Licensing Technical Report

Human Factors Engineering Staffing and Qualification Results Summary Report

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Abstract

Staffing and qualifications is a significant element of the Human Factors Engineering Program. In support of this program, NuScale Power, LLC (NuScale) staffing and qualifications activities determine the number and qualifications of licensed operator personnel required for safe and reliable NuScale Power Plant operation. The staffing and qualifications analysis considers tasks from a range of plant operating modes, including startup, normal operations, low-power and shutdown conditions, transient conditions, abnormal conditions, emergency conditions, and severe accident conditions. The Concept of Operations Technical Report (Reference 8.2.11) establishes minimum main control room staffing levels as well as operator roles and responsibilities for the NuScale Power Plant.

NuScale utilized the collective operating experience of its design staff, initial functional requirements analysis and function allocation and task analysis results, tabletop activities, and preliminary simulator observations to determine initial staffing levels, and then made iterative changes to those levels using the Human Factors Engineering Program elements. Because of the NuScale Power Plant's passive safety systems, simple operation, automation, expected reduced licensed operator workload, and limited number of important human actions, the final staffing level for operating a NuScale Power Plant is a minimum main control room shift contingent of one licensed reactor operator and two licensed senior reactor operators.

The NuScale staffing plan was validated utilizing the processes consistent with NUREG-1791 (Reference 8.2.17) and the applicable provisions of NUREG-0711 (Reference 8.1.1).

Executive Summary

The staffing and qualifications (S&Q) analysis was performed by NuScale to determine the number and qualifications of licensed operator personnel required for safe and reliable plant operation. Licensed operator personnel include licensed operators and senior operators as defined by Code of Federal Regulations (CFR) 10 CFR 55.4 (Reference 8.1.3) and main control room (MCR)-specific personnel subject to the training program as described by 10 CFR 50.120 (Reference 8.1.5), as applicable. These S&Q activities are consistent with those of the overall Human Factors Engineering Program described in the Human Factors Engineering Program Management Plan (Reference 8.2.10).

Staffing level goals and staffing roles and responsibilities are evaluated and modified, as required, in an iterative fashion through the NuScale design change control process, through the use of the human engineering discrepancy process, and as information from other Human Factors Engineering elements and S&Q analyses, evaluations, and tests becomes available.

The NuScale Power Plant, as described in the Design Certification Application, is designed for operating up to 12 units from a single MCR, which is not specifically addressed in 10 CFR 50.54(m) (Reference 8.1.3). The staffing level for the Design Certification Application was a minimum MCR shift contingent of three licensed reactor operators and three licensed senior reactor operators which was discussed in the earlier revision to this document (Reference 8.2.6).

The staffing and qualifications results in this report are derived from the HFE analysis work completed for the NuScale Power Plant design documented in the Design Certification Application. The US460 is designed with up to six modules operated from a single MCR. The HFE work performed for the US460 design builds upon the earlier design and analysis completed under the Design Certification Application. The S&Q analysis documented herein yields an updated minimum MCR shift contingent for the NuScale Power Plant US460 standard design of one licensed reactor operator and two licensed senior reactor operators. Changes to the staffing levels are done using the analyses described with this document.

The Control Room Staffing Plan Methodology (Reference 8.2.12) incorporated guidance contained in NUREG-1791, Section 10, “Review the Staffing Plan Validation”. The methodology was successfully used during testing to provide the technical justification for the S&Q results summary report and subsequently the NuScale Control Room Staffing Plan Topical Report (Reference 8.2.15).

This report is organized into six major sections and appendices. Section 1.0 describes the purpose and scope of S&Q. Section 2.0 provides an overview of the S&Q implementation process and a description of the S&Q Team composition and responsibilities. Section 3.0 describes the methodology and specifies the criteria for performing the staffing and qualifications evaluations. Section 4.0 provides a detailed summary of the results of S&Q activities (i.e., the staffing levels, staff qualifications, staff roles and responsibilities, and the results of staffing plan validation). Section 5.0 provides a high-level conclusion derived from the experience of performing the S&Q activities. Section 6.0 describes conformance with NUREG-0711. Section 7.0 summarizes the S&Q work and conclusions. The source and referenced documents applicable to and used in the S&Q effort are listed in Section 8.0.

1.0 Introduction

1.1 Purpose

This document provides the Human Factors Engineering (HFE) staffing and qualifications (S&Q) results summary report (RSR) for the NuScale Power Plant documented in the NuScale Power Plant US460 standard design.

The S&Q analysis determines the minimum number and qualifications of licensed operator personnel required for safe and reliable NuScale Power Plant operation under all operating conditions based on task and regulatory requirements. For the purposes of this RSR, licensed operator personnel include reactor operators (ROs) and senior reactor operators (SROs) as defined by Code of Federal Regulations (CFR) 10 CFR 55.4 (Reference 8.1.4) and main control room (MCR)-specific personnel subject to the training program as described by 10 CFR 50.120 (Reference 8.1.5), as applicable to the NuScale design.

1.2 Scope

The staffing and qualifications RSR includes staffing evaluations for activities performed by licensed control room operators for the NuScale Power Plant. The work performed utilizes the design and analysis completed under the Design Certification Application. Staffing analysis for non-licensed operators, maintenance 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 included only if they are determined to impact licensed operator workload. When licensed operator workload is impacted, then the area of concern is analyzed to a degree sufficient to quantify the impact to licensed operator workload or staffing and to develop human-system interface (HSI) or staffing adjustments required to address the specific task and associated staffing requirements.

1.3 Abbreviations

Table 1-1 Abbreviations

Term	Definition
ANSI/ANS	American National Standards Institute/American Nuclear Society
CFR	Code of Federal Regulations
CRS	control room supervisor
DCA	Design Certification Application
FA	function allocation
FRA	functional requirements analysis
HED	human engineering discrepancy
HFE	Human Factors Engineering
HFEITS	Human Factors Engineering issues tracking system
HSI	human-system interface
I&C	instrumentation and controls

Table 1-1 Abbreviations (Continued)

Term	Definition
IHA	important human action
ISV	integrated system validation
MCR	main control room
NPP	NuScale Power Plant
NRC	Nuclear Regulatory Commission
NSIDE	NuScale simulator interface development environment
OER	operating experience review
RO	reactor operator
RSPV	revised staffing plan validation
RSR	results summary report
S&Q	staffing and qualifications
SDAA	Standard Design Approval Application
SME	subject matter expert
SM	shift manager
SMR	small modular reactor
SPV	staffing plan validation
SRO	senior reactor operator
TA	task analysis
TIHA	treatment of important human actions
TLX	Task Load Index
V&V	verification and validation

Table 1-2 Definitions

Term	Definition
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.
Subject Matter Expert	A person that has completed the NuScale HFE or Operations Initial company Training Program, has previous licensed operating nuclear plant experience, and has performed TA or NuScale system reviews and is familiar with the NuScale Power Plant design. The definition of SME for staffing plan validation testing purposes is a person who has completed the Simulator Participant qualification, has previous licensed operating nuclear plant experience, and has worked at NuScale in some capacity to be familiar with the design, such as performing TA, NuScale system reviews, or operating the NuScale Integral Systems Test (NIST) facility.
Situation (or Situational) Awareness	An individual's mental model of what has happened, the current status of the system, and what will happen in the next brief time period.
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.
Workload	The cognitive and physical demands placed on plant personnel.

2.0 Implementation

2.1 Staffing and Qualification Process Overview

2.1.1 Staffing Levels

Minimum MCR staffing levels as well as operator roles and responsibilities are described in detail in Concept of Operations (Reference 8.2.11). {{

}}2(a),(c) Because of the NuScale Power Plant's passive safety systems, simple operation, automation, expected reduced licensed operator workload, and no important human actions (IHAs), a NuScale Power Plant of up to six units is operated with a minimum MCR shift contingent of one licensed RO and two licensed SROs .

The NuScale Power Plant uses design-specific staffing levels as an alternative to 10 CFR 50.54(m). In order to evaluate and justify the staffing levels, NuScale implemented an approach to establishing the basis for staffing levels and qualification, including operator roles and responsibilities, in accordance with the Control Room Staffing Plan Validation Methodology (Reference 8.2.12). Section 2.3.2 contains more information on the NuScale approach. Section 5.0 and the Revised Staffing Plan Validation Test Report (Reference 8.2.14) contain a summary of the results for the final staffing levels.

2.1.2 Task Analysis Inputs

Task Analysis results are used to determine the crew roles and responsibilities and are used as input to the initial licensed operator staffing level. Personnel tasks, addressed in TA, are assigned to staffing positions considering

- task characteristics, such as the knowledge and abilities required, relationships among tasks, time available, and time required to perform the task.
- the operator's ability to maintain situational awareness within the area of assigned responsibility.
- teamwork and team processes, such as peer checking.
- workload associated with each job within the crew.

For this report, the TA as described in the initial Human Factors Engineering Task Analysis Results Summary Report (Reference 8.2.3) was used as an input to updated staffing goals. No significant difference to the TA in the SDAA and DCA task analysis results are expected. This assumption will be confirmed using the process described in the Human Factors Engineering Task Analysis Implementation Plan (Reference 8.2.4) and documented in the final task analysis RSR, and gaps will be evaluated for impact on the S&Q results.

The relationship between TA and S&Q with respect to the process for validation of the NuScale staffing plan is described in Reference 8.2.12.

2.1.3 Determining the Number and Qualifications of Licensed Operator Personnel

The scope of S&Q analyses includes determining both the number of licensed operator personnel and their qualifications. For the purposes of this RSR, licensed operator personnel include operators and senior operators as defined by 10 CFR 55.4 (Reference 8.1.4) and MCR-specific personnel subject to the training program as described by 10 CFR 50.120 (Reference 8.1.5), as applicable to the NuScale design. Licensed operators' roles include those of SM, CRS, and RO. The role of SM and CRS can be combined as one watch-stander when desired. An SRO license is required to fill these roles. There are normally two RO watch-standers. This position requires an RO license as a minimum; however, one of these watch-standers must also have an SRO license to provide short-term relief for the combined SM and CRS position.

Staffing and qualifications analyses define numbers and qualifications of licensed personnel for a range of conditions and tasks, including operational tasks (under normal, abnormal, and emergency conditions).

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2.1.4 Iterative Nature of Staffing Analysis

Initial staffing level goals and staffing roles and responsibilities are evaluated and modified, as required, in an iterative fashion through NuScale design change control procedures, through the use of the human engineering discrepancy (HED) process, and as information from other HFE elements and S&Q analyses, evaluations, and tests becomes available.

Human engineering discrepancies are generated during human factors verification and validation (V&V) activities within the NuScale HFE Program as described in the Human Factors Engineering Program Management Plan (Reference 8.2.10). Design discrepancies identified during HFE design development activities are resolved as part of the NuScale design process, whenever possible. Those HFE issues that cannot be immediately resolved or that potentially change the initial staffing goals for the MCR or potentially impact their roles and responsibilities are captured in the Human Factors Engineering issues tracking system (HFEITS) for evaluation and resolution.

2.2 Staffing and Qualification Team Composition and Responsibilities

The HFE team is responsible for conducting the S&Q analysis. The qualifications of the HFE team members supporting this HFE Program element are stipulated in the NuScale HFE Design Implementation Implementation Plan (Reference 8.2.9).

An S&Q Team and S&Q Team lead are selected by the HFE supervisor to conduct the S&Q element. The S&Q Team lead is responsible for

- organizing the S&Q Team.
- assigning team member responsibilities.
- managing resources.
- developing schedules.
- receiving access to activities and results from other HFE elements.
- ensuring that S&Q issues are completed with supporting documentation and entered into HFEITS as necessary.
- production of the validation trial results report and the staffing and qualifications RSR.

Staffing goals for the MCR crew for the NuScale Power Plant documented in the SDAA are an input to the HFE Program elements and are confirmed using the process described in the Control Room Staffing Plan Validation Methodology (Reference 8.2.12). The results of the validation exercises applicable to the SDAA are documented in the Revised Control Room Staffing Plan Validation Results, RP-0419-65209 (Reference 8.2.14).

The S&Q process is detailed in Section 3.0, Methodology. Further details are provided in the Control Room Staffing Plan Validation Methodology (Reference 8.2.12).

2.3 Applicable Regulatory Guidance for Staffing and Qualifications

2.3.1 Standard Review Plan Guidance on Staffing and Qualifications

The NUREG-0800 Standard Review Plan (Reference 8.1.2), Section 13.1.1 “Management and Technical Support Organization”, and Sections 13.1.2–13.1.3 “Operating Organization”, provide guidance for addressing the management and technical support organization, and operating organization. A license applicant that references the NuScale Power Plant (NPP) standard design will address the management and technical support organization, operating organization, and qualifications of non-licensed operators and other plant personnel. The qualification of licensed operators is addressed in this report.

2.3.2 Requirements on Staffing and Qualifications (10 CFR 50.54(m))

The NuScale Power Plant US460 standard design is designed for the operation of up to six units from a single MCR, which is not addressed by 10 CFR 50.54(m). Because of NuScale's passive safety systems, simple operation, automation, reduced licensed

operator workload, no identified IHAs, and ample time to complete operator actions, the NuScale Power Plant uses design-specific staffing levels as an alternative to 10 CFR 50.54(m).

SECY-11-0098 (Reference 8.1.15) provides the Nuclear Regulatory Commission (NRC) staff's proposed approach to resolving the issue of the appropriate number of on-site licensed operators for multi-module nuclear power plants, and potential requests for exemptions from the on-site operator staffing requirements in 10 CFR 50.54(m).

SECY-11-0098 recommends "a two step approach to address operator staffing requirements for SMRs. In the near-term, applicants can request exemptions to the current operator staffing requirements in 10 CFR 50.54(m) and the staff will review the request using existing or modified guidance. Once experience is gained, the staff would initiate the long-term solution, which is to revise the regulations to provide specific control room staffing requirements for SMRs." Consistent with SECY-11-0098 and NUREG-0711 Section 6.4, NuScale is using the existing guidance in NUREG-0800 (Reference 8.1.2), NUREG-0711 (Reference 8.1.1), NUREG-1791 (Reference 8.1.17), and NUREG/CR-6838 (Reference 8.1.19) to develop the methodology to justify an alternate staffing solution. This report and its supporting documents provide the technical justification for the alternate licensed operator staffing of a NuScale Power Plant. A license applicant that references the US460 standard plant design will seek an exemption from 10 CFR 50.54(m) to implement the alternate staffing levels at a facility.

3.0 Methodology

3.1 Establishing the Basis for Staffing and Qualification Levels

The staffing levels for the MCR crew are identified in Section 2.1.1 and further described in the Concept of Operations (Reference 8.2.11). Staffing goals for the MCR crew are an input to or have an impact on many of the HFE Program elements and are confirmed using the revised Control Room Staffing Plan Validation Methodology (Reference 8.2.12). The staffing goals are subject to revision based on the results of HFE analyses, including operating experience review (OER), FRA/FA, TA, HSI design, and S&Q. The methodologies used in the analyses of these HFE elements are described in the corresponding RSRs and implementation plans, as applicable. These analyses provide the basis for the staffing levels, including subsequent changes. This Staffing and Qualification Results Summary Report is developed with the assumption that those HFE elements supporting the NuScale US460 standard design, and where implementation plans are being submitted, will require confirmation of the staffing and qualification levels once the results of those elements are developed and analyzed. Gaps identified at that time may require revisions to this document. Those HFE elements that will be submitted as implementation plans as part of the SDAA submittal are

- Human Factors Engineering Operating Experience Review Implementation Plan (Reference 8.2.1).
- Human Factors Engineering Functional Requirements Analysis and Functional Allocation Implementation Plan (Reference 8.2.2).
- Human Factors Engineering Task Analysis Implementation Plan (Reference 8.2.4).
- Human Factors Engineering Human System Interface Design Implementation Plan (Reference 8.2.7).
- Human Factors Engineering Verification and Validation Implementation Plan (Reference 8.2.8).
- Human Factors Engineering Design Implementation Implementation Plan (Reference 8.2.9).

The following sections describe NuScale methodology for performing the S&Q analyses to determine and change staffing levels, staffing qualifications, and roles and responsibilities for safe operation of a multi-module nuclear power plant.

A top criterion for staffing is individual and crew task performance. Successful task performance is the main criterion for evaluating a proposed staffing level. However, crew task performance can be negatively impacted by other factors. High workload and poor situational awareness are examples of factors that can lead to poor task performance and are addressed during the S&Q analyses. The S&Q analyses include periodic tests conducted at increasing levels of design maturity, procedure development, simulator fidelity, and operator training. These testing methodologies and results are described below and in Reference 8.2.12 and Reference 8.2.14.

3.1.1 Operating Experience Review

The NuScale Power Plant is a new and innovative modular, passive design with no commercial nuclear reactor power plant considered as a direct predecessor. Nonetheless, the operating experience of current commercial nuclear power plants is analyzed as described in the Human Factors Engineering Operating Experience Review Implementation Plan (Reference 8.2.1) and in the Human Factors Engineering Functional Requirements Analysis and Function Allocation Implementation Plan (Reference 8.2.2) because many systems and components similar to those in the NuScale design are also found in operating nuclear power plants. The roles and responsibilities of the SROs, specifically the SM and CRS, in existing commercial nuclear plants is considered effective in establishing and maintaining command and control and technical oversight during normal and off-normal conditions. Therefore, staffing for the MCR crew levels and qualifications are based, in part, on staffing levels and qualifications from commercial nuclear power plants, while taking into account the passive features and a high degree of automation of the NuScale Power Plant.

Operating experience at commercial nuclear power plants is reviewed as described in Reference 8.2.1. Initial staffing goals for the NPP were developed in consideration of the following factors based on subject matter expert (SME) knowledge and experience, and were considered as a part of OER, FRA/FA, and TA:

- operational strengths and weaknesses resulting from staffing levels
- initial staffing goals for the MCR crew and their bases, including a description of significant similarities and differences
- staffing considerations described in NRC Information Notice 95-48, "Results of Shift Staffing Study" (Reference 8.1.6)
- possible impact on staffing because of work hour limits, required break times, and required days off, as specified in 10 CFR 26.205, “Work Hours,” (Reference 8.1.7) as part of the Fitness-For-Duty rule
- Regulatory Issue Summary 2009-10, “Communications between the NRC and Reactor Licensees during Emergencies and Significant Events” (Reference 8.1.8)
- automatic action crediting described in NRC Information Notice 97-78, "Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times" (Reference 8.1.9)
- NUREG/IA-0137, “A Study of Control Room Staffing Levels for Advanced Reactors” (Reference 8.1.16)

The OER focus is on the unique features of the NuScale design that include multi-module applications, use of digital control systems, heavy use of automation, and use of computer-based procedures. The OER identifies human performance errors that may indicate strengths or weaknesses in commercial nuclear power plant S&Q. Human performance errors are evaluated to determine if strengths are maintained and weaknesses are resolved by the NuScale design. The OER bases related to S&Q are re-confirmed during S&Q analyses to ensure they remain valid.

3.1.2 Functional Requirements Analysis and Function Allocation

The FRA determines plant functions performed to satisfy plant safety objectives and identifies the preferred normal and emergency success paths used to control those functions. The FA assigns these success paths to human (manual), machine or system (automation), or shared actions. The process for assigning or allocating success paths is described in the Human Factors Engineering Functional Requirements Analysis and Function Allocation Implementation Plan (Reference 8.2.2) and includes consideration of the complexity and time criticality of controlling these success paths. The FA considers not only primary task allocation to personnel but also the responsibility to monitor automatic functions, to detect I&C and HSI degradations and failures, and to assume manual control when necessary.

The FA to an individual operator is based on HFE criteria and may not fully consider the operating crew as a whole. {{

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During S&Q analyses, HFEITS items may be generated in order to bring about changes to FRA/FA during successive iterations.

3.1.3 Task Analysis

The functions assigned to licensed operator personnel from FRA/FA define their roles and responsibilities for both manual actions and monitoring of or backup to automation. Human actions performed to accomplish these functions are grouped to obtain common objectives or goals. Task analysis helps to define operator S&Q for each task and includes an assessment of workload and time margins for task execution. The Task Analysis Implementation Plan (Reference 8.2.4), provides more detail on TA.

Initially, tasks are identified via system-task level analysis, and systems tasks are combined into system level functional groups. As the TA progresses, multi-system functions are combined.

The results of TA are used to develop and mature the HSI, define the roles and responsibilities of personnel, develop the draft operating procedures, capture knowledge, skills, and abilities, and identify training needs.

The TA inputs to S&Q analyses include

- time available and time required to perform a task.

- SME estimates of the workload involved.
- high-workload personnel tasks.
- knowledge, skills, and abilities for personnel.
- personnel communication and coordination, including interactions among individuals for diagnosing, planning, and controlling the plant, and interactions among personnel for administrative, communications, and reporting activities.
- the job requirements resulting from the sum of tasks allocated to each individual inside the MCR.

The TA may identify required workload outside of the MCR, such as fire brigade support; however, licensed operators who fill a minimum shift staffing role are not assigned other duties that prevent them from fulfilling their licensed operator duties within the MCR. Further information on operator roles is available in the Concept of Operations (Reference 8.2.11).

The S&Q analyses consider tasks from the full scope of TA (e.g., a range of plant operating modes, including startup, normal operations, low-power and shutdown conditions, transient conditions, abnormal conditions, emergency conditions, and severe accident conditions) (Reference 8.2.3).

The S&Q-related issues that may be generated during TA are tracked in the HFEITS and resolved during human factors V&V activities.

It is recognized that the control room staff is responsible for implementing the initial emergency response per 10 CFR 50.47, “Emergency Plans” (Reference 8.1.10), using the guidance contained in NUREG-0654, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants” (Reference 8.1.11). This responsibility includes diagnosis, assessment, mitigation, emergency declaration, off-site notifications, and implementing emergency measures within the site boundary, including protective measures and aid for on-site personnel. {{

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3.1.4 Treatment of Important Human Actions

The Treatment of Important Human Actions (TIHA) Results Summary Report (Reference 8.2.5) describes the method that is used to identify important human actions and consider them in the overall control room design. Detailed TA determines the feasibility and reliability of performing the mitigating actions of IHAs, if any are identified. Task analysis would also perform a workload assessment, time margin assessment, and determine the number of people required to accomplish a task as well as the knowledge and abilities that determine qualifications. No important human

actions were identified for the NuScale Power Plant, thus no further evaluation was needed.

3.1.5 Procedure Development

Staffing and qualifications analyses use task sequencing from TA as preliminary procedures and assume specific personnel numbers, and a certain level of secondary tasks such as communication. The S&Q analyses also consider when task sequencing suggests the concurrent use of multiple procedures. Computer-based procedures are used during scenario-based testing of operator and crew performance tests, workload analysis, and situational awareness assessments.

Procedure development is a licensee activity. Issues identified during S&Q or other HFE activities performed by NuScale during the design development process that have impacts to procedure development are entered into the HFEITS database. Training program development related issues are then passed to the licensee for disposition by their training program, as applicable.

3.1.6 Training Program Development

Staffing and qualifications analyses provide input to the training program development related to knowledge, skills, and abilities to be attained and maintained. As S&Q analyses encompass licensed operator personnel, they provide input essential to coordinating actions between individuals inside and outside the MCR. The training program includes this set of knowledge, skills, and abilities.

Training program development is a licensee activity. Any issue identified during S&Q or other HFE activities performed by NuScale during the design development process that have impacts to training program development are entered into the HFEITS database. Training program development related issues are then passed to the licensee for disposition by their training program, as applicable.

3.2 Baseline Assumptions

Before completion of the initial S&Q analyses, a NuScale Power Plant of up to 12 units was assumed to be operated with an MCR shift contingent of three licensed ROs and three licensed SROs covering the roles of SM, shift technical advisor, and CRS. Staffing and qualifications analyses were conducted to validate the initial staffing goals for the MCR crew. These initial staffing goals for the MCR crew reflect the inputs from OER, FRA/FA, TA, and TIHA. The staffing goals were then adjusted and validated as described throughout this document. The MCR shift continent for the NuScale SDAA plant is assumed to be a minimum of one licensed RO and two licensed SROs, as described in the Concept of Operation technical report (Reference 8.2.11).

Qualification requirements (education and job experience) and the training program for the licensed operator personnel at a NuScale Power Plant are expected to be similar to those described in ACAD 10-001, Guidelines for Initial Training and Qualification of Licensed Operators (Reference 8.1.20).

4.0 Evaluation of Staffing Levels and Operator Qualifications

The bases for licensed operator personnel staffing are established as described in Section 3.1 using input from other HFE Program elements to support the staffing goals for the MCR crew (numbers and qualifications baseline) described in Section 3.2. Staffing and qualifications evaluations then confirm or modify the baseline to achieve the final staffing and qualification levels. For the NuScale Power Plant design described in the SDAA the Revised Control Room Staffing Plan Validation Test Report (Reference 8.2.14) was performed to confirm the staffing levels. A summary of that report, and the Control Room Staffing Plan Validation Methodology (Reference 8.2.12) are provided in this section.

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These tests and assessments are performed to gain a high level of confidence in the adequacy of licensed operator staffing levels and their qualifications, roles, and responsibilities.

4.1 Staffing Plan Validation Methodology

4.1.1 Staffing Plan Validation Methodology Overview

The Control Room Staffing Plan Validation Methodology (Reference 8.2.12) was developed following a review of numerous regulatory and research studies on staffing, situational awareness, and workload measurements. {{

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The Control Room Staffing Plan Validation Methodology (Reference 8.2.12) consists of the following elements:

- Identify Challenging Operating Conditions
- Identify Primary and Dependent Tasks
- Identify Independent Tasks
- Construct Scenarios and Assign Operator Responsibilities
- Operating Staff Assignments
- Staffing Assumptions
- Scenarios Development Input
- Scenario Development Content Goals
- Creation of Scenario Guides
- Scenario Test Plan
- Analyze Workload

4.1.2 Staffing Plan Validation Scenario Development

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Scenarios selected for staffing plan validation exercises are also identified using input from other HFE Program elements:

- OER (Reference 8.2.1) identifies situations and technologies that affect human performance. These factors are evaluated during TA for effects on crew size or qualifications.
- FRA/FA (Reference 8.2.2) identifies success paths to determine the best allocation of functions. The FRA/FA also identifies associated workload to control those success paths while maintaining critical functions (including monitoring of automatic functions).
- TA (Reference 8.2.3) identifies constraints where time required to conduct a task is less than time available. Secondary tasks, distractions, and process delays (e.g., valve stroke time or digital processing time) are considered within time required constraints. Licensed operator workload is determined by the collective time required vs. time available calculation. Staffing and qualifications identifies the tasks that have the highest workload conditions for evaluation as part of the staffing plan validation exercises (Reference 8.2.12).
- TIHA (Reference 8.2.4) identifies both probabilistic and deterministic IHAs, however, no IHAs are identified for the NuScale US460 design.
- Human factors V&V (Reference 8.2.8) identifies the need to identify a range of operational conditions to guide task support verification, HFE design verification, and integrated system validation (ISV) by means of performing sampling of operational conditions. The need to use sampling of operational conditions as a means to support the development of challenging scenarios for evaluating workload as part of the staffing plan validation exercises is promoted in Brookhaven National Laboratory Technical Report No. 20918-1-2015 (Reference 8.1.18).

The scenario selection includes those items that are unique to NuScale such as situations evaluating changing conditions on multiple modules, common system interface failures and their effect on multiple modules, high levels of automation, and beyond-design-basis events. For workload considerations, certain plant evolutions that are planned and executed with additional staff beyond the minimum proposed are not included. For example, a reactor startup is not an activity that is performed as an unplanned evolution or needs to be done in an expeditious manner with a minimum crew; therefore, it is not considered. A reactor startup is more appropriately tested during ISV activities. Refueling operations are also not considered (except as a potential distraction) in the workload assessment. They are performed by a dedicated staff (including an SRO) separate from the MCR operating staff. The control room operators, with the exception of the SM, have little direct interaction with the refueling team.

Staffing plan validation exercises are also conducted for scenarios that, in SME judgment, challenge the initial staffing levels for the MCR in terms of numbers or qualifications. {{ }}$^{2(a),(c)}$

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4.1.3 Data Collection during Staffing Plan Validation Exercises

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}}2(a),(c) Evaluation criteria, as described in Reference 8.2.13, are established and used to determine the acceptability of operator performance and the adequacy of the HSI to permit operators to correctly diagnose and mitigate high-workload scenarios and to ensure the proposed staffing plan is acceptable. Reference 8.2.12 contains a detailed description of the methodology for performing staffing plan validation exercises, including the criteria and method for scenario development, qualification of the test bed, test conditions and evaluation criteria, test participants, and participant training.

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The testing plan results are evaluated and included in Section 4.0 and Reference 8.2.13. As each test is performed, lessons learned are captured and incorporated as needed to enhance the ability of the operators to identify key parameters and to manage the workload demands.

The results included in Section 4.0 document the changes made to the HSI, conduct of operations, or design as appropriate. By utilizing an integrated, systematic approach to evaluate the workload conditions for an operating crew, validation of the minimum licensed operator staffing for a multi-unit NuScale Power Plant is established.

4.1.4 Simulator Scenario-Based Testing

The simulator is able to support the scenarios required for staffing plan validation exercises. Reference 8.2.12 contains additional information about the status of the simulator. The validation environment is based on the control room design to the extent practicable.

Scenario-based testing is performed in accordance with the NuScale Simulator Scenario-Based Testing Procedure described in detail in Reference 8.2.12.

The testing is conducted by determining a set of key parameters and ensuring those parameters behave as expected for the developed SPV scenarios. The American National Standards Institute/American Nuclear Society (ANSI/ANS)-3.5-2009 Nuclear Power Plant Simulators for Use in Operator Training and Examination (Reference 8.1.21) is referenced to select steady state and transient parameters.

4.2 Simulator Readiness for Staffing Plan Validation Exercises

Simulator readiness to support staffing plan validation exercises is essential for reliable, credible testing. The simulator provides operators with the HSI necessary to interact with working models of the plant design, thus putting the NuScale concepts of operation into practice. {{

}}2(a),(c)

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}}2(a),(c)

4.3 Simulator Scenario-Based Testing

Scenario based testing was performed in accordance with the NuScale Simulator Scenario-Based Testing Procedure before validation testing exercises.

The testing was conducted by determining a set of key parameters and ensuring those parameters behaved as expected for the developed staffing plan validation scenarios.

The ANSI/ANS-3.5-2009 Nuclear Power Plant Simulators for Use in Operator Training and Examination (Reference 8.1.21) was referenced for a draft list to select steady state and transient parameters.

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}}2(a),(c)

Reference 8.2.12 contains more information about simulator testing criteria.

4.4 Simulator Human-System Interface Testing for Staffing Plan Validation

The following sections describe the HSI testing performed to ensure the integrity of the HSI used during staffing plan validation exercises.

4.4.1 Inventory and Characterization

This section describes the method NuScale used to develop the inventory and characterization of the HSI displays, controls, and related equipment needed for the scope defined by the scenarios discussed in the Control Room Staffing Plan Validation Methodology (Reference 8.2.12).

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}}2(a),(c)

A sample form is provided in Appendix A of Reference 8.2.12, Table 8-1.

4.4.2 Human-System Interface Task Support Verification before Staffing Plan Validation Exercises

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}}2(a),(c)

A sample form is provided in Appendix B of Reference 8.2.12, Table 8-2.

4.4.3 Human Factors Engineering Design Verification before Staffing Plan Validation Exercises

The HFE design verification was conducted to confirm that HSI characteristics conform to HFE guidelines as represented in the style guide. The style guide consists of procedures for use, general considerations, and system-specific guidance for screen-based HSIs.

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}}2(a),(c)

A sample form is shown in Appendix C of Reference 8.2.12, Table 8-3 and Table 8-4.

4.5 Data Collection during Staffing Plan Validation Exercises

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}}2(a),(c)

Reference 8.2.13 contains further information on data collected.

5.0 Results Summary of Revised Staffing Plan Validation Testing

After reviewing the HFE analysis results, the initial validation effort (Staffing Plan Validation Testing (Reference 8.2.13)), and the ISV testing, an additional study was conducted entitled the Revised Control Room Staffing Plan Validation Test Report (Reference 8.2.14). The crew complement during this testing was revised to one licensed RO and two licensed SROs. The full report of the results of this testing is described in the Revised Control Room Staffing Plan Validation Results (Reference 8.2.14). The report contains the following information:

- test purpose, scope, acceptance criteria and diagnostic measures
- test participants
- control room simulator used during the testing
- scenarios
- data collection
- results of validating the revised staffing levels

5.1 Revised License Operator Staffing Levels, Position Descriptions, and Qualifications Used during Revised Staffing Plan Validation Trials

The crew complement for the revised staffing plan validation (RSPV) consisted of three licensed operators. The following staff and license levels were used during testing as part of the on-shift operating crew:

- dual role shift manager and control room supervisor - senior reactor operator license
- reactor operator one - reactor operator license or senior reactor operator license
- reactor operator two - reactor operator license or senior reactor operator license

5.2 Participants in Revised Staffing Plan Validation Trials

The three-person crew members were chosen based on previous experience as crew members during integrated systems validation testing.

5.3 Participants Training for Revised Staffing Plan Validation Trials

The participants in the RSPV were selected from the ISV crews who had previously attended the ISV Program training. This training consisted of the following:

- 260 hours of classroom training that included an overview of NuScale design, system interactions, normal and abnormal conditions, technical specifications, emergency action levels, and applicable administrative processes
- four quizzes to assess individual comprehension
- 120 hours of simulator familiarization of system tasks, normal and abnormal conditions, IHAs, teamwork, communications, and formality
- two program dynamic simulator scenario tests to assess crew performance

- one final dynamic simulator audit test

Additional training before the start of the second validation testing consisted of four hours of classroom refresher training followed by 30 hours of simulator practice.

Classroom training consisted of the following topics:

- purpose of RSPV testing
- results of ISV testing
- description of simulator differences from ISV
- conduct of operations refresher
- assumed operator timed actions

5.4 Revised Staffing Plan Validation Test Design Summary

The original SPV scenarios performed in 2016 were not used for this validation because the previous scenario information was published both internally and submitted to the NRC for review. Therefore, it could not be ensured that participants would be unaware of the contents of the previous validation test. For this reason, new scenarios were generated using the same method as used to generate the original SPV scenarios in accordance with Control Room Staffing Validation Methodology (Reference 8.2.12). The scenarios were developed using the following inputs:

- challenging operating conditions listed in Section 3.0 of Control Room Staffing Validation Methodology (Reference 8.2.12)
- sampling of operational conditions derived from Section 11.4.1 of NUREG-0711
- high-workload tasks identified by the TA

Three potentially higher-workload themes for the NuScale design were incorporated into three different scenarios:

- performing potential IHAs to add inventory to the reactor vessel or containment vessel in beyond-design-basis, low-probability events
- multi-module transients or events
- higher levels of automation and incorporation of various automation-related failures or loss of nonsafety controls

Three validation scenarios were created using a framework designed around the three potentially high-workload themes listed above. One scenario included the performance of an IHA that is no longer designated as an IHA in the NuScale US460 design. Two scenarios were designed to test varying multi-module events. Automation failures were then incorporated into these scenarios. A comprehensive sampling-of-conditions approach was then used to ensure that a representative high-workload sample was tested. A review of the current TA concluded there was no change in required workload tasks previously identified in Control Room Staffing Plan Validation Methodology (Reference 8.2.12). The list of required high-workload tasks from Appendix F of the

methodology document was input into a computer-generated randomizer. The randomizer was used to provide the initial population of scenario events.

The scenarios were then developed being informed by the random high-workload tasks and the high-workload themes. Details were added to support scenario tasks and acceptance criteria was applied based on timing criteria used during ISV testing. NUREG-0711 provides a list of sample conditions that were referenced with the goal of including 70 percent of the listed conditions within the three scenarios in total.

5.5 Workload and Situational Awareness Data for Revised Staffing Plan Validation Test

The range of average workload for each 2019 RSPV test crew member is as follows:

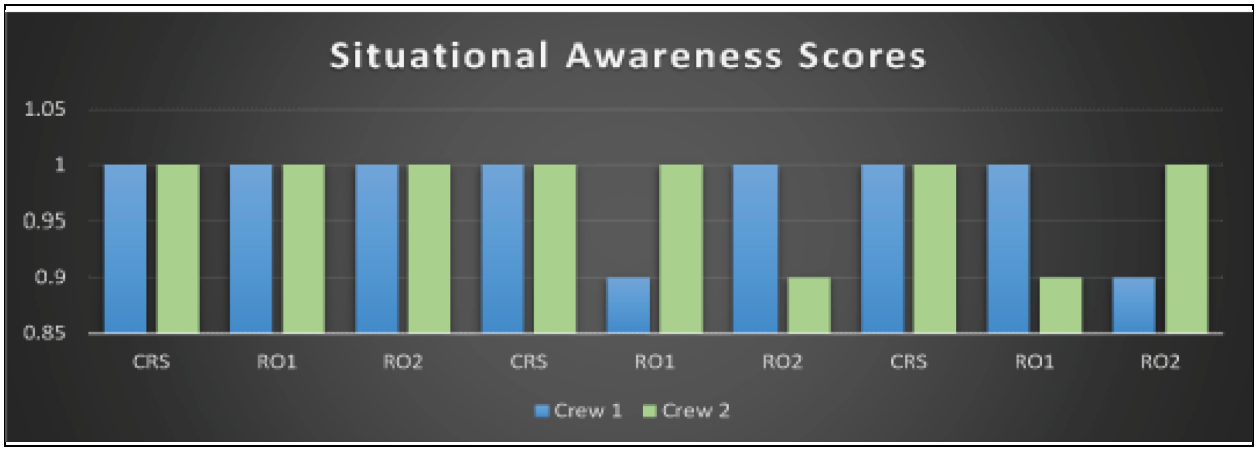
Table 5-1 Revised Staffing Plan Validation Average Workload Data

Crew Member	Avg.	Lowest Avg. Workload	Highest Avg. Workload
RO1	21	15	20
RO2	13	10	15
CRS	18	11	25

The maximum workload value measured during the trials was a raw score of 80. This score was tied to a scenario event that was designed so that the crew would not be successful. During this event, reactor coolant inventory was leaking from the module and the crew had to take action to inject additional inventory. Subsequently, the crew had indications of fuel clad degradation. In this scenario their actions were not allowed to be successful. Both CRSs stated that this no-win situation was very stressful, which was reflected in their higher TLX scores.

Situational awareness questionnaires were used at predetermined points administered in conjunction with TLX workload measures. The figure below shows the actual scores for scenarios 1, 2, and 3 from left to right on the x-axis.

Figure 5-1 Revised Staffing Plan Validation Situational Awareness Scores



The range of scores were 90 to 100 percent. The average situational awareness score was 97 percent. There was no trend to indicate that one position or person had a deviation of results from any other person or position. No situational awareness comments were generated during the RSPV.

5.6 Summary of Revised Staffing Plan Validation Test Results

The results of the RSPV confirmed that an NPP and the associated plant facilities can be operated safely and reliably by a minimum staffing contingent of three licensed operators from a single control room during high-workload conditions.

The RSPV tests demonstrate that, like the SPV test results, the minimum NuScale licensed operator staffing is sufficient to protect public health and safety, while operating up to a 12-module NPP from a single control room. The RSPV tests are applicable to the US460 standard design for an up to six module plant.

- The completion times for the required tasks were performed within the scenario acceptance criteria, with margin. Diagnostic criteria were used to identify potentially high-workload tasks using a holistic approach using convergence of measured results. For example, the TLX data collection methodology and the data analysis approach were designed to identify potential high workload by examining deviations in data with less emphasis on absolute value. This analysis was done so that even small deviations at low workload levels would be identified. When workload met predetermined criteria then other tools such as direct questioning, observations, and self-critiques were used to validate or gather further evidentiary information. Actual or perceived level of workload and stress was related to the impact on performance.
- The trial scenarios included evaluation criteria that could have warranted additional testing if not met. However, the evaluation criteria were met during each scenario testing and trials, thus no additional tests were required, nor additional validation performed.
- During the tests, no discrepancies were identified that warranted being entered into the NuScale Corrective Action Program. No identified HEDs were designated as nuclear safety concerns that would require retest (category priority 1). Some discrepancies were identified and categorized as improvements to the process, HSI, procedures, or conduct of operations (category priority 2 or 3). Identified HEDs were documented in the HFEITS database.

Further information about the second validation trial is documented in the Revised Control Room Staffing Plan Validation Test Report (Reference 8.2.14).

6.0 Staffing and Qualification Results as Compared to NUREG-0711 Review Criteria

As stated in Section 2.3.1, an applicant that references the NuScale Power Plant US460 standard design will provide a description of the corporate or home office management and technical support organizations.

Task analysis is used for the development of scenarios as described in Section 3.0 and Appendices E and F of the Control Room Staffing Plan Validation Methodology (Reference 8.2.12). The following criteria as demonstrated in the Staffing Plan Validation Results (Reference 8.2.13) and the Revised Staffing Plan (Reference 8.2.14) are also included in the validation measurement criteria:

- the task characteristics, such as the knowledge and abilities required, relationships among tasks, time required to perform the task, and estimated workload
- the operator’s ability to maintain situational awareness within the area of assigned responsibility
- teamwork and team processes (e.g., peer checking)

The number and qualifications of operations personnel for a range of plant conditions and operational tasks under normal, abnormal, and emergency conditions from the initial staffing goals were validated as demonstrated in the Staffing Plan Validation Results (Reference 8.2.13).

NuScale's staffing analysis methodology is iterative as described in Section 2.1.4. Staffing levels have changed from initial goals, as they have been continuously evaluated throughout the HFE analysis and design process as demonstrated, for example in Human Factors Engineering Task Analysis Results Summary Report (Reference 8.2.3), and roles and responsibilities have evolved as described in the NuScale Concept of Operations (Reference 8.2.10). The revised number and qualifications of operations personnel were validated as demonstrated in the Revised Staffing Plan Validation Results (Reference 8.2.14).

The basis for NuScale staffing and qualification levels were established and have been optimized as a result of the specific staffing-related issues included in the HFE elements listed in Section 3.1 and their respective RSRs and implementation plans (Reference 8.2.1 through Reference 8.2.6). The basis is also established in the process described in the Control Room Staffing Plan Methodology (Reference 8.2.12), and the results as described in the Control Room Staffing Plan Validation Results (Reference 8.2.13) and Revised Staffing Plan Validation Results (Reference 8.2.14).

7.0 Analysis Conclusions

The NPP is innovative in both design and staffing requirements. The passive systems operate with no operator actions required for design-basis events. At the time RSPV was conducted, two IHAs had been identified. Reference 8.2.5 describes the US460 standard design TIHA, which reflects the updated analysis identifying zero important human actions. NuScale Power Plant design features provide operators large time margins to complete tasks that historically would need to be performed without delay.

The HSI design provides “at-a-glance” assessment of plant conditions and facilitates early detection of degrading conditions. The features of the HSI such as design of the overview screens, safety function displays, ease of navigation, and universal display of active processes promote high levels of situational awareness.

The Concept of Operations (Reference 8.2.11) specifies that one operator has the primary focus to monitor the NPP as demonstrated in the SPV testing. One person is able to monitor multiple modules and quickly detect changing trends and off-normal conditions. This designated monitoring allows other operators to be focused on specific task completion. During the RSPV, the shift technical advisor position was eliminated, and the test successfully validated the functionality of the upgraded HSI, the effectiveness of the embedded safety function monitoring, and the backup validation by the crew members. These results demonstrated an equivalent and effective level of plant safety monitoring.

Staffing plan validations have been conducted using guidance in NUREG-0711, NUREG-1791, and NUREG/CR-6838 as well as other industry guidance. The SPV and RSPV testing included performance-based tests using a simulator focused on operator performance, workload, and situational awareness during challenging plant operating conditions, including design-basis-events, beyond-design-basis events, multi-module events, and events in series and parallel.

Two independent crews were trained and qualified to conduct three challenging and workload-intensive scenarios utilizing conduct of operations guidance that was reflective of the current industry standards with respect to communications and use of human performance tools. Three scenarios were designed to be challenging and reasonably bounding. By using those tasks from TA that were not only high workload, but also could not be ignored, operators were required to confront and manage issues affecting multiple units, beyond-design-basis events, and large scale loss of controls and indications. As was expected because of the scenario design, the testing tools (such as TLX) showed that, at certain points in the scenarios, operators experienced higher levels of workload. However, when examining the aggregate results from various testing tools, the levels of workload were found acceptable for both individuals and the crew as a whole.

A team of trained and qualified observers consisting of operations, management, and HFE personnel observed and analyzed the crew performances utilizing multiple methods of monitoring crew performance, workload, and situational awareness.

The test and evaluation team was effective in administering the test and analyzing the test results.

The results of the analysis, performed using the methods described above, confirm that an NPP may be operated safely and reliably by a minimum staffing contingent of three licensed operators from a single control room during high-workload conditions. The staffing level requires that at least two of the control room staff are licensed at the senior license level to allow for any crew member to leave the control room.

8.0 References

8.1 Source Documents

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

8.1.2. U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, March 2007.

8.1.3. U.S. Code of Federal Regulations, "Conditions of licenses," Section 50.54, Part 50, Title 10, "Energy," (10 CFR 50.54).

8.1.4. U.S. Code of Federal Regulations, "Definitions," Section 55.4, Part 55, Title 10, "Energy," (10 CFR 55.4).

8.1.5. U.S. Code of Federal Regulations, "Additional Standards for Licenses, Certifications, and Regulatory Approvals," Section 50.120, Part 50, Title 10, "Energy," (10 CFR 50.120).

8.1.6. U.S. Nuclear Regulatory Commission, "Results of Shift Staffing Study," Information Notice 95-48, 1995.

8.1.7. U.S. Code of Federal Regulations, "Work Hours," Section 26.205, Part 26, Title 10, "Energy," (10 CFR 26.205).

8.1.8. Regulatory Issue Summary 2009-10, Communications between the NRC and Reactor Licensees during Emergencies and Significant Events.

8.1.9. U.S. Nuclear Regulatory Commission, "Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times," Information Notice 97-78, 1997.

8.1.10. U.S. Code of Federal Regulations, "Emergency Plans," Section 50.47, Part 50, Title 10, "Energy," (10 CFR 50.47).

8.1.11. U.S. Nuclear Regulatory Commission, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," NUREG-0654, Rev. 1, November 1980.

8.1.12. U.S. Nuclear Regulatory Commission, "Review of Findings for Human Performance Contribution to Risk in Operating Events," NUREG/CR-6753, March 2002.

8.1.13. American National Standards Institute/American Nuclear Society, ANSI/ANS 3.1-2014, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants," ANS, LaGrange Park, IL.

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

8.1.15. SECY-11-0098, Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities, July 2011.

8.1.16. U.S. Nuclear Regulatory Commission, "A Study of Control Room Staffing Levels for Advanced Reactors," NUREG/IA-0137, November 2000.

8.1.17. U.S. Nuclear Regulatory Commission, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in10 CFR 50.54(m)," NUREG-1791, July 2005.

8.1.18. Technical Report No. 20918-1-2015, Methodology to Assess the Workload of Challenging Operational Conditions In Support of Minimum Staffing Level Reviews, March 2015.

8.1.19. U.S. Nuclear Regulatory Commission, "Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," NUREG/CR-6838, February 2004.

8.1.20. ACAD 10-001, Guidelines for Initial Training and Qualification of Licensed Operators, Revision 2.

8.1.21. ANSI/ANS-3.5-2009 Nuclear Power Plant Simulators for Use in Operator Training and Examination.

8.2 Referenced Documents

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

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

8.2.3. Human Factors Engineering Task Analysis Results Summary Report, RP-0316-17616.

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

8.2.5. Human Factors Engineering Treatment of Important Human Actions Results Summary Report, TR-130413, Revision 0.

8.2.6. Human Factors Engineering Staffing and Qualification Results Summary Report, RP-0316-17617, Revision 0.

8.2.7. Human Factors Engineering Human System Interface Design Implementation Plan, TR-130417, Revision 0.

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

8.2.9. Human Factors Engineering Design Implementation Implementation Plan, TR-130417.

8.2.10. Human Factors Engineering Program Management Plan, TR-130414.

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

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

8.2.13. Control Room Staffing Plan Validation Results, RP-0516-49116, Revision 1.

8.2.14. Revised Control Room Staffing Plan Validation Results, RP-0419-65209, Revision 2.

8.2.15. NuScale Control Room Staffing Plan Topical Report, TR-0420-69456, Revision 1.