of reactor module)
Control Systems	reactor protection system	reactor protection system
	engineered safety features actuation system	engineered safety features actuation system
	diverse actuation system	diverse protection system
	plant control	module process computer
	rod control	rod control and information system
	control rod drive system	control rod drive system
Monitoring Systems	neutron monitoring system	neutron monitoring system
Main Power Cycle and Auxiliaries	main steam system	main steam system
	main turbine system	turbine generator system
	condensate system	feedwater and condensate system
	feedwater system	feedwater and condensate system
	demineralized water transfer and storage system	demineralized water system
Cooling Systems	passive containment cooling system	ultimate heat sink system (passive)
	passive core cooling system	emergency core cooling system (passive)
		decay heat removal system (passive)
	normal residual heat removal system	ultimate heat sink system
		containment flood and drain system
	spent fuel pool cooling system	pool cooling water system
AC & DC Power Systems	On-site standby power system	backup diesel generator
	AC power system	medium voltage AC electrical distribution system
		low voltage AC electrical distribution system
Fire Protection Systems	fire protection system	fire protection system
HVAC Systems	normal control room HVAC	normal control room HVAC
	containment recirculation cooling system	not a NuScale system - NuScale containment does not require a recirculation cooling system
	control room habitability system	control room habitability system
	containment air filtration system	not a NuScale system - NuScale containment does not require air filtration
	containment hydrogen control system	not a NuScale system - NuScale containment does not require a hydrogen control system

Table 3-1 Comparison of Commercial Pressurized Water Reactor Systems to NuScale Systems (Continued)

System Category	Commercial PWR Systems	Corresponding NuScale System
Fuel Handling Systems	fuel handling and refueling system	fuel handling equipment
		refueling monitoring station
		spent fuel storage system

Table 3-2 Examples of Systems and Components Eliminated in the NuScale Design

System or Component Eliminated in NuScale Design	NuScale Design Feature
reactor coolant pumps	buoyancy forces drive natural circulation of the primary coolant
reactor coolant system piping	reactor core, steam generator, and pressurizer contained within the reactor pressure vessel
pressurizer surge line	
residual heat removal system	reactor pressure vessel housed in a steel containment partially immersed in water that provides an effective passive heat sink for long-term emergency cooling
pumps with associated piping and heat exchangers	
auxiliary feedwater system safety injection system	

Table 3-3 Operating Experience Review Scope, Predecessor Determination, and Relevance

NuScale Plant, System, or Technology	System Code	Similar Plant, System, or Technology	{{
NuScale Power Module	N/A	None	
Reactor Pressure Vessel	A011	PWR plants	
Pressurizer	A012	PWR plants	
Containment Vessel	A013	PWR plants	
Steam Generator	A014	Ansaldo and Siet test facilities, Otto Hahn	
Reactor Module Support	A015	None	
Control Rod Drive	A022	PWR plants	
Reactor Vessel Internals	A023	Ansaldo and Siet test facilities, PWR plants	
Reactor Fuel Assembly	A025	PWR plants	
Control Rod Assembly	A026	PWR plants	
Chemical and Volume Control	B010	PWR plants	
Boron Addition System	B011	PWR plants	
Emergency Core Cooling	B020	Oregon State University NuScale Integral effects test facility	
Decay Heat Removal	B030	GE SBWR and SWBR, KEPCO SMART testing	
Containment Heat Removal	B040	None	
Control Room Habitability	B060	PWR plants	
Normal Control Room HVAC	B080	PWR plants	
Fuel Handling Equipment	B140	PWR plants	}}2(a),(c)

Table 3-3 Operating Experience Review Scope, Predecessor Determination, and Relevance (Continued)

NuScale Plant, System, or Technology	System Code	Similar Plant, System, or Technology	{{
Spent Fuel Storage	B160	PWR plants	
Pool Cooling and Cleanup System	B170	PWR plants	
Pool Leakage Detection	B180	PWR plants	
Containment Evacuation	B190	None	
Main Steam	C010	LWR plants	
Condensate and Feedwater	C020	LWR plants	
Demineralized Water	C140	LWR plants	
Fire Protection	C190	LWR plants, Other Industries	
Medium Voltage AC Electrical Distribution	D020	LWR plants, Other Industries	
Low Voltage AC Electrical Distribution	D030	LWR plants, Other Industries	
Augmented DC Power Distribution	D040	LWR plants	
Backup Diesel Generator	D060	Other Industries	
Reactor Protection	E011	PWR plants	
Neutron Monitoring	E013	LWR plants	
Rod Control and Information	E040	PWR plants	
Refueling Monitoring	E070	PWR plants	
Reactor Building	F010	LWR plants	
Digital I&C	N/A	LWR plants, Other Industries	
All video display units	N/A	LWR plants, Other Industries	
High level of automation	N/A	LWR plants, Other Industries	
Controlling more than one unit or process from same control room	N/A	Other Industries	}}2(a),(c)

In the table above, digital I&C, all video display units, high level of automation, and controlling more than one unit or process from same control room are listed as either “MEDIUM” or “LOW.” While this may seem incongruent with the importance of these topics to the NuScale design, they do accurately depict the relative OE relevance in these areas with the existing commercial reactors. Existing plants have performed individual system digital upgrades, which leaves their control rooms with a majority of analog panels and components, with an interspersing of digital control systems and video displays added on. While some automation has been utilized in existing plants (e.g., engineered safety features actuation system trips, load sequencing), no plant has utilized automation to the same degree as the NPP. Finally, while there are several dual control room plants in the U.S., and the CANDU fleet operates four reactors from the same control room, the NuScale design is novel in the control of up to six individual units from the same control room.

3.2 Review of Recognized Industry Human Factors Engineering Issues

NUREG/CR-6400 (Reference 4.2.6) provides a detailed list of HFE-relevant OE pertinent to the HSI design process for advanced nuclear power plants. Six categories of issues and experience are addressed:

- unresolved safety issues/generic safety issues
- Three Mile Island issues
- NRC generic communications (generic letters, information notices and Part 21 reports)
- Office for Analysis and Evaluation of Operational Data issues
- lower power and shutdown operations
- operating plant event reports

Sections 2 and 3 of NUREG/CR-6400 (Unresolved Safety Issues/Generic Safety Issues and Three Mile Island Issues) are summarized in Table II and Appendix B of NUREG-0933 (Reference 4.2.7). The issues listed in NUREG-0933 Appendix B are derived from the NRC's analysis of the issues listed in NUREG-0933 Table II. Therefore, the issues in NUREG-0933 Appendix B are a subset of the items in Table II. For this reason, NUREG-0933 Table II is used in the NuScale OER process instead of NUREG-0933 Appendix B.

The results of the NRC's Office for Analysis and Evaluation of Operational Data Program to identify human factors and human performance issues from mid-1980s through the year 2000 were published in Volumes 1 through 14 of NUREG-1275 (Section 5 of NUREG/CR-6400) (Reference 4.2.6). NuScale's OER includes review of the items contained in these volumes (Table 3-4). The potential issues identified from initial screening of NUREG-1275 Volumes 1 through 14 are entered into the HFEITS database and evaluated using the method described in Section 3.6.

The OER issues from sources other than NUREG/CR-6400 (published in January 1997) and NUREG-1275 are also reviewed for potential human performance issues or for identifying design elements that might support or enhance human performance. This includes reviews of additional literature and nuclear industry websites and databases (e.g., U.S. Nuclear Regulatory Commission, Institute of Nuclear Power Operations).

In addition to nuclear industry sources, literature, and websites of non-nuclear industries (U.S. military platform such as an aircraft carrier or submarine, the petrochemical industry, automotive industry, railway industry, and the airline industry) are also reviewed.

The events at Chernobyl and at the Fukushima Daiichi power station preceded the design of the NuScale Power Plant. Therefore, as the development of NuScale Power Plant design is ongoing, the lessons learned from these events are considered, and the

applicable lessons learned incorporated in the design. With regard to the Fukushima event, the following documents are considered:

- U.S. Nuclear Regulatory Commission, “Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” EA-12-049, March 12, 2012 (Reference 4.2.8)
- NEI 12-02, “Industry Guidance for Compliance with NRC Order EA-12-051, ‘To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation,’” Revision 1 (Reference 4.2.9)
- NEI 12-06, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,” Revision 2 (Reference 4.2.10)

Table 3-4 NUREG-1275 Human Performance Studies

NUREG-1275 Volume No.	NUREG Operating Experience Feedback Report Title	Publication Date
1	Operating Experience Feedback Report - New Plants	July 1987
2	Air Systems Problems	December 1987
3	Service Water System Failures and Degradations	November 1988
4	Technical Specifications	March 1989
5	Progress in Scram Reduction	March 1989
6	Operated Valve Problems	February 1991
7	Experience with Pump Seals Installed in Reactor Coolant Pumps Manufactured by Byron Jackson	September 1992
8	Human Performance in Operating Events	December 1992
9	Pressure Locking and Thermal Binding of Gate Valves	March 1993
10	Reliability of Safety-Related Steam Turbine-Driven Standby Pumps	October 1994
11	Turbine-Generator Overspeed Protection Systems	April 1995
12	Assessment of Spent Fuel Cooling	February 1997
13	Evaluation of Air-Operated Valves at U.S. Light-Water Reactors	February 2000
14	Causes and Significance of Design-Based Issues at U.S. Nuclear Power Plants	November 2000

3.3 Review of Related Human-System Interface Technology

The NuScale design uses a modern HSI design to control up to six units from one control room. Nuclear industry OE in multi-unit operation from a single control room is limited. Therefore, the review of operating experience in these areas is expanded to other facilities and industries including nuclear installations that do not produce power, non-nuclear power plants, a U.S. military platform, the petrochemical industry, automotive industry, railway industry, and the airline industry (including air traffic controller operator experience data).

Operating experience research of HSI technology in these facilities and industries focuses specifically on

- highly automated, digitally-controlled process systems.
- computerized procedures systems.
- use of flat panel displays (video display units).
- use of touch screens (as a design enhancement).
- multi-unit control rooms.

3.4 Review of Issues Identified by Plant Personnel

The review of issues identified by plant personnel was performed for the DCA, and documented in a results summary report (RSR) (Reference 4.2.11). This aspect of the OER is incorporated into the predecessor design. As this report documents methodology to be used in the reviews of OE subsequent to the completion of the DCA, OER issues identified during the DCA Human Factors Engineering work will be evaluated against design changes implemented in the Standard Design Approval Application for the US460 standard design.

Telephone or in-person interviews of plant personnel (nuclear and non-nuclear industries) were conducted for the DCA based on their experience with systems or technology applicable to the NuScale design. Personnel that were included are those with experience and knowledge in plant design documents, plant operations, and HFE topics discussed below. The personnel interviewed included

- operators (non-nuclear) or reactor operators.
- supervisors (non-nuclear) or senior reactor operators.
- maintenance technicians.
- supervisors and managers from Operations, Maintenance, and Work Control.
- operations administrators, particularly those who handle condition reports.
- procedure developers.
- training staff.

Interview questions and topics were developed by the OER team lead and tailored to the job description of the individual being interviewed.

The interviews cover the following topics:

- plant operations
  - normal plant evolutions (start-up, full-power, and shutdown)
  - instrument and control system degraded conditions and failures
  - HSI equipment failures and processing failures
  - transients

  - accidents
  - reactor shutdown and cool down using remote shutdown systems
- HFE design topics
  - alarm and annunciation
  - display
  - control and automation (highly automated control systems) information processing and job aids
  - real-time communications with plant personnel, real-time communications with other organizations
  - procedures, training, staffing qualifications, and job design
  - multi-unit control room design effect on plant operation

The data obtained from each interview was reviewed for positive or negative aspects and further evaluated for incorporation into the NuScale design. Each potential issue identified in an interview was entered into the HFEITS database and evaluated in a manner similar to the process outlined in Section 3.6.

In addition to obtaining data from outside plant personnel, the expertise of NuScale's HFE team members was utilized to perform reviews of NuScale design documents and provide recommendations for improvements and refinements to the design as appropriate. These personnel possess experience in the operation of commercial nuclear power plants, and are an integral part of the HFE team. Inputs related to OE provided by these personnel were provided to the appropriate system design engineers and addressed by an inter-disciplinary review process.

3.5 Review of Important Human Actions

Important human actions include risk-important human actions and deterministically important human actions. Risk-important human actions are identified early in the design process by the probabilistic risk assessment, and human reliability analysis processes. Deterministically important human actions are derived from the transient and accident analysis, and diversity and defense-in-depth coping analysis. If IHAs are identified, they are recorded in the HFEITS database so that this information is available while analyzing OE. The HFEITS database is updated as necessary with IHAs as the PRA is updated during design. The OER issues that indicate a potential to impact NuScale-specific IHAs can be tracked as HFE issues in the HFEITS for resolution during appropriate HFE Program elements.

Reference 4.2.4 contains further information on IHAs. The purpose of evaluating IHAs as part of OER is to determine whether other operating nuclear plants or systems with similar HSI technology have experienced related error-causing conditions. The IHAs are used in succeeding HFE Program elements (task analysis, staffing and qualifications, and HSI design) to define the roles and responsibilities of plant personnel and to produce interfaces designed to minimize human error probabilities. More details on the IHAs are contained in the treatment of important human actions RSR (Reference 4.2.4).

In examining the OE data, both the successful completion of IHAs applicable to NuScale and the errors that may have occurred in the execution of those IHAs are identified and considered. Treatment of IHAs is further discussed in Reference 4.2.4.

The human actions that are not identified as IHAs for the NuScale design but, if not performed correctly, could potentially have negative consequences are also selected for task analysis (Reference 4.2.3). This selection is accomplished with multiple subject matter experts by reviewing the OER and using their personal experience.

3.6 Documentation

3.6.1 Human Factors Engineering Issue Tracking System Database - Operating Experience Review Issues

The HFEITS database is used for tracking HFE issues within the scope of the NuScale Power Plant HFE Program that are identified using the screening process described in this section. These include issues identified as potential human performance issues and sources of human error and design elements that might support or enhance human performance.

If a potential HFE issue has been identified and cannot be resolved immediately, the issue is entered into the HFEITS database and tracked. Only the issues that are within the HFE Program scope but not incorporated by the current design are captured in HFEITS. The HFEITS issues can be evaluated for incorporation during the analyses or design of the HFE elements performed later as described in the implementation plans or RSRs for those elements, as applicable.

The OER items that are preliminarily screened as applicable are entered into the HFEITS database. The database is designed to provide complete details of the collected data, and is maintained as an electronic database. Items are categorized to show which HFE elements they affect. This categorization facilitates future OE searches of the HFEITS database by HFE element.

The HFEITS database is administered by the HFE team lead. Consistency of entries is monitored during data entry and checked periodically by the OER team lead.

If an OER issue is determined to be not related to HFE scope, or not applicable to the NuScale design, a justification is written and reviewed by the OER team. Following approval of the justification, the OE item is closed, but retained in the HFEITS database.

If an OE item is determined to be applicable to the NuScale design but not applicable to the HFE Program scope, a justification is written and reviewed by the OER team. Following approval of the justification, the OE item is transferred to the appropriate engineering discipline. The OE item is then closed, but retained in the HFEITS database.

If an OE item is determined to be applicable to the NuScale HFE Program scope, but is resolved by the current design, documentation of that resolution is captured in the database. Documentation includes reference to appropriate approved design documents. The OER team reviews the resolved-by-design documentation and closes and retains the OE item in the database.

An OE item that is determined to be applicable to the HFE Program scope and not resolved by the current design is documented as such in the HFEITS database. The OER team member proposes a design modification to incorporate the OE item. The OER team reviews the documentation and proposed design modification. If approved, the OE item is assigned to the greater HFE team. The HFEITS issues not resolved as part of the OER are evaluated during later stages of analyses or design for incorporation as described in the RSRs for those HFE Program elements.

In the event the OER team disapproves a justification or set of documentation for closure of an OE item, the OER team and HFE supervisor have the discretion to either reassign the OE item to another team member or resolve the item as a team.

4.0 References

4.1 Source Documents

4.1.1. U.S. Nuclear Regulatory Commission, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NUREG-0800), Formerly issued as NUREG-75/087,” Chapter 18, Human Factors Engineering.

4.1.2. U.S. Nuclear Regulatory Commission, “Shutdown and Low-Power Operation at Commercial Nuclear Power Plants in the United States,” NUREG-1449, September 1993.

4.1.3. U.S. Code of Federal Regulations, “Contents of Applications; Technical Information,” Section 52.47, Part 52, Chapter 1, Title 10 “Energy” (10 CFR Part 52.47).

4.2 Referenced Documents

4.2.1. U.S. Nuclear Regulatory Commission, “Human Factors Engineering Program Review Model,” NUREG-0711, Revision 3, November 2012.

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

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

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

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

4.2.6. U.S. Nuclear Regulatory Commission, “Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience,” NUREG/CR-6400, 1996.

4.2.7. U.S. Nuclear Regulatory Commission, “Resolution of Generic Safety issues,” NUREG-0933 (Supplements 1 - 34), 2011.

4.2.8. U.S. Nuclear Regulatory Commission, “Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” EA-12-049, March 12, 2012.

4.2.9. NEI 12-02, “Industry Guidance for Compliance with NRC Order EA-12-051, ‘To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation,’” Revision 1.

4.2.10. NEI 12-06, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,” Revision 2.

4.2.11. Human Factors Engineering Operating Experience Review Results Summary Report, RP-0316-17614, Revision 0.

4.2.12. NRC Information Notice 95-48: Results of Shift Staffing Study, October 10, 1995.