December 17, 2020 Project No. 99902078

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of "NuScale Control Room Staffing Plan," TR-0420-69456, Revision 1

REFERENCE: Letter from NuScale to NRC, "NuScale Power, LLC Submittal of 'NuScale Control Room Staffing Plan,' TR-0420-69456, Revision 0," dated June 11, 2020 (ML20163A556)

NuScale Power, LLC (NuScale) hereby submits Revision 1 of the "NuScale Control Room Staffing Plan" (TR-0420-69456).

The enclosure to this letter contains the non-proprietary report entitled "NuScale Control Room Staffing Plan."

This letter makes no regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions, please feel free to contact Jim Osborn at 541-360-0693 or at JOsborn@nuscalepower.com.

Sincerely,

Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure: "NuScale Control Room Staffing Plan," TR-0420-69456, Revision 1

Enclosure:

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Licensing Topical Report

NuScale Control Room Staffing Plan

December 2020

Revision 1

Docket No. 99902078

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Licensing Topical Report

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Licensing Topical Report

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Abstract

This report documents the technical basis of the NuScale Power, LLC (NuScale) control room staffing plan. The conditions of applicability of the staffing plan comprise a set of attributes that, if met by a license applicant, justify the applicant's control room staff complement.

This analysis employed an alternative approach to control room staffing in lieu of 10 CFR 50.54(m), that was conducted in accordance with the applicable NRC guidance contained in NUREG-0800, Chapter 18; NUREG-0711; NUREG-1791; SECY-11-0098; and NUREG/CR-6838. Because of the NuScale plant's passive safety systems, simple operation, automation, expected reduced licensed operator workload, and limited number of important human actions, an initial minimum main control room shift contingent of six licensed operators was established. After reviewing the results of initial validation efforts, NuScale conducted an additional study to evaluate a minimum shift contingent of three licensed operators.

NuScale validation tested the staffing plan to evaluate licensed operator workload in challenging, high-workload situations within a NuScale 12-module control room environment. The goal was to validate with a high level of confidence the cognitive workload, situational awareness, and task completion times associated with safely operating a 12-module facility remained acceptable while using the minimum licensed operator crew.

The results of the analysis confirm that up to 12 NuScale Power Modules 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.

NuScale requests NRC approval of the NuScale control room staffing plan as described in this topical report in lieu of staffing requirements set forth by 10 CFR 50.54(m) or other alternative control room staffing regulations.

Executive Summary

The NuScale Power Plant (NPP) is designed to operate up to 12-modules from a single main control room, which is not specifically addressed in 10 CFR 50.54(m). The NuScale plant has been designed with the assumption that there will be an alternate staffing solution from 10 CFR 50.54(m). NuScale performed a staffing and qualifications analysis 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 10 CFR 55.4.

This topical report requests NRC review and approval of the control room staffing plan detailed herein. It is intended that a license applicant using an NRC-approved NPP design as described by 10 CFR Part 52 may use this topical report as an alternate method to establish their minimum licensed operator control room staff.

This topical report provides the technical justification for an NPP to be operated with a minimum operating crew of three licensed operators and no shift technical advisor (STA). Two of those operators perform the roles of reactor operator 1 and reactor operator 2. The third operator performs the role of shift manager and control room supervisor. NUREG-0737 (Reference 8.1.6) states "the need for the STA position may be eliminated when the qualification of the shift supervisors and senior operators have been upgraded and the man-machine interface in the control room has been acceptably upgraded." These conditions have been met in the NPP, and the minimum operating crew of three operators does not include the STA role (see Table 6-1).

To validate the staffing plan, NuScale conducted high-workload, performance-based, staffing plan validation tests to provide assurance that the licensed operator control room staff complement is sufficient to safely operate an NPP with up to 12 modules.

Summary of the test results:

- The staffing validation tests demonstrated the proposed NuScale licensed operator staffing is sufficient to protect public health and safety while operating an NPP with up to 12 modules from a single control room.
- All required tasks were performed within the times established by the scenario acceptance criteria with margin. Diagnostic criteria were used to identify potentially high-workload tasks using a holistic approach by using a convergence of measured results. For example, the Task Load Index data collection methodology and the data analysis approach were designed to identify potential high workload by examining deviations in data with less emphasis on the absolute value. This was done so even small deviations at low workload levels would be identified. When workload met predetermined criteria, other tools, such as direct questioning, observations, and self-critiques, were used to validate or gather further evidentiary information.
- The scenarios included evaluation criteria that were met during all trial scenarios. No additional tests or retests were required.
- During the tests, no discrepancies were identified that warranted being entered into the NuScale Corrective Action Program. No identified human engineering

discrepancies (HEDs) were designated as a nuclear safety concern that would require retest (category priority 1).

1.0 Introduction

1.1 Purpose

The purpose of this report is three-fold:

- Establish the minimum number and qualifications of licensed operator personnel required for safe and reliable NuScale Power Plant (NPP) operation under operating conditions based on task analysis (TA) and validation testing of the staffing plan.
- Request NRC review and approval of the control room staffing plan. A license applicant using an NRC-approved NPP design as described by 10 CFR Part 52 may use this topical report as an alternate method to establish their minimum control room staff provided the conditions of applicability are satisfied.
- Describe the results of staffing plan validation testing performed to evaluate licensed operator workload in challenging, high-workload situations within a NuScale 12-module control room environment. Testing was performed to provide a high level of confidence that up to a 12-module NPP can be safely operated with a three-person licensed operator control room crew.

1.2 Scope

This topical report addresses the minimum number and qualifications of licensed operator personnel required for safe and reliable NPP operation under challenging, high-workload operating conditions based on task analysis and validation testing of the staffing plan. For the purposes of this report, licensed operator personnel include reactor operators (ROs) and senior reactor operators (SROs) as defined by 10 CFR 55.4.

The NuScale licensed operator control room staffing plan has been developed in two stages. The first stage uses the human factors engineering (HFE) analysis to set an initial staffing level. The second stage uses control room crews in performance-based testing using a simulator. The focus of the testing is on operator performance, workload, and situational awareness during challenging plant operating conditions that included design basis events (DBEs), beyond design basis events, and multi-module events in series and in parallel. This topical report presents the results of the HFE analysis and describes how validation testing was used to check and adjust the number of operators. The results of the HFE analysis, the validation testing methodology, and the first validation testing have been previously reviewed by the NRC staff. An additional validation test has been performed and is also presented here. This topical report also describes why the role of the STA is not required for the NuScale control room.

1.3 Regulatory Acceptance Criteria

Standard Review Plan, NUREG-0800, Chapter 18.0, Table 1 (Reference 8.2.2), lists Chapter 18 Attachment B as the acceptance criteria for work load evaluation. The attachment provides a methodology to identify high-workload operational conditions and analyze the associated workload. The methodology is rooted in task analysis and relies on the identification of appropriate challenging scenarios, realistic portrayals of task

performance that is complicated by separate, but often necessary, dependent and independent tasks, and the judgment of subject matter experts (SMEs) obtained in a manner conducive to obtaining realistic workload estimation.

1.4 Regulatory Requirements

10 CFR 50.54(m) specifies minimum licensed operator staffing requirements and responsibilities as a license condition on operating licenses. These requirements do not address a design with more than three units on a site or more than two units operated from a single control room. Further, licensee decisions regarding licensed operator staffing, including the number, composition, and qualifications of licensed personnel, are more appropriately based on features unique to the design rather than on the existing large, light water reactor-based staffing levels. 10 CFR 50.120 requires a program for training and qualifying plant personnel, including the STA position.

1.5 Conditions of Applicability

The conditions of applicability of the staffing plan comprise a set of attributes that, if met by a license applicant, justify the applicant's control room staff complement. The control room staffing plan described here can be used by a combined license applicant for a NuScale small modular reactor plant of up to 12 NuScale power modules that meets the following features:

- no operator actions are credited in DBEs
- two important human actions (IHAs) which are easily recognizable and can be completed from the main control room (MCR) by a single licensed operator
- a human-system interface (HSI) design that retains the following features:
  - critical safety function and defense-in-depth monitoring and display, which provide direct links to response procedures
  - tiered alarm scheme
  - computer-based alarm response procedures that are directly linked to assist the operator in efficiently locating the correct instruction
  - twelve-module trend monitoring

An applicant can show the proposed design complies with the conditions of applicability by performing an evaluation or demonstration of their design to these attributes. Additionally, any changes or differences from the control room staffing assumptions listed in Section 5.2.1 by a license applicant have to be evaluated to understand potential impact to control room staff workload before this staffing plan can be used.

The applicants' licensed operator training programs for the plant include the following attributes and items:

- developed using a systems approach to training, as described in 10 CFR Part 55
- the math, physics, thermodynamics, and component design topics that are of specific relevance to the operation of a nuclear power plant

- training for mitigating core damage
- plant specific training, including:
  - plant systems
  - plant specific reactor technology (including core physics data)
  - plant chemistry and corrosion control
  - reactor plant materials
  - reactor plant thermal cycle
  - transient/accident analysis
  - emergency procedures

1.6 Abbreviations and Definitions

Table 1-1 Abbreviations

Term	Definition
BDBE	beyond design basis event
CFR	Code of Federal Regulations
CRS	control room supervisor
DBE	design basis event
HED	human engineering discrepancy
HFE	human factors engineering
HSI	human-system interface
IHA	important human action
ISV	integrated system validation
MCR	main control room
NRC	Nuclear Regulatory Commission
PRA	probabilistic risk assessment
RO	reactor operator
RSPV	revised staffing plan validation
SM	shift manager
SPV	staffing plan validation
SRO	senior reactor operator
STA	shift technical advisor
TA	task analysis
TLX	Task Load Index (NASA)
TMI	Three Mile Island

Table 1-2 Definitions

Term	Definition
Participant	A person who has been selected as a control room operator to perform validation exams
Scenario guide	A document that describes the initial conditions, sequence of events, and evaluation criteria used in simulator testing of participants
Simulator	A facility constructed to model as close as practical the actual NuScale design control room. NUREG-0711 uses the term “validation testbed” to describe the area in which the human-system interface (HSI) is displayed for performance evaluations. Within this document the “testbed” is referred to as the simulator.

2.0 Human Factors Engineering Program

The HFE Program for the NPP is described in Chapter 18 of the Final Safety Analysis Report. This program uses proven technology, and incorporates accepted HFE standards and guidelines, including the applicable guidance provided in Human Factors Engineering Program Review, NUREG-0711, Rev. 3 (Reference 8.2.1). The planning and analysis part of the HFE Program includes an operator TA and a staffing and qualifications analysis to establish the number and qualification of licensed operators required for safe and reliable NPP operation. This section of the topical report summarizes how these parts of the HFE Program influenced initial control room staffing assumptions.

2.1 Task Analysis Inputs to Determine Control Room Staffing

The HFE task analysis is used to determine the crew roles and responsibilities, and is used as input to the initial licensed operator staffing level. Personnel tasks, addressed in the 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

As discussed in Section 18.4 of the FSAR, task analysis provides early definition of individual roles, responsibilities, and qualifications. It also identifies the time needed to perform a task, the workload involved, and the number of personnel needed to complete each task. Further information about the HFE task analysis is documented in the Human Factors Engineering Task Analysis Results Summary Report, RP-0316-17616 (Reference 8.2.5). An audit of HFE task analysis results was conducted by NRC staff in May 2017 (ADAMS Accession No. ML17181A415.)

2.2 Using Staffing and Qualification Analysis to Determine the Number and Qualifications of Licensed Operator Personnel

The HFE staffing and qualifications analysis includes determining the number of licensed operator personnel and their qualifications. For the purposes of this analysis, licensed operator personnel include operators and senior operators as defined by 10 CFR 55.4. Licensed operator roles and qualifications considered at NPPs include those of shift manager (SM), control room supervisor (CRS), STA, and RO. Staffing and qualifications analysis define numbers and qualifications of licensed personnel for a range of conditions and tasks under normal, abnormal, and emergency conditions.

The staffing and qualification analysis uses task sequencing from the TA element as preliminary procedures, assumes specific personnel numbers, and assumes a certain level of secondary tasks such as communication. Initial staffing level goals and staffing

roles and responsibilities are evaluated and modified, as required, in an iterative fashion. The modifications are done using input from the HED process, and as information from other HFE elements, evaluations, and tests become available. Further information about the HFE staffing and qualifications analysis is documented in the Human Factors Engineering Staffing and Qualifications Results Summary Report, RP-0316-17617 (Reference 8.2.6).

2.3 Control Room Staff Level Based on Staffing and Qualification Analysis

The initial licensed operator staffing level for a 12-module NPP was assumed to be six licensed operators. Validation testing of the staffing plan was conducted to validate the initial staff assumption. The positive results of those activities led to an additional validation test with a MCR shift contingent of three licensed operators: two control board operators and a combined CRS/SM. Additional discussion on validation activities is provided in Section 5.0.

Licensed operators are selected, trained, and qualified with standards that are comparable to the approved standards of Guidelines for Initial Training and Qualification of Licensed Operators, ACAD 10-001 (Reference 8.2.4), and fully comply with the applicable license operator training programs described in 10 CFR Part 55 and 10 CFR Part 50.120.

3.0 Analysis of the Shift Technical Advisor Position

The STA was created following the Three Mile Island (TMI) accident in 1979 to ensure a nuclear control room included an individual knowledgeable in engineering principles. These recommendations were incorporated into NUREG-0737, Clarification of TMI Action Plan Requirements (Reference 8.1.6), which states that “the need for the STA position may be eliminated when the qualification of the shift supervisors and senior operators have been upgraded and the man-machine interface in the control room has been acceptably upgraded.” No further guidance has been developed to establish the required level of upgrade to the man-machine interface or what upgrades to senior operator qualifications are required.

3.1 Industry Upgrades to Qualifications of Shift Supervisors and Senior Operators

The training of the licensed operators was upgraded following the addition of the STA position. Applicable engineering principles are now an integral part of any licensed operator training program. Licensee training programs also now include specific training on transient and accident analysis, and on mitigating core damage. A requirement to complete the training is included in NUREG-1021 license requirements and specifically called out on "NRC Form 398, Personal Qualification Statement-Licensee."

3.2 NuScale Control Room Upgrades

The NuScale control room design includes safety function monitoring that is integrated into the man-machine interface. 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, keep the operators situationally aware of plant status. The emergency operating procedures are embedded into the interface and directly linked to the safety functions. The control room design also includes active monitoring of emergency action levels in the emergency plan. These features are upgrades to the conditions facing plant operators during the TMI accident when the need for an STA position was identified.

3.3 Validation Activities

The NuScale HSI meets NUREG-0737 criteria for an upgraded man-machine interface as follows. The two NuScale validation tests of the staffing plans and the integrated systems validation (ISV) are the HFE-related activities that NuScale has conducted to validate how the man-machine interface has been upgraded. These activities demonstrate that operators can be successful at recognizing and mitigating beyond design basis events (BDBEs) using the upgraded control room man-machine interface.

During the three-person crew validation tests, the STA was not manned, and the SM and CRS positions were combined as a dual role assigned to one SRO. Initial emergency plan duties were assigned to that role.

3.4 Shift Technical Advisor HFE Task Analysis and Conclusion

The HFE task analysis, as discussed in Section 2.1 of this report, identified 32 tasks associated with the STA position. These tasks have been reassessed utilizing insights from the results of the staff plan validation (SPV), integrated system validation, and revised staffing plan validation (RSPV) and using the more mature plant design information now available. The tasks were further evaluated such that five tasks were added, and ten tasks were deleted, resulting in twenty-seven tasks remaining. The five additional tasks were a result of doing a further breakdown of the original tasks. The ten tasks that were deleted were grouped together in three common categories. Five of the tasks duplicated tasks assigned to other crew members. Three tasks were no longer required based on updated plant information. The remaining two tasks were duplicates of existing STA tasks.

The twenty-seven tasks were grouped together into three common categories. Seventeen tasks were related to oversight functions that were assigned to both the STA and CRS roles. Removal of the STA position and assignment of these tasks solely to the CRS has no significant impact to the CRS workload since the oversight function remains the same during these conditions. Eight of the tasks are associated with emergency plan assessment and implementation. In a declared emergency, the crew will be backed up by the emergency response organization. The remaining two tasks are associated with administrative duties tied to non-emergency notifications, which are tasks that the crew could delay or disregard if needed.

Based on the low number of tasks, the high amount of time available to identify and complete the tasks, and the redundant nature of how specific HFE tasks assigned to the CRS can also be peer checked by the second senior reactor operator on the crew, NuScale has concluded that the control room staff as described in the topical report is adequate to support the task reassignment. There is adequate time for the second on-shift senior reactor operator to independently assess and provide advice to the CRS in a reasonable amount of time or to engage off-site or off-shift resources for assistance. There are HFE tasks primarily assigned to the CRS, that are also assigned to the second senior reactor operator on the crew. Both are qualified to complete the task. The second SRO on shift is available to perform independent assessment and provide advice to the CRS.

After completing the reassessment, each of the remaining HFE tasks were also verified to be covered by a companion SRO training task which supports the NuScale learning objective based knowledge, skills and ability catalog.

3.5 Conclusion

NUREG-0737 provides two conditions in which the STA position may be eliminated; an upgrade to qualification of senior operators and an upgrade to the man-machine interface. The upgrade to senior operator qualification has been accomplished by the upgrades integrated into accepted industry licensed training programs. Specifically, the addition of generic fundamentals to licensed operator training, as well as the addition of mitigating core damage and transient accident analysis training. The upgrades to the

man-machine interface have been accomplished by the HFE improvements incorporated into NuScale control room design. The NuScale validation testing of the staffing plan and ISV activities have demonstrated that operators are successful at recognizing and mitigating BDBEs using this upgraded control room man-machine interface.

For NPPs, the use of passive safety features and lower operational complexity have resulted in no required operator actions for DBEs as well as improvement in overall safety. The design only has two IHAs associated with events that have a very small probability of occurrence. Both IHAs are simple, straight-forward actions that can be completed from the MCR by a single operator. These IHAs also have large time margins to complete tasks that historically would need to be performed without delay. These design features reduce the need for additional oversight.

Satisfaction of these conditions justifies excluding the STA position from the NuScale staffing plan and technical specifications. Although the STA position addressed by NUREG-0737 is not a regulatory requirement applicable to NuScale or future licensees, 10 CFR 50.120 requires a licensee to provide a training and qualification program for the STA position. Based on the foregoing, an STA training program is not required for applicants and licensees referencing an approved NuScale design.

An exemption from the regulations is not appropriate for a standard design applicant because 10 CFR 50.54(m) and 10 CFR 50.120 are applicable only to a licensee. Therefore, NuScale is requesting approval for the design-specific MCR staffing requirements presented in this topical report, in lieu of the current requirements of 10 CFR 50.54(m) and 10 CFR 50.120(b)(2)(iii).

4.0 Additional Staffing Considerations

The three-person crew staffing complement is intended to identify the minimum crew size to support safe plant operations. An additional requirement is added for at least two of the crew members to have senior operator licenses so that the CRS could leave while the second senior license holder remained in the control room. An additional senior license holder is required to support refueling operations.

4.1 Compliance with Regulatory Guide 1.114

The requirement to have at least two of the three control room operators licensed at a senior operator license level has been added to accommodate occurrences in which one licensed operator would leave the control room area. This allows the crew to meet the methods set forth in Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit, Regulatory Guide 1.114 (Reference 8.2.3) without the need for any additional exemptions. The specific NuScale requirements for the manning of operators in the control room is provided in Table 6-1:

b. A person holding a senior reactor operator license shall be in the control room at all times when there is fuel in any reactor vessel. In addition to this senior reactor operator, a licensed reactor operator or senior reactor operator shall be present at the controls at all times when there is fuel in any reactor vessel.

4.2 Staffing Level during Refueling Operation

Table 6-1 includes a requirement for a senior license holder during refueling operations. The NuScale requirement is similar to that required in the existing fleet facilities:

d. Each licensee shall have present, during alteration or movement of the core of a nuclear power unit (including fuel loading, fuel transfer, or movement of a module that contains fuel), a person holding a senior operator license or a senior operator license limited to fuel handling to directly supervise the activity and, during this time, the licensee shall not assign other duties to this person. This person is in addition to the two senior operator license holders identified in Table 6-1.

4.3 Conclusion

Table 6-1 provides the control room staffing level for combined license applicants who meet the conditions of applicability in Section 1.5. This includes the requirement for an additional senior license holder who is dedicated to fuel handling. The staffing level also 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. The three-person crew size for a NPP establishes a minimum control room manning to safely operate the facility.

5.0 Staffing Plan Validation and Verification

5.1 Staffing Plan Validation Methodology Overview

The Control Room Staffing Plan Validation Methodology, RP-1215-20253 (Reference 8.2.7) has been developed following a review of numerous regulatory and research studies on staffing, situational awareness, and workload measurements. The methods selected use multiple approaches from these reviews to gather and analyze data for a holistic approach and to form conclusions. The review of multiple data collection methods to produce an evidentiary conclusion acknowledges that each analysis method taken individually has certain testing bias and uncertainty.

The validation plan 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
- scenario development input
- scenario development content goals
- creation of scenario guides
- scenario test plan
- analyze workload

This methodology has been used to conduct two validation efforts. These tests are referred to as the control room staffing plan validation (SPV) and the revised staffing plan validation (RSPV). Two improvements to the methodology were made following the SPV, the addition of an independent observer role and the elimination of applying weighting factors to the National Aeronautics and Space Administration Task Load Index (TLX). The results of these tests successfully validated the crews could safely operate an NPP of up to 12 power modules from a single control room under high-workload conditions. There is reasonable assurance that the workload during each of the scenarios was representative of the highest-workload conditions the operators might face. The testing was limited to control room licensed operator staffing positions.

Both tests were conducted using two independent crews with a basic level of training, each performing three high-workload scenarios. The crew size was changed between the SPV and the RSPV scenarios.

During the trials, data was collected using time measurements, TLX, pre-screened questionnaires related to situational awareness, performance measures developed as task attributes by subject matter experts during TA, independent operations and expert

HFE observations, and post-test critiques similar to those used in current operating plant training programs.

Further information about the methodology that NuScale used during validation testing is documented in RP-1215-20253. An audit of the staffing plan validation methodology was conducted by NRC staff in May 2016 (ADAMS Accession No. ML16137A129).

5.2 First Validation Trials

The SPV was performed in August 2016. Three scenarios were used for the trials. These scenarios focused on operator performance, high workload, and situational awareness during challenging plant operating conditions. These scenarios were performed by two independent crews for a total of six tests.

5.2.1 License Operator Staffing Assumptions Used During SPV and RSPV

- Refueling operations and module assembly and disassembly are not directed from the MCR. Refueling is a planned activity and has a dedicated staff assigned for specific performance and oversight. Because the NPM is electrically and mechanically disconnected during refueling, the control room operators have no direct interaction with the refueling team other than operating common system components (e.g., align reactor pool cooling) or to update the SM on refueling status.
- A work control center (WCC) is available to assist the control room with work management during periods of significant workload. This reduces the distractions to the control room crew and is common practice among existing nuclear plants.
- The crew staffing complement includes one non-licensed operator acting as a communicator to offsite agencies during emergencies. The crew responsibilities do not include the fire brigade, supplemental emergency plan responder, or emergency medical team responder.

5.2.2 Licensed Operator Staffing Levels, Position Descriptions, and Qualifications Used During First Validation Trials

The crew complement for the SPV consisted of six licensed operators. The following staff and license levels were used during testing as part of the on shift operating crew:

- one SM - SRO license
- one CRS - SRO license
- one STA - SRO license and having a degree in a science or applied science field
- three ROs - RO license

5.2.3 Participants in First Validation Trials

The crew participants were selected based on having prior nuclear control room operating experience and some experience with the NuScale design. The operating crew participants were considered subject matter experts in nuclear plant operations.

The definition of subject matter expert for testing purposes is a person that has completed the NuScale HFE/operations initial company training program, 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 facility.

5.2.4 Participant Training for First Validation Trials

Participant crew training was required to ensure the same base level of knowledge existed among the crew members regarding the NPP design, plant controls, and conduct of operations. This provided a reference for anticipated operator response and provided some assurance that observations and ratings of high workload would be attributed to actual workload and not because operators were unfamiliar with how to accomplish the tasks.

The crew participants were trained in basic fundamental operation of the safety systems, selected systems used during normal operation, and applicable support systems. The participants also received basic HSI navigation, conduct of operations, and administrative task training. All participants had previous licensed operator experience at nuclear facilities, which allowed the training to be condensed and drew on the operators' experience with nuclear power plant fundamentals and control room etiquette.

5.2.5 Staffing Plan Validation Test Design Summary

The three-high workload, challenging operating conditions or themes for NuScale were determined using the methodology described in RP-1215-20253. The scenarios include:

- A scenario in which the operators are required to implement the IHA to add inventory to the containment to avoid reactor core damage or large radiological releases. These are needed in BDBEs that result from multiple safety-related system failures. In the most limiting probabilistic risk assessment (PRA) analysis, this failure requires operator action to add inventory within approximately 90 minutes from the event initiation. The probability of this event is extremely low.
- A multi-module transient is another potential high-workload condition and would present a challenge to the crew to manage and communicate. There are many possible events that may result in a multi-module transient. Some examples are a loss or malfunction in the common systems that support more than one module or a loss of offsite power or other major electrical transient.
- Failures of automation on a large scale that may produce taxing and high-workload conditions. Automation failures may occur at many levels, but from TA, the most workload intensive is a loss of nonsafety digital systems used to control the NPP. This scenario was analyzed with the instrumentation and control architecture designers and thought not to be a credible event with the multiple levels of redundancy incorporated in the design, but it is useful to encompass the many credible possibilities. A high-workload scenario should include many

variations of automation failure or failure of the nonsafety controls and indications. This condition would challenge the operator's ability to detect accident conditions and ensure the correct response of the safety systems.

The simulator scenarios were developed using the three challenging conditions listed above as the overall theme for each. Additional events were added referencing the sampling criteria described in NUREG-0711 and the high-workload tasks from the NuScale TA.

5.2.6 Summary of Staffing Plan Validation Trial Results

The SPV test results demonstrate that the initial NuScale licensed operator staffing size was sufficient to protect public health and safety while operating up to a 12-module NPP from a single MCR.

- The completion times for the required tasks were performed within the scenario acceptance criteria, with margin. Diagnostic criteria was 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 used were designed to identify potential high workload by examining deviations in data with less emphasis on absolute value. This 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 scenarios included evaluation criteria that could have warranted additional testing if not met. However, all of the evaluation criteria were met in all trials. No additional retests were required and no additional validation was performed.
- During the tests, no discrepancies were identified that warranted being entered into the NuScale Corrective Action Program. No identified HEDs were designated as a 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 HFE issue tracking system.

The trial results demonstrate that the plant can be safely operated by a crew of three ROs and three SROs. The validation testing resulted in comprehensive data that supported the initial staffing plan.

Further information about the original SPV trials is documented in the Control Room Staffing Plan Validation Results, RP-0516-49116 (Reference 8.2.8). An audit of staffing plan validation testing was conducted by NRC staff in November 2016 (ADAMS Accession No. ML16137A257).

5.3 Second Validation Trials

After reviewing the HFE analysis program results, the initial validation effort, and the ISV, an additional study was conducted in May 2019 entitled the Revised Staffing Plan Validation Test Report, RP-0419-65209 (Reference 8.2.9). Three new scenarios from the ones used for SPV were used for the trials. These scenarios were performed by two independent crews, for a total of six tests. The crew participants were selected based on having previous experience as ISV crew participants. This section of the topical report provides the activities and results of the RSPV trials.

5.3.1 Licensed Operator Staffing Levels, Position Descriptions, and Qualifications used during Second Validation Trials

The crew complement for the RSPV consisted of three licensed operators. The following staff and license levels were used during testing as part of the on shift operating crew:

- Shift Manager / CRS - SRO license
- Reactor operator 1 - RO or SRO license
- Reactor operator 2 - RO or SRO license

5.3.2 Participants in Second Validation Trials

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

5.3.3 Participant Training for Second 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 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
- A list of assumed operator timed actions

5.3.4 Staffing Plan Validation Test Design Summary

The original SPV scenarios performed in 2016 were not used for this validation primarily 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 that earlier validation test. For this reason, new scenarios were generated using the same method as used to generate the original SPV scenarios in accordance with RP-1215-20253, Control Room Staffing Validation Methodology. The scenarios were developed using the following inputs:

- Challenging operating conditions listed in Section 3.0 of RP-1215-20253
- Sampling of operational conditions 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 PRA-credited 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 non-safety 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 a PRA-credited IHA. 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 RP-1215-20253, Control Room Staffing Plan Validation Methodology. 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 all three scenarios in total.

5.3.5 Workload and Situational Awareness Data for Second Validation Trials

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

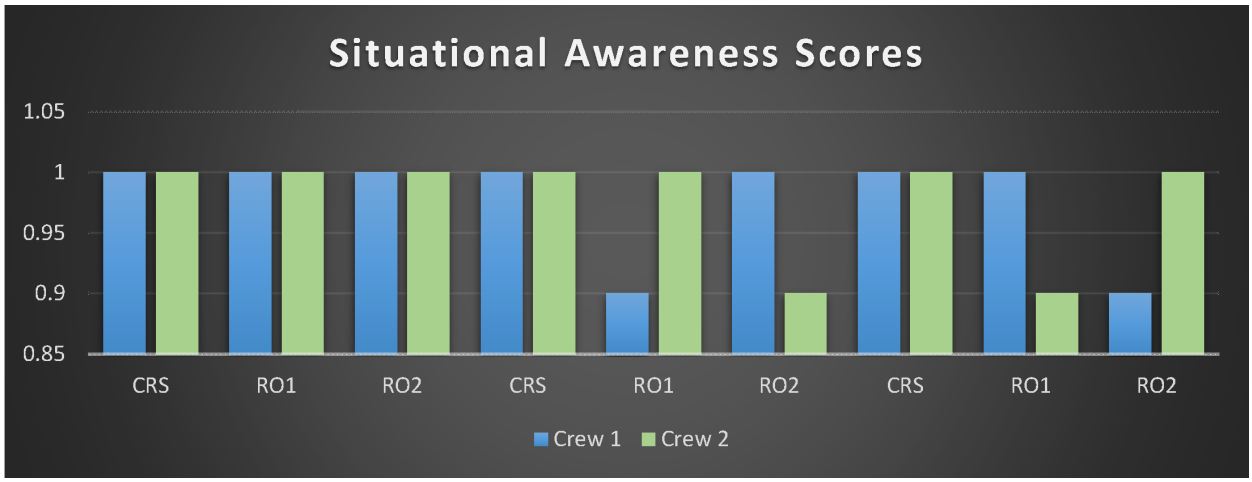
Table 5-1 RSPV Average Workload Data

Crew Member	Avg.	Lowest Avg. Workload	Highest Avg. Workload
RO1	21	15	28
RO2	13	10	15
CRS	18	11	25

The maximum workload value measured during all the trials was a raw score of 80. This score was tied to a scenario event which 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 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 RSPV Situational Awareness Scores



The range of scores were 90%-100%. The average situational awareness score was 97%. 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.

5.3.6 Summary of Revised Staffing Plan Validation Trial Results

The results of the RSPV confirmed that up to a 12-module 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 completion times for the required tasks were performed within the scenario acceptance criteria, with margin. Diagnostic criteria was 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 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, all of the evaluation criteria were met during all scenario testing, and in all trials, so no additional retests were required and no additional validation was performed.
- During the tests, no discrepancies were identified that warranted being entered into the NuScale Corrective Action Program. No identified HEDs were designated as a 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 HFE issue tracking system.

Further information about the second validation trial is documented in RP-0419-65209, Revised Staffing Plan Validation Test Report.

6.0 Results

6.1 Facility Staff

The minimum licensed operator staffing for licensees referencing an NRC-approved NPP design of up to 12 modules is shown in the following table:

Table 6-1 Minimum Onsite Licensed Operator Staffing

Reactor Operator	Senior Reactor Operator
1	2

a. A person holding a senior operator license for all fueled units at the site who is assigned responsibility for overall plant operation shall be onsite at all times when there is fuel in any reactor vessel.

b. A person holding a senior reactor operator license shall be in the control room at all times when there is fuel in any reactor vessel. In addition to this senior reactor operator, a licensed reactor operator or senior reactor operator shall be present at the controls at all times when there is fuel in any reactor vessel.

c. Shift crew composition may be less than the minimum requirement for a period of time not to exceed two hours in order to accommodate unexpected absence of on-duty shift crew members provided immediate action is taken to restore the shift crew composition to within the minimum requirements.

d. Each licensee shall have present, during alteration or movement of the core of a nuclear power unit (including fuel loading, fuel transfer, or movement of a module that contains fuel), a person holding a senior operator license or a senior operator license limited to fuel handling to directly supervise the activity and, during this time, the licensee shall not assign other duties to this person. This person is in addition to the two senior operator license holders identified in Table 6-1.

The control room staff requirement excludes the STA position and excludes an STA program under 10 CFR 50.120(b)(2) from the licensee's training program.

6.2 Results Summary of Staffing Plan Validation Testing

The results of iterative validation testing of the staffing plan confirmed that up to a 12-module NPP and the associated plant facilities may be operated safely and reliably by a minimum staffing contingent of three licensed operators from a single control room during high-workload conditions.

7.0 Summary and Conclusions

The NuScale design provides passive systems that operate with no required operator actions for DBEs. The design has a small number of PRA-identified IHAs that have very remote probability for occurrence related to BDBEs. The NPP design features provide operators large time margins to complete tasks that historically would need to be performed without delay. All IHAs were tested during the staffing plan validations and met the acceptance criteria.

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 situation awareness.

The Concept of Operations, RP-1020-72177 (Reference 8.2.10) specifies that one operator has the primary focus to monitor the NPP as demonstrated in the validation testing of the staffing plan. One person is able to monitor up to 12-modules and quickly detect changing trends and off-normal conditions. This allows other operators to be focused on specific task completion. During the second validation test the STA position was eliminated, and the test successfully validated the functionality of the upgraded HSI, the effectiveness of the embedded safety function monitoring, and the back-up validation by the crew members. This demonstrated an equivalent and effective level of plant safety monitoring.

Staffing plan validations were conducted using guidance in NUREG-0711, NUREG-1791, and NUREG/CR-6838 as well as other industry guidance. The validation testing of the staffing plan included performance-based tests using a simulator focused on operator performance, workload, and situational awareness during challenging plant operating conditions, including DBE, BDBE, and multi-module events. These events were tested in cases where they occurred in series, and other times with one or more of the events happening in parallel.

Two independent crews were trained and qualified to conduct three challenging and workload-intensive scenarios using conduct of operations guidance reflective of the current industry standards with respect to communications and use of human performance tools during the scenarios. The three scenarios were designed to be challenging and create high workload conditions. By using those tasks from TA that were high workload and could not be ignored, operators were required to confront and manage issues affecting multiple modules, BDBEs, and large scale loss of controls and indications. As was expected because of the scenario design, the testing tools such as TLX showed at certain points in the scenarios, operators experienced higher levels of workload. However, when examining all of the tools used to measure workload, a preponderance of evidence shows that individuals, and the crew as a whole, experienced acceptable levels of workload.

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

The results of the validation testing confirm that up to a 12-module 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 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 SECY-11-0098, "Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities," Commission Paper SECY-11-0098, July 22, 2011.

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

8.1.3 U.S. Nuclear Regulatory Commission, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," NUREG-1791, July 2005.

8.1.4 Brookhaven National Laboratory Technical Report No. 20918-1-2005, "Methodology to Assess the Workload of Challenging Operational Conditions In Support of Minimum Staffing Level Reviews," March 9, 2015.

8.1.5 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.

8.1.6 U.S. Nuclear Regulatory Commission, "Clarification of TMI Action Plan Requirements: Requirements for Emergency Response Capability" NUREG- 0737 Supplement No.1, January 1983.

8.1.7 NuScale Standard Plant Design Certification Application.

8.1.8 U.S. Nuclear Regulatory Commission, "Operator Licensing Examination Standards for Power Reactors" NUREG-1021, Revision 11, February 2017.

8.2 Referenced Documents

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

8.2.2 U.S. Nuclear Regulatory Commission, "Standard Review Plan, Human Factors Engineering," NUREG-0800, Chapter 18.0, Table 1, Rev. 3, December 2016.

8.2.3 U.S. Nuclear Regulatory Commission, "Guidance to Operators at the Controls and Senior Operators in the Control Room of a Nuclear Power Unit," Regulatory Guide 1.114, Rev. 3, October 2008.

8.2.4 National Academy for Nuclear Training, "Guidelines for Initial Training and Qualification of Licensed Operators," ACAD 10-001, Rev. 1, November 2016.

8.2.5 NuScale Power, LLC, "Human Factors Engineering Task Analysis Results Summary Report," RP-0316-17616, Revision 2, April 2019.

8.2.6 NuScale Power, LLC, "Human Factors Engineering Staffing and Qualifications Results Summary Report," RP-0316-17617, Revision 0, December 2016.

8.2.7 NuScale Power, LLC, "Control Room Staffing Plan Validation Methodology," RP-1215-20253, Revision 3, December 2016.

8.2.8 NuScale Power, LLC, "Control Room Staffing Plan Validation Results," RP-0516-49116, Revision 1, December 2016.

8.2.9 NuScale Power, LLC, "Revised Staffing Plan Validation Test Report," RP-0419-65209, Revision 2, November 2020.

8.2.10 NuScale Power, LLC, "Concept of Operations," RP-1020-72177, Revision 1, December 2020.

8.3 Forms

8.3.1 U.S. Nuclear Regulatory Commission, "Personal Qualification Statement - Licensee," Form 398, October 2019.