Human Factors Engineering (HFE) Operating Experience Review Technical Report

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Revision 0

Nonproprietary

NuScale Power, LLC

1100 NE Circle Blvd Suite 200

Corvallis, Oregon 97330

www.nuscalepower.com

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This technical report has been developed and is being submitted to support the NuScale Pre-Application program. It is intended to serve as a basis for discussion of the NuScale approach to performance of the OER process as described in NUREG-0711 Rev 3. The information contained in this report is preliminary. The formal OER implementation plan will be submitted with the NuScale Design Certification Application (DCA) in support of Chapter 18 of the NuScale DCA.

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1.0 Introduction

1.1 Operating Experience Review (OER) Purpose

The purpose of conducting a NuScale operating experience review (OER) is to identify and document safety issues and lessons learned from the applicable operating experience of multiple industries. The applicable lessons learned will then be addressed in the design of NuScale systems in order to reduce human errors and their impact on risk and reliability of plant operation. In addition, the lessons learned will be applied to NuScale plant operations, operational procedures and training of NuScale plant operators. Thus, NuScale design and NuScale plant operations can avoid negative features in previous designs while retaining the positive features.

NuScale design will implement a modern computer-based, automated human-system interface (HSI) technology including a computer-based procedure system. The NuScale OER will support the development of this design by review of operating experience with the proposed technology.

The unique NuScale modular design requires an additional OER focus to provide documented lessons learned for the following plant operations:

- 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 startup testing) coincident with operating units
- refueling of a unit coincident with operating units
- incident and accident management of a unit coincident with operating units

In other words, the NuScale design allows multiple units at power while additional units are in construction, initial module testing, or refueling.

1.2 Predecessor and Related Plants and Systems

The NuScale reactor is a new and innovative modular passive pressurized water (PWR) reactor design. {{

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1.3 OER Scope

This technical report establishes the NuScale OER process that will conform to NUREG-0711, Revision 3 (Reference 2.1.1).

The NuScale OER scope includes

- review of recognized industry HFE issues contained in NUREG/CR-6400 (Reference 2.1.2) (discussed in sections 3.0 through 5.1.8)
- review of recognized industry HFE issues identified since January 1996, one year before NUREG/CR-6400 was issued (discussed in section 5.2)
- review of operating experience related to the proposed NuScale HSI technology (discussed in section 6.0)
- identification of HFE issues obtained through interviews with plant personnel (discussed in section 7.0)
- identification of important human actions in the NuScale design (see section 8.0)

1.4 Abbreviations

Table 1-1 Abbreviations

Term	Definition
AEOD	NRC's Office for Analysis and Evaluation of Operational Data
AFW	auxiliary feedwater water
CFR	U.S. Code of Federal Regulations
USI/GSIs	unresolved safety issues/generic safety issues (GSIs)
HFE	human factors engineering
HFEITS	human factors engineering issues tracking system
HRA	human reliability analysis
HSI	human-system interface
NRC	Nuclear Regulatory Commission
NUREG	Technical Report of the United States Nuclear Regulatory Commission
OER	operating experience review
PRA	probabilistic risk assessment
PWR	pressurized water reactor

2.0 References

2.1 Referenced Documents

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

2.1.2 U.S. Nuclear Regulatory Commission, “Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience,” NUREG/CR-6400, January 1997.

2.1.3 U.S. Nuclear Regulatory Commission, “A Prioritization of Generic Safety Issues,” NUREG-0933, Supplement 20, June 1996.

2.1.4 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Human Performance in Operating Events,” NUREG-1275, Volume 8, December 1992

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

2.1.6 U.S. Nuclear Regulatory Commission, “Resolution of Generic Safety Issues,” NUREG-0933, supplement 34, September 2011.

2.1.7 U.S. Federal Code of Regulations, 10 CFR 52.47.

2.1.8 U.S. Nuclear Regulatory Commission, “Human Factors Engineering Program Review Model,” NUREG-0711, Revision 2, February 2004.

2.1.9 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – New Plants,” NUREG-1275, Volume 1, July 1987.

2.1.10 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Air System Problems,” NUREG-1275, Volume 2, December 1987

2.1.11 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Service Water System Failures and Degradations,” NUREG-1275, Volume 3, November 1988

2.1.12 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Technical Specifications,” NUREG-1275, Volume 4, March 1989

2.1.13 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Operating Experience Feedback Report – Progress in Scram Reduction,” NUREG-1275, Volume 5, February 1991

2.1.14 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Solenoid-Operated Valve Problems,” NUREG-1275, Volume 6, February 1991

2.1.15 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Experience with Pump Seals Installed in Reactor Coolant Pumps Manufactured by Byron Jackson,” NUREG-1275, Volume 7, September 1992

2.1.16 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Pressure Locking and Thermal Binding of Gate Valves,” NUREG-1275, Volume 9, March 1993

2.1.17 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Reliability of Safety-Related Steam Turbine-Driven Standby Pumps,” NUREG-1275, Volume 10, October 1994

2.1.18 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Turbine-Generator Overspeed Protection Systems,” NUREG-1275, Volume 11, April 1995

2.1.19 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Assessment of Spent Fuel Cooling,” NUREG-1275, Volume 12, February 1997

2.1.20 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Evaluation of Air-Operated Valves at U.S. Light-Water Reactors,” NUREG-1275, Volume 13, February 2000

2.1.21 U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Causes and Significance of Design-Basis Issues at U.S. Nuclear Power Plants,” NUREG-1275, Volume 14, November 2000

3.0 NuScale Screening of Known HFE Issues

When an OER team member identifies a document for OER analysis, the document information will be entered into the OER database per the instructions contained in the current HFE Operating Experience Review (OER) Procedure. Appendix A provides further details of the process.

An initial screening will be performed on each OER document to determine if further evaluation of the document is necessary to identify potential HFE issues related to NuScale design. If there is no correlation between the operating experience related to these eliminated systems and components and the NuScale design, the OER document will be closed as non-applicable. Appendix B provides a cross reference between systems contained in commercial nuclear power plants and NuScale systems. Table 3-1 provides examples of systems and components eliminated in NuScale design and the design features that allowed their elimination.

Table 3-1 Systems and components eliminated in NuScale design

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

The elimination of predecessor plant systems and components in the NuScale plant design reduces the likelihood that the associated operating experiences for these systems will apply to NuScale. The following are examples of recognized HFE issues that may not apply to NuScale:

- reactor coolant pump seal failures and leakage
- reactor coolant pump vibration monitoring
- AFW pump overspeed trip
- AFW turbine trip valve reset/trip status
- loss of suction to emergency feedwater pumps
- residual heat removal suction valve testing
- throttling of high pressure safety injection during emergency operation

4.0 NuScale Capture of Positive Features of Previous Plant Designs

A NuScale OER team member will identify any positive HFE features of a system or HFE process while evaluating a document for HFE issues. Any noted positive features of a system or HFE process will be entered into the OER database, in addition to recording identified negative issues.
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5.0 Recognized HFE Issues

NuScale will evaluate the issues contained in NUREG/CR-6400 (Reference 2.1.2). This NUREG document contains evaluations of HFE issues that have the potential to impact the NuScale design. The HFE issues that are identified in NUREG/CR-6400 are wide-ranging and were derived from a variety of sources.

5.1 Review of NUREG/CR-6400 HFE Issues

NUREG/CR-6400 was issued in January 1997 (Reference 2.1.2). The purpose of the document was to identify and summarize HFE issues recognized prior to January 1997 that would be relevant to the HSI design process for advanced reactors. NUREG/CR-6400 documents the evaluation of HFE issues contained in numerous NRC publications and various special reports, and provides potential resolutions.

Table 5-1 provides summary details of NUREG/CR-6400 contents by NUREG section number. The number of HFE items and number of documents in the table are approximate, but are provided to show the relative magnitude of the review scope.

Table 5-1 NUREG/CR-6400 details

Section Number	Section Title	{{		}}3(c)
2	unresolved safety issues/ generic safety issues			
3	Three Mile Island issues			
4	NRC generic letters and information notices			
5	Office for Analysis and Evaluation of Operational Data (AEOD) Issues			
6	low power and shutdown operations			
7	operating plant event reports			

5.1.1 Relationship between NUREG-6400 and NUREG-0933

Section 2 and 3 of NUREG/CR-6400 (Reference 2.1.2) states that the issues in these two sections are described in NUREG-0933, but does not specify if the issues are summarized in Table II or Appendix B. {{

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5.1.2 Unresolved Safety Issues/Generic Safety Issues

NuScale will evaluate the potential USI/GSIs listed in NUREG-6400, section 2, Unresolved Safety Issues/ Generic Safety Issues, for NuScale applicability (Reference 2.1.2). Evaluation data for each listed GSI will be entered into the NuScale OER database as required by the governing NuScale procedure, and generally described in Appendix A.

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5.1.3 Three Mile Island Issues

NuScale will evaluate the Three Mile Island (TMI) issues listed in section 3 of NUREG-6400 (Reference 2.1.2), for NuScale applicability. These TMI issues will be entered into the NuScale OER database as potential issues and evaluated using the method discussed in Appendix A.

5.1.4 Chernobyl Issues

NUREG/CR-6400 (Reference 2.1.2) does not identify and evaluate any Chernobyl items from NUREG-0933 (Reference 2.1.3). However, NuScale will include the Chernobyl issues within the OER scope. The Chernobyl issues shall be entered into the NuScale OER database and evaluated using the method described in Appendix A.

5.1.5 NRC Generic Letters and Information Notices

As indicated in Table 5-1, section 4 of NUREG/CR-6400 (Reference 2.1.2) describes three NRC generic letters and two NRC information notices that contain HFE aspects. NuScale will perform an OER of the five NRC documents.

The NuScale OER of each NRC document may indicate the need to enter OER information at the document level (generic letter or information notice), or require entering multiple issues per document. All issues generated from the evaluation of these documents will be entered into the NuScale OER database and evaluated using the method described in Appendix A.

5.1.6 Human Performance in Operating Events

From the mid-1980s through 2000 the NRC's Office for Analysis and Evaluation of Operational Data (AEOD) conducted a program to identify human factors and human performance issues associated with operating events at nuclear power plants. The results of the program were published in NUREG-1275 in 14 volumes whose titles are provided in Table 5-2 (References 2.1.9 through 2.1.21).

Table 5-2 NUREG-1275 Human Performance Studies

NUREG-1275 Volume #	NUREG Operating Experience Feedback Report Title	Publication Date
1	Operating Experience Feedback Report - New Plants (Reference 2.1.9)	July 1987
2	Air Systems Problems (Reference 2.1.10)	December 1987
3	Service Water System Failures and Degradations (Reference 2.1.11)	November 1988
4	Technical Specifications (Reference 2.1.12)	March 1989
5	Progress in Scram Reduction (Reference 2.1.13)	March 1989
6	Operated Valve Problems (Reference 2.1.14)	February 1991
7	Experience with Pump Seals Installed in Reactor Coolant Pumps Manufactured by Byron Jackson (Reference 2.1.15)	September 1992
8	Human Performance in Operating Events (Reference 2.1.4)	December 1992
9	Pressure Locking and Thermal Binding of Gate Valves (Reference 2.1.16)	March 1993
10	Reliability of Safety-Related Steam Turbine-Driven Standby Pumps (Reference 2.1.17)	October 1994
11	Turbine-Generator Overspeed Protection Systems (Reference 2.1.18)	April 1995
12	Assessment of Spent Fuel Cooling (Reference 2.1.19)	February 1997
13	Evaluation of Air-Operated Valves at U.S. Light-Water Reactors (Reference 2.1.20)	February 2000
14	Causes and Significance of Design-Basis Issues at U.S. Nuclear Power Plants (Reference 2.1.21)	November 2000

NuScale will perform an OER of NUREG-1275 items contained in volumes 1 thru 14 listed in Table 5-2. Because the content of each volume is extensive and detailed, NuScale experience from the initial reviews of NUREG-1275 volumes will determine the best method of summarizing the information in the reports into discrete portions in order to enter the evaluation information into the OER database. The potential issues identified from initial screening of NUREG-1275 volumes 1 through 14 will be entered into the NuScale OER database and evaluated using the method described in Appendix A.

5.1.7 Low Power and Shutdown Operations

In September 1993, the NRC issued NUREG-1449 (Reference 2.1.5). The report contained the results of the NRC staff's evaluation of shutdown and low-power operations at commercial nuclear power plants in the United States. The report describes studies conducted by the staff in the following areas: operating experience related to shutdown and low power operations, probabilistic risk assessment (PRA) of shutdown and low-power conditions, and utility programs for planning and conducting activities during periods the plant is shut down. The report also documented the staff's evaluations of a number of technical issues regarding shutdown and low-power operations, including the principal findings and conclusions.

As noted in Table 5-1, the information contained in NUREG/CR-6400 section 6 is largely taken from NUREG-1449. NUREG/CR-6400 section 6 contains a description of the following groupings of operational issues and their potential resolutions:

- outage management and planning
- operator training
- procedures
- instrumentation
- equipment
- communications

NuScale will perform an OER of the issues in NUREG/CR-6400 section 6 using NUREG-1449 as supporting information. These 6 issues will be entered into the NuScale OER database and evaluated using the method described in Appendix A.

5.1.8 Operating Plant Event Reports

NUREG/CR-6400 section 7 (Reference 2.1.2) contains the results of an NRC study of operating plant event reports that provides a description of issues and corresponding potential solutions. Table 5-1 provides a summary of the types of documentation used in the analysis. The type (grouping) of issues in each specific area identified in the report is as follows

- main control room
- system-related insights
- component-related insights
- local control stations

NuScale will perform an OER of the issues in NUREG/CR-6400 section 7 and their potential resolutions. These issues will be entered into the NuScale OER database and evaluated using the method described in Appendix A.

5.2 Recognized HFE Issues since Publication of NUREG/CR-6400

Table 5-1 indicates the types of operating experience documents that were used for NUREG/CR-6400 (Reference 2.1.2) analysis. NuScale will use the same types of documents to execute an analysis of operating experience issued from the time NUREG/CR-6400 was issued in January 1997. The document types are

- NUREGs
- licensing event reports
- NRC generic letters
- NRC industry Event (IE) bulletins
- NRC information notices

In addition, NuScale will perform a search of operating experience from January 1997 to the present using other industry sources, such as operating experience databases maintained by the Institute of Nuclear Power Operations and the Electric Power Research Institute. Initial searches on these databases will be focused on human error.

6.0 OER of Human-System Interface (HSI) Technology

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7.0 OER Issues Identified by Plant Personnel

NuScale will conduct interviews with plant personnel (nuclear and non-nuclear industries) based on experience with systems or technology applicable to the new design. Each interview will be conducted in accordance with the applicable NuScale procedure. The interview topics will be tailored to the job description of the individual being interviewed.

- plant operations
  - normal plant evolutions (startup, 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 system
- HFE design topics
  - alarm and annunciation
  - display
  - control and automation
  - 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
  - highly automated control systems

The data obtained from each interview will be reviewed for positive or negative aspects that will be further evaluated for incorporation into the NuScale design. Each potential issue identified in an interview will be entered into the OER database and evaluated in a manner similar to the process outlined in Appendix A.

8.0 Important Human Actions

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9.0 OER Issue Analysis, Tracking, and Review

The HFE design team is responsible for conducting the operating experience review. The qualifications of the HFE design team members supporting this HFE program element are stipulated in the current NuScale Human Factors Engineering Project Management Plan.

The OER process is detailed in the Human Factors Engineering OER Procedure. A flowchart of the process is provided in Appendix A of this plan. The Human Factors Engineering OER Procedure also contains administrative instructions to control the NuScale OER process, including

- OER team and OER team lead responsibilities
- OER information review criteria
- OER database data entry
- OER item analysis approval
- OER results output to requisite NuScale engineering organizations
- OER database field descriptions
- OER plant personnel interview criteria
- distribution of OER reports to NuScale engineering groups
- coordination between the OER database and the HFE issues tracking database

As documented in NUREG-0711, Revision 3 (Reference 2.1.1) Table 3-1, the OER analysis may contribute to several other HFE elements. {{

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10.0 OER Results Summary Report

NuScale will submit an OER results summary report at the completion of the OER effort. The report will contain, as a minimum

- identification of related systems
- methodology used to review the OE
- list of OE documents reviewed
- discussion of the OER conducted
- results of reviewing relevant HSI technology
- description and findings from interviews with plant personnel or other users
- listing of OER-identified issues incorporated into the design
- enumeration of open issues still being tracked in the HFEITS

Appendix A. Process for Resolution of OER Issues

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Appendix B. Comparison of Commercial Pressurized Water Reactor (PWR) Systems to NuScale Systems

Commercial Pressurized Water Reactors (PWR) Systems	Corresponding NuScale System
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Commercial Pressurized Water Reactors (PWR) Systems	Corresponding NuScale System
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