November 30, 2016

MEMORANDUM TO: Samuel Lee, Chief
Licensing Branch 1
Division of New Reactor Licensing
Office of New Reactors

FROM: Rocky Foster, Project Manager ***/RA/***
Licensing Branch 1
Division of New Reactor Licensing
Office of New Reactors

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION AUDIT REPORT TO REVIEW NUSCALE POWER, LLC, PRE-APPLICATION ACTIVITIES HUMAN FACTORS ENGINEERING TOPICS (PROJ0769)

As part of the pre-application review activities related to the NuScale Power, LLC (NuScale) design, the U.S. Nuclear Regulatory Commission (NRC) staff performed an audit related to Human Factors Engineering (HFE) topics on August 16, 2016, through August 19, 2016. The audit was held at the NuScale Headquarters located in Corvallis, Oregon.

The purpose of the audit was to perform a review of supporting documents and observe simulator operations to aid in resolving technical issues concerning documents, mentioned below, provided by NuScale to the NRC staff relating to pre-application activities for HFE topics, implementation plans, scenario test procedures, and the concept of operations summary.

The documents that the staff reviewed were the following:

1. "Conduct of Operations," Revision 0, RP-1215-19691, dated July 13, 2016;

2. "NuScale Power Small Modular Reactor Human System Interface Style Guide," Revision 0, ES-0304-1381, dated December 10, 2015;

3. "Simulator Scenario Based Testing Procedure," Revision 1, OP-0504-50019, dated August 4, 2016;

4. "Concept of Operations," Revision 0, RP-0215-10815, dated August 11, 2016;

5. "Control Room Staffing Plan Validation Scenario Descriptions," Revision 1, RP-0316-48456, dated August 8, 2016;

CONTACT: Rocky Foster, NRO/DNRL/LB1
(301) 415-5787

6. "Concept of Automation," Revision A, RP-1215-19690, dated February 1, 2016; and

7. "Control Room Staffing Plan Validation Methodology," Revision 2, RP-1215-20253, dated August 4, 2016.

The audit plan, dated July 14, 2016, can be found in ADAMS under Accession No. ML16195A178. The results of the audit, list of NRC staff attendees and reference documents are documented in Enclosure 1.

NRC staff conducted an audit exit brief with NuScale staff on August 19, 2016. During the exit brief, NRC staff stated that all of the audit objectives were addressed by observing the staffing plan validation and by having discussions with NuScale staff. The NRC staff also stated that observing the staffing plan validation allowed them to gain a better understanding of the novel aspects of the NuScale plant system, control room and Human System Interface design. The NRC staff shared the observation that the control room simulator and concept of operations had matured since the March/April 2016 audit. The NRC staff also stated that continued development of the alarm inventory and alarm prioritization strategy must occur to determine the impact of the alarm system on workload.

In summary, NRC staff determined the following:

- The staffing plan validation was conducted in accordance with the applicable NuScale procedures.

- The staffing plan validation included a wide range of challenging operational conditions to produce high workload scenarios for the operators, and the simulator ran all of the planned events in these scenarios.

Preliminary analysis of the test results demonstrated that the goals for workload, situation awareness, and timed operator actions were satisfied.

Project No.: PROJ0769

Enclosure:
As stated

cc: NuScale DC ListServ

6. “Concept of Automation,” Revision A, RP-1215-19690, dated February 1, 2016;

7. “Control Room Staffing Plan Validation Methodology,” Revision 2, RP-1215-20253, dated August 4, 2016.

The audit plan, dated July 14, 2016, can be found in ADAMS under Accession No. ML16195A178. The results of the audit, list of NRC staff attendees and reference documents are documented in Enclosure 1.

NRC staff conducted an audit exit brief with NuScale staff on August 19, 2016. During the exit brief, NRC staff stated that all of the audit objectives were addressed by observing the staffing plan validation and by having discussions with NuScale staff. The NRC staff also stated that observing the staffing plan validation allowed them to gain a better understanding of the novel aspects of the NuScale plant system, control room and Human System Interface design. The NRC staff shared the observation that the control room simulator and concept of operations had matured since the March/April 2016 audit. The NRC staff also stated that continued development of the alarm inventory and alarm prioritization strategy must occur to determine the impact of the alarm system on workload.

In summary, NRC staff determined the following:

- The staffing plan validation was conducted in accordance with the applicable NuScale procedures.

- The staffing plan validation included a wide range of challenging operational conditions to produce high workload scenarios for the operators, and the simulator ran all of the planned events in these scenarios.

Preliminary analysis of the test results demonstrated that the goals for workload, situation awareness, and timed operator actions were satisfied.

Project No.: PROJ0769

Enclosure:
As stated

DISTRIBUTION:

PUBLIC	GCranston, NRO	RidsAcrsAcnwMailCenter
LB1 R/F	RFoster, NRO	RidsOgcMailCenter
NuScale DC Listserv	MBrown, NRO	RidsNroDnrlLB1
SLee, NRO	FAkstulewicz, NRO	RidsOpaMailCenter
PPieringer, NRO	MScheetz, NRR	LKent, NRO
JDemarshall, NRO	DTaneja, NRO	ARivera-Varona, NRO

ADAMS Accession No: ML16259A110 *via email NRO-002

OFFICE	DNRL/LB1: PM	DNRL/LB1: LA	DCIP/HOIB: BC	DNRL/LB1: PM
NAME	RFoster*	MBrown*	ARivera-Varona*	GCranston*
DATE	11/16/2016	11/23/2016	11/30/2016	11/30/2016

OFFICIAL RECORD COPY

NUSCALE POWER, LLC

HUMAN FACTORS ENGINEERING

AUDIT SUMMARY REPORT

NRC Audit Team:

- Paul Pieringer, Sr. Human Factors Engineer, Audit Lead (NRO/DCIP/HOIB)
- Lauren Kent, Reactor Operations Engineer (NRO/DCIP/HOIB)
- Amy D'Agostino, Human Factors Analyst (RES/DRA/HFRB)
- Maurin Scheetz, Reactor Operations Engineer (NRR/DCIP/HOIB)
- Joe Demarshall, Reactor Operations Engineer (NRO/DCIP/HOIB)
- Dinesh Taneja, Sr. Electronics Engineer (NRO/DEIA/ICE)
- Rocky Foster, Project Manager (NRO/DNRL/LB1)

I. Purpose

Members of the U.S. Nuclear Regulatory Commission (NRC) staff conducted an audit beginning August 16, 2016, and ending August 19, 2016, at NuScale Power, LLC (NuScale) Headquarters located in Corvallis, Oregon. NuScale plans to submit a design certification application for its small modular reactor design. The design certification application (DCA) will describe the human factors engineering (HFE) design for the main control room, which includes control room staffing. The purpose of the audit was to observe the staffing plan validation to support the NRC staff's review of NuScale's proposed control room staffing level.

The NRC staff conducted the audit in accordance with the guidelines in Office of New Reactors (NRO) Office Instruction NRO-REG-108 (Revision 0), "Regulatory Audits."

II. Background and Audit Basis

As stated in NuScale's preliminary concept of operations summary (Agencywide Document Access and Management System (ADAMS) Accession No. ML15258A846), NuScale has assumed an initial control room staffing level of six licensed operators[1] for a plant consisting of up to 12 units. This staffing level does not comply with the requirements for minimum staffing in Section 50.54(m) of Title 10 of the *Code of Federal Regulations* (10 CFR). The NRC staff uses the guidance in NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," and NUREG/CR-6838, "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)," to determine whether staffing levels that do not comply with 10 CFR 50.54(m) provide adequate assurance that public health and safety will be maintained at a level that is commensurate to that afforded by compliance with 10 CFR 50.54(m). The method described in NUREG-1791 includes a staffing

---

[1] The term "operator(s)" is used to refer to personnel who participated in the staffing plan validation scenarios as one of the control room operators and to personnel who will be licensed to operate a NuScale plant.

plan validation, which is "an evaluation using performance-based tests to determine whether the staffing plan meets performance requirements and acceptably supports safe operation of the plant."

From March 29, 2016, to April 15, 2016, the NRC staff completed an audit of the process NuScale planned to use for the staffing plan validation. The audit results are documented in an audit report dated May 26, 2016 (ADAMS Accession No. ML16137A257). The May 26, 2016, audit report also identified topics for the NRC staff to consider during observation of the staffing plan validation. The NRC staff used these topics, in part, to develop objectives for this audit.

III. Audit Objectives

1. Verify the simulator configuration supports validation testing:

   - Review simulator testing results.

   - Review simulator deficiency list.

   Regulatory Reference: NUREG-1791, Part II, "Evaluation of Exemption Requests," Section 1.2, "Application Submittals," and NUREG-0711, "Human Factors Engineering Program Review Model," Section 11.4.3.3, "Validation Testbeds," Criteria 1-9.

2. Verify scenarios acceptably address high workload conditions.

   Regulatory Reference: NUREG-0711, Section 11.4.1.2, "Identification of Scenarios."

3. Verify the number of scenarios used sufficiently addresses workload scope.

   Regulatory Reference: NUREG-1791, Part II, Section 3.3.1, "Operational Conditions Sampling for an Advanced Reactor Design," and NUREG-0711, Section 11.4.1.1, "Sampling Dimensions."

4. Verify concept/conduct of operations is sufficiently defined. The NRC staff should understand the expected concept/conduct of operations prior to beginning validation observations.

   Regulatory Reference: NUREG-1791, Part II, Section 2.2, "Applicant Submittals," and Section 8.3, "Review Criteria."

5. Verify the concept/conduct of operations is consistently and appropriately exercised during the scenarios:

   - Communications.

   - Supervisory direction.

   - Teamwork.

Regulatory Reference: NUREG-1791, Part II, Section 2.2, and Section 8.3.

6. Observe the impact on human performance as a result of operators having the ability to control multiple modules from a single operating console. Specifically, observe how the Human-System Interface (HSI) design minimizes personnel errors and supports error detection and recovery capability:

    - Impact on workload of mouse-click vs touch screen to interface with the controls.

    Regulatory Reference: NUREG-1791, Part II, Section 2.2, and Section 8.3.

7. Verify the testing is conducted under appropriate controls (similar to the Integrated System Validation).

    Regulatory Reference: NUREG-1791, Part II, Section 10, "Review the Staffing Plan Validation."

8. Verify observers are used and are actively engaged in assessing the Control Room Design's capability to support operators in high work load conditions.

    Regulatory Reference: NUREG-0711, Section 11.4.3.6.3, "Training Test Personnel."

9. If possible, verify that problems identified are not inappropriately relegated to training or procedure improvements.

    Regulatory Reference: NUREG-0711, Section 11.4.4, "Human Engineering Discrepancy Resolution Review Criteria."

10. Verify that data collection tools (e.g., surveys) conform to guidance in NUREG-1791, and NUREG/CR-7190, "Workload, Situation Awareness, and Teamwork."

    Regulatory Reference: NUREG-1791, Part II, Section 10.

11. Observe the displays and control room layout in the simulator and compare to guidance in NUREG-0700, "Human-System Interface Design Review Guidelines," about font size, accessibility of displays, and spatially dedicated & continuously visible indications.

    Regulatory Reference: NUREG-0700, Various Sections.

12. Observe use of unique HSI design features (e.g., features associated with the alarm response system) and any impacts on human performance.

    Regulatory Reference: NUREG-0711, Section 8.4.4, "HSI Detailed Design and Integration," and NUREG-0700, Various Sections.

13. Determine the extent to which automation is used and observe impacts on human performance.

Regulatory Reference: NUREG-0711, Section 8.4.5, "Degraded I&C and HSI Conditions," and Section 4, "Functional Requirements Analysis and Functional Allocation."

14. Observe how the lead operator turns over responsibility for a module to other operators and determine whether he/she is "directing" the activities of the other operators, which requires a senior reactor operator license, or informing the other operators. If the latter, determine the role of the control room supervisor in this process.

    Regulatory Reference: 10 CFR 55.4, "Operator Licenses; Definitions."

15. Observe the extent and nature of the interconnection of the protection and control systems to assure that this interconnection supports or enhances plant operations as related to operator interface.

    Regulatory Reference: 10 CFR 50, Appendix A, General Design Criteria 24, "Domestic Licensing of Production and Utilization Facilities; General Design Criteria for Nuclear Power Plants; Separation of Protection and Control Systems."

IV. Audit Scope

The NRC staff observed three simulator scenarios that combined normal, abnormal, and emergency conditions to establish high workload conditions for the operators. During these scenarios, the NRC staff observed the simulator's performance, the operating crew's ability to manage the events in the scenarios, and the assessment process NuScale used to evaluate workload, situation awareness, and task performance. Additionally, the NRC staff observed the NuScale staff's implementation of its procedures for conducting the staffing plan validation.

Also, NRC staff held discussions with NuScale staff[2] about the staffing plan validation method and the scope of information to be included in the staffing and qualifications section of Chapter 18, "Human Factors Engineering," of the DCA.

The NRC staff reviewed the following proprietary documents during the audit at NuScale:

- RP-1215-20253, "Control Room Staffing Plan Workload Analysis," Revision 2, which contains the procedure (i.e., the method) for conducting the staffing plan validation.
- RP-0316-48456, "Control Room Staffing Plan Validation Scenario Descriptions," Revision 1, which describes and identifies the sequence of events in each of the three scenarios.

[2] The NuScale staff members who participated in substantive discussions include Timothy Tovar, Manager, Plant Operations; Shawn Jerrow, Supervisor, Plant Operations; Doug Bowman, Operations Engineer; Ross Snuggerud, Operations Engineer; Ryan Flamand, Operations Engineer; Jessica Stevens, Human Factors Engineer; and Kevin LaFerriere, Human Factors Engineer.

- RP-0215-10815, “Concept of Operations,” Revision 0, which describes how the design, systems, and operational characteristics of the NuScale plant relate to the organizational structure, staffing, and management framework.

- RP-1215-19690, “Concept of Automation,” Revision A, which describes the basis for the implementation of automation.

- RP-1215-19691, “Conduct of Operations,” Revision 0, which describes administrative controls applied by operators in the NuScale control room.

- ES-0304-1381, “NuScale Power Small Modular Reactor Human System Interface Style Guide,” Revision 0, which contains design-specific HFE guidelines and standards.

- OP-0504-50019, “Simulator Scenario Based Testing Procedure,” Revision 1, which describes a method for performing simulator testing.

V. Audit Activities and Observations

Objective 1: Verify the simulator configuration supports validation testing.

Simulator Testing Results

NuScale used a control room simulator to run the scenarios developed for the staffing plan validation. NUREG/CR-6838 states,

> *“Simulator studies may be used as data sources when a moderate to high fidelity simulator and human system interface (HSI) are available.”*

NUREG-1791 defines “simulator” as “a facility that physically represents the human-system interface configuration and that dynamically represents the operating characteristics and responses of the plant in real time.” NuScale developed OP-0504-50019, “Simulator Scenario Based Testing Procedure,” as a method for validating that the simulator physically represents the HSI configuration and dynamically represents the predicted[3] operating characteristics and responses of the plant during the scenarios (i.e., to demonstrate a sufficient level of simulator fidelity).

The NRC staff reviewed OP-0504-50019 and noted that the method of scenario-based testing (SBT) described in it is similar to the method described in NEI 09-09, “Nuclear Power Plant-Referenced Simulator Scenario Based Testing Methodology,” Rev 1. NEI 09-09 was endorsed by the NRC in Regulatory Guide 1.149, “Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations,” Revision 4, as a method to ensure a simulator is capable of producing the expected plant response during operator licensing examinations without significant simulator performance discrepancies or deviation from the approved scenario sequence.

[3] Because a NuScale plant has not yet been built, the simulator must be evaluated against predicted plant performance.

The OP-0504-50019 directs the completion of a results package, which contains documentation of successful SBT for each scenario. The NRC staff requested to review the results packages for the scenarios used for the staffing plan validation. NuScale staff stated that prior to the staffing plan validation, they had validated the simulator (1) adequately modeled the plant's expected response during the events included in the scenarios as they are described in the design documentation (e.g., draft Chapter 15 of the final safety analysis report) and (2) provided the expected alarms and indications directly related to each scenario. NuScale staff said documentation of successful SBT existed for each scenario and was stored electronically; however, it had not yet been assembled into a results package as described in OP-0504-50019. Therefore, NRC staff did not review documentation of simulator fidelity test results during this audit.

Simulator Deficiency List

The NRC staff observed the pre-job briefs the NuScale staff performed for the operators prior to each simulator scenario. During each brief, the NuScale staff listed the simulator deficiencies and informed the operators about what actions they should take if they observed any of the deficiencies during the scenario. NuScale stated that there were 22 items on the simulator deficiency list.

During the three simulator scenarios, the NRC staff observed two instances where simulator deficiencies were present. The deficiencies caused the simulator to provide some indications (e.g., alarms) to the operators that were not planned as part of the scenarios, and consequently, the operators took actions to respond to these indications as directed by procedures. The NRC staff observed that these simulator deficiencies did not (1) prevent the operators from taking any actions that were part of the scenarios or (2) result in the simulator freezing or being unable to simulate any of the events in the scenarios; however, the NRC staff observed one instance where a screen at an operator workstation froze unexpectedly and needed to be rebooted.

The NRC staff observed that the operators took actions to address the indications that resulted from these simulator deficiencies that were not planned as part of the scenarios. Taking these actions increased the number of tasks that the operators performed during the scenario. The NRC staff determined that the increased number of tasks that resulted from the simulator deficiencies served to make the scenario more challenging, which is conservative when assessing workload.

Additional Observations and Conclusions

Simulator configuration and scope of simulation:

The NRC staff observed that the control room simulator included sit-down operator workstations, 12 unit overview displays, the safety display and instrumentation (SDI) panels with indications for 12 modules, 12 dedicated stand-up unit workstations with Module Protection System (MPS) hardwired manual initiation pushbuttons, and a stand-up common systems panel. The NRC staff discussed the scope of simulation with NuScale staff. NuScale staff stated the scope of plant simulation was limited to the events that were included in the scenarios for the staffing plan validation. Therefore, the simulator did not model the following:

(1) The full inventory of the alarms and notifications that are expected to be part of the final HSI design.

The NRC staff reinforced that incomplete alarm inventory and alarm logic could impact the staffing validation scenarios in a non-conservative manner. Operating experience has demonstrated that digital technology enables additional alarm modelling. If the alarms are not tied to logic that causes them to initiate when relevant, significant operator workload can be created when the operator must make the determination of relevancy. NuScale stated that they are still working on alarm logic and will demonstrate that the final alarm system applies logic to limit the alarms to those needed for the conditions. Thus, NuScale expects the workload associated with alarm response, which will be evaluated during the integrated systems validation (ISV), will be comparable to that observed during the staffing validation scenarios.

(2) The full inventory or full capabilities of the computer-based procedure system.

As explained in the discussion of Objective 12 in this report, the computer-based procedure system design is useable, but it is not yet complete. Its current configuration increases work load, and this has a conservative impact on the staffing plan validation.

(3) The full inventory of information displays that will be part of the final HSI design (e.g., not all of the fire protection displays were modeled).

The navigation features of the NuScale control room provide direct display of information needed to address the staffing validation scenarios. The incomplete information display inventory does not affect work load measures. The complete display inventory is needed to support the ISV where a more diverse inventory of information displays will be needed to address a broader range of scenarios.

Simulator software:

The NRC staff and the NuScale staff discussed the types of software used in the NuScale simulator. For example, the NuScale staff described that the simulator uses a version of the same code used for analysis of plant transients and accidents to model the thermo-hydraulic aspects of the simulation. The NuScale staff stated that the NuScale staff responsible for developing the probabilistic risk analysis validated the analysis of the anticipated transient without scram (ATWS) event using the simulator. The NRC staff identified this as an example of how the simulator is being used during the design process. The NRC staff noted that using the simulator during the design process can help to ensure early identification and resolution of both simulator fidelity and plant design issues.

Simulator performance: The NRC staff observed the ability of the simulator to model the events described in RP-0316-48456, “Control Room Staffing Plan Validation Scenario Descriptions.” For each event in each scenario, RP-0316-48456 describes the expected simulated plant response and the actions the operators should take. The NRC staff observed that the simulator ran every event planned for each of the three scenarios, and the operators were able to use the indications provided by the HSI to diagnose the events in a timely manner and take corrective actions. For example, one event resulted in an increase in megawatts and reactor power for a unit. The HSI for the affected unit showed an increase in megawatts and reactor power. The

operators identified the change in these plant parameters for the affected unit within seconds of the HSI indicating the changes. During this event, the operators also used other indications provided by the HSI on the affected unit to confirm their diagnosis.

Additionally, during the March/April 2016 audit, the NRC staff noticed that the operator workstations did not consistently display indications of plant status, and the module overview screens did consistently display these indications. During this audit, the NRC staff observed the operator workstations as well as the module overview screens and SDI panels consistently indicated the plant status.

In summary, the NRC staff observed that the simulator modeled all of the planned events and the plant system responses to those events as defined in RP-0316-48456.

Objective 2: Verify scenarios acceptably address high workload conditions.

NUREG-0800, Chapter 18, draft Revision 3, Attachment B, "Methodology to Assess the Workload of Challenging Operational Conditions In Support of Minimum Staffing Level Reviews," provides a methodology to identify high-workload operational conditions and analyze the workload associated with them. It states,

> *"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 (SME) obtained in a manner conducive to obtaining realistic workload estimation."*

The NRC staff reviewed RP-0316-48456, "Control Room Staffing Plan Validation Scenario Descriptions," and observed that NuScale combined the following high-workload plant conditions and personnel tasks listed in NUREG-0800, Chapter 18, Attachment B in their sample of challenging operational conditions: transients and accidents, including design basis events (DBE), beyond DBEs, and external events; instrumentation and control (I&C) and HSI failures and degraded conditions; important human actions; tasks associated with monitoring automation; tasks associated with a range of human cognitive activities; and tasks associated with a range of human interactions. The NRC staff observed that these high-workload plant conditions and tasks were distributed among three scenarios, and the scenario events occurred both sequentially and concurrently.

The NRC staff also observed that the scenario descriptions identified primary tasks, dependent tasks, and independent tasks operators would have to perform during the sample of operational conditions. For example, the scenarios identified dependent administrative tasks, such as initiating technical specifications in response to a particular plant condition, and dependent communication tasks, such as conducting crew briefings and communicating with auxiliary operators. Additionally, the NRC staff observed a scenario that created an error-forcing context and fatigue situation by requiring the operators perform a set of repetitive tasks (i.e., post trip actions) following a trip of all 12 units.

In summary, the NRC staff observed the scenario descriptions were detailed and comprehensive, and the scenarios sampled a substantial number and wide range of the high-

workload conditions listed in NUREG-0800, Chapter 18, Attachment B. Thus, the NRC staff determined that the scenarios included a sufficient sample of high workload conditions.

Objective 3: Verify the number of scenarios used sufficiently addresses workload scope.

The staffing plan validation used three scenarios, which each lasted 2 - 3 hours. The NRC staff observed during the staffing plan validation that the scenarios did not deviate from the scenario descriptions contained in RP-0316-48456, "Control Room Staffing Plan Validation Scenario Descriptions." As discussed for Objective 2, the scenario descriptions included a sample of challenging operational conditions and identified relevant primary, dependent, and independent tasks associated with managing those conditions.

Thus, the staff verified that three scenarios were sufficient to sample challenging operational conditions that produce high workload.

Objective 4: Verify concept/conduct of operations is sufficiently defined.

At operating reactors[4], the "conduct of operations" generally refers to a set of administratively-controlled guidelines for plant personnel to use during the performance of their assigned tasks. These guidelines are typically contained in a licensee-controlled document. Industry-endorsed human performance tools, such as place-keeping procedures and three-way communication, are guidelines typically included in a conduct of operations document.

"Concept of operations" is described in NUREG-1791, Section 2.1, "Discussion," which states, "At the most general level, the term, *concept of operations* refers to a description of how the design, systems, and operational characteristics of a plant, such as an advanced reactor, relate to a licensee's or applicant's organizational structure, staffing, and management framework." Specifically, a concept of operations includes the roles and responsibilities of each individual operator; the overall operating environment and primary HSIs; and the interactions of operators with each other, with automated systems, and with other personnel who are not directly responsible for the control and safe operation of the plant.

During the March/April 2016 audit, the NRC staff noted that the concept and conduct of operations were still being finalized. For example, NRC staff found that the set of tasks that Unit Supervisor 1 (US1) was allowed to perform had not yet been fully defined. During this audit, the NRC staff reviewed RP-1215-19691, "Conduct of Operations;" RP-0215-10815, "Concept of Operations;" and RP-1215-19690, "Concept of Automation." The NRC staff observed that the set of tasks US1 may perform was more clearly defined in the Conduct of Operations. Furthermore, the NRC staff observed that performing the limited set of tasks did not challenge US1's ability to monitor plant status effectively.

Also, the NRC staff observed that NuScale adopted applicable elements from the concept and conduct of operations developed by operating plants and added elements to address design-specific aspects of operating a NuScale plant. Therefore, NRC staff concluded that the concept of operations and conduct of operations were sufficiently defined for the staffing plan validation.

---

[4] The term "operating reactors" is used to reference domestic reactors that are currently licensed and operating in the United States.

Objective 5: Verify the concept/conduct of operations is consistently and appropriately exercised during the scenarios: communication, supervisory direction, teamwork.

The NRC staff observed that the operators were familiar with and applied the guidelines in RP-1215-19691, "Conduct of Operations," and RP-0215-10815, "Concept of Operations," while performing their tasks during the scenarios. For example, the NRC staff observed that the operators used three-way communication, which is part of the Conduct of Operations. The NRC staff observed that peer checks seemed to be over-used and contributed to higher workload. The control room operators appeared to be using these error-prevention tools as they had learned them on previous designs and were not yet fully proficient in applying the NuScale conduct of operation for these tools (e.g., the Conduct of Operations specifies times when peer checking is required, and the NRC staff observed the operators used peer checking when it was not required). In any case, a higher workload was conservative to the objectives of the staffing plan validation, and the practices being used did not challenge the operators' abilities to fulfill their responsibilities. It did illustrate that the proposed staffing levels have margins with respect to operator workload that allow for less experienced operators.

Implementation of crew communication and supervisory direction is addressed under the discussion of Objective 14 below.

NUREG-1791, identifies the significant elements of the concept of operations that define the relationship between the staffing, the plant design, and the control room design. A sufficiently defined concept of operations is an input to determining the operators' roles and responsibilities, including how and when the operators interact with the HSI. For example, RP-1215-19691, "Conduct of Operations," Section 2.2.4, "Unit Supervisor 1"; Section 2.2.5, "Unit Supervisor 2"; and Section 2.2.6, "Unit Supervisor 3"; describes design-specific guidelines for how the monitoring and control responsibilities for the 12 units are assigned to Unit Supervisor 1(US1), Unit Supervisor 2 (US2), and Unit Supervisor 3 (US3). During the scenarios, the NRC staff observed that when the operators applied these guidelines, the operating crew maintained awareness of the status of each of the 12 units, which the NRC staff noted directly contributed to successful task performance during the scenarios. As such, the NRC staff determined that these guidelines are an important aspect of the concept of operations for a NuScale plant because it is a fundamental operating philosophy that supports the ability of the crew to successfully operate the plant during challenging, high-workload conditions.

The NRC staff noted that the second paragraph of RP-1215-19691, Section 2.2.4, "Unit Supervisor 1," contains a statement that is not consistent with the NRC staff's observations of US1 during the scenarios. The NRC staff observed US1 monitoring all 12 units during the scenarios, not just those in steady state. Additionally, the NRC staff observed the control room supervisor (CRS) reinforce the expectation that US1 monitor all operating units continually. During the scenarios, the NRC staff observed that US2 and US3 performed time-intensive, unit-specific tasks. These activities reduced their ability to maintain situation awareness of the other units and evolving conditions on the unit they are actively manipulating. Having US1 perform continuous monitoring of all 12 units at all times helps to ensure that the crew maintains situation awareness of each unit continually. The NRC staff observed this behavior directly contributed to ability of the crew to successfully diagnose abnormal conditions on the units and take prompt action to perform procedure-guided tasks in response to the abnormal condition.

To summarize, the NRC staff observed the operators perform the behaviors, roles and responsibilities as described in the conduct and concept of operations consistently during the staffing plan validation. The concept and conduct of operations impose operator workload (e.g. by requiring three-way communication and peer checks) as well as manage interfaces between operators and HSIs. Both attributes were observed to be sufficiently integrated into the scenarios and supported safe operation by the staffing level being validated.

Objective 6: Observe the impact on human performance as a result of operators having the ability to control multiple modules from a single operating console. Specifically, observe how the HSI design minimizes personnel errors and supports error detection and recovery capability.

<u>Impact on workload of mouse-click vs touch screen to interface with the controls</u>

The screens at the sit-down operator workstations are capable of responding to both mouse and touch control, but during the staffing plan validation, the operators only used mouse control. The NuScale staff stated that the operators may also use the touch screen capability during the ISV. The NRC staff noted that there may be a difference in workload reported by the operators during the ISV as compared to that measured during the staffing plan validation if both options or if only touch screens are available.

<u>Additional Observations</u>

During the scenarios, there were units that were in the same operating mode and condition. The NRC staff observed that when plant status changed for one or more of these units, the change in indications on the unit overview displays was readily noticeable from the sit-down operator workstations because of the difference between the indications for the different, affected module(s) and the similar, non-affected modules. For example, in one scenario, all 12 modules were operating normally at 100% power. The NRC staff observed that at the start of one of the scenario events, the HSI on a unit overview display indicated a change in a plant parameter for one of the 12 modules, and it was easy to recognize because the difference in indication(s) on the unit overview display stood out from the others. The indications on the unit overview displays for the similar, non-affected modules provided a point of reference to compare indications on the unit overview display(s) for the different, affected units(s).

The NRC staff observed that under certain circumstances, US2 and US3 transitioned from the sit-down operator workstations to the dedicated stand-up unit workstations to perform control actions on individual units. The HSI at the dedicated stand-up unit workstations includes the unit number for its associated unit so that operators can confirm the unit they are about to operate is the unit they intend to operate.

During the scenarios, there were times when US2 and US3 were each responsible for performing tasks on more than one unit. The NRC staff observed features of the HSI that helped to inform the control room operating crew which operator had control of a particular unit at any given time. The NRC staff noted that the design feature was limited to the individual units and was not included on the stand-up common systems panel.

The NuScale control room HSI includes a unique, proprietary feature that is designed to provide operators with prompt indication of changes in key plant parameters for each unit. During the scenarios, the NRC staff observed that this HSI feature often provided the first indication to the

operators of an abnormal condition for a unit. However, NRC staff observed that the colors and shapes used on this HSI feature made trends somewhat difficult to interpret.

The NRC staff observed that there are large time margins associated with any operator actions that will be performed at a NuScale plant. There are no time-critical operator actions that have been identified by deterministic methods at this point in time, and protective actions that are required to mitigate the consequences of design basis accidents are performed automatically by the MPS. Therefore, the operators at a NuScale plant have significantly more time to assess plant conditions, make a diagnosis, and take any actions directed by plant procedures as compared to operators at operating reactors. The NRC staff noted that this may help to reduce perceived time pressure and stress by the operators during plant transients, which can help to reduce human performance errors.

The NRC staff observed the operators' interaction with the automated HSI features during the scenarios. Under certain circumstances, the HSI prompts the operator to permit the control system to perform a routine task. The operator verifies that the prompt is valid and then permits the control system to perform the task. The operator can then monitor the control system's performance of the task. In the staffing plan validation scenarios, the NRC staff observed that increased automation was a significant factor that enabled the operating crew to monitor and control multiple modules simultaneously. As a result of automating more tasks, the workload in the NuScale control room was mostly cognitive. When physical action was needed, the NRC staff observed the operators were able to perform actions within the time limits identified in the scenario descriptions

Additionally, the NRC staff observed the operators exhibiting the following behaviors that provided defense-in-depth for maintaining situation awareness of multiple modules simultaneously:

- The US1 primarily monitored indications for all units even when US2 or US3 were assigned to control one or more units. Although he occasionally performed a limited number of tasks that diverted attention from monitoring and observing indications for all units, these tasks took less than a few minutes to perform.

- The US2 and US3 monitored a unit when they were assigned to control it. When they were not assigned to control a particular unit, they generally monitored and observed indications for all 12 units.

- The shift technical advisor (STA) performed dedicated monitoring of safety function status at periodic time intervals for units that had tripped.

- Multiple features of the control room HSI, such as the trend indications on the unit overview displays and the alarm system, alerted operators to changes in plant status requiring attention. The operators responded to the changes in indications and the alarms that the control room HSI provided.

- The large time margins that result from a simpler, passive design reduce the need for relatively rapid operator actions and also reduce the total number of operator actions that must be performed to operate the plant safely compared to an operating reactor.

As a result, the operators had a relatively large amount of time to evaluate conditions and perform actions in accordance with plant procedures. Additionally, the NRC staff observed that this helps to aid in recovery of operator errors. For example, during an ATWS event in one scenario, the operating crew did not take action to manually trip the unit after the MPS failed to automatically trip the unit. The Concept of Operations states that operators should perform manual actions when automatic actions fail to occur. Several minutes passed before an operator manually tripped the affected unit. During this time, the NRC staff did not observe any indications of adverse consequences; in fact, reactor power lowered significantly and remained stable at a new, lower power level. The NRC staff noted that the behavior of a NuScale unit following an ATWS is significantly different from an operating reactor, where adverse consequences are likely to occur following a failure to manually trip a unit promptly after an ATWS.

Objective 7: Verify the testing is conducted under appropriate controls (similar to the Integrated System Validation).

RP-1215-20253, "Control Room Staffing Plan Workload Analysis," Appendix A, "Scenario Testing Plan," contains the procedure the NuScale staff developed for conducting the staffing plan validation. The NRC staff reviewed Appendix A and observed that it contained methods for training the operators prior to the testing, establishing the initial conditions, collecting data during and after testing, and conducting the scenarios. The NRC staff observed that the NuScale staff conducted the staffing plan validation in accordance with the method described in its test plan in Appendix A. Specifically, the NRC staff confirmed the following items through direct observation and/or through discussions with the NuScale staff:

- Each of the three scenarios were conducted twice with two different operating crews.

- The NuScale staff provided documentation to demonstrate that the operators had received the training specified by Appendix A prior to the staffing plan validation. The NRC staff reviewed the syllabus for the operator training and observed that the operators received classroom training on the NuScale plant systems and simulator training to practice using the HSI and responding to the kinds of events they could expect to see in the staffing plan validation. This included two pilot scenarios. The NRC staff found that the training scenarios and pilot scenarios did not include the events in the same sequence as the staffing plan validations scenarios. The NRC staff determined that the scenarios for the staffing plan validation were sufficiently different from the pilot scenarios. Additionally, the NRC staff found that the operators received a relatively small amount of training (i.e., several weeks of training) on plant systems and use of the control room HSI as compared to the training initial license operator candidates would receive at an operating reactor. Nonetheless, the NRC staff observed the operators were able to correctly diagnose the plant events during the scenarios and use the HSI effectively to perform their tasks. The NRC staff also noted that a minimal amount of training could result in increased cognitive difficulty during the scenarios, would could increase workload. This is conservative for a test that attempts to create high workload conditions. Thus, the NRC staff determined the operators received a sufficient amount of training to be able to participate effectively in the staffing plan validation.

- The NRC staff observed the NuScale staff maintaining physical control of the scenario documentation to prevent the operators from viewing it and learning the scenario events before the scenarios commenced.

- The NRC staff noted that the thresholds the NuScale staff established for determining whether a scenario event produced high workload were conservative.

- The NRC staff observed the operators' post-scenario debriefs. The NRC staff noted that the operators were highly engaged in the discussions. For example, each of the operators provided feedback and candid opinions about their perceived level of workload, how to improve the HSI, and how they could have improved their own performance during the scenario.

- The NuScale staff followed its testing plan and scenario guidance for interacting with participants during the scenarios.

- NuScale used video and sound recording to support analysis of the scenarios.

- During the pre-job briefs for the NuScale staff conducted prior to the start of each scenario, the NuScale staff confirmed that the testing prerequisites were satisfied. They also reviewed the scenario events and discussed when the workload and situational awareness assessments would be performed during the scenarios.

In summary, the NRC staff observed the NuScale staff exercised appropriate test controls during performance of the staffing plan validation.

Objective 8: Verify observers are used and are actively engaged in assessing the control room design's capability to support operators in high work load conditions.

There were two HFE observers and two operations observers for each scenario in addition to a management observer. The simulator supervisor was also present in the simulator booth during the scenarios. The NRC staff observed that the observers took detailed notes during the scenarios. The NRC staff observed the observers' debriefs following the scenarios, which included discussions about workload, operator performance, and ways to improve the HSI. Thus, the NRC staff verified the observers were actively engaged.

Objective 9: If possible, verify that problems identified are not inappropriately relegated to training or procedure improvements.

During the observers' debriefs, the NuScale staff discussed the following issues and their possible causes and areas for improvement.

- During one scenario, US2 did not immediately initiate a reactor trip following an ATWS on a unit. During the operators' debrief, US2 indicated that he wasn't certain as to whether he should perform the action or US1 should perform the action to trip the reactor. The Conduct of Operations defines the roles and responsibilities for US1 and US2, and the observers appropriately determined that it would be necessary to evaluate whether the guidance in the Conduct of Operations should be clarified.

- The operators identified that there were some aspects of the existing computer-based procedure (CBP) system design that made it cumbersome to use. The observers appropriately assigned this as an area where the HSI design should be improved.

The NRC staff did not review NuScale's documentation of any issues identified during the staffing plan validation as part of the audit; however, the NRC staff did find that the observers discussed appropriate solutions for identified issues during their debriefs.

Objective 10: Verify that data collection tools (e.g., surveys) conform to guidance in NUREG-1791 and NUREG/CR-7190, "Workload, Situation Awareness, and Teamwork."

NuScale used multiple types of data collection tools to measure human performance, workload and situation awareness (SA) during the staffing validation testing. The NRC staff observed the NuScale staff use the following data collection tools:

- Audio/video logs
    - Used to assess timing, accuracy, and completeness of operator actions.
- Expert Observers
    - Used to assess timing, accuracy, and completeness of operator actions.
- Simulator logs
    - Used to assess timing, accuracy, and completeness of operator actions.
- Self-report evaluation
    - National Aeronautics and Space Administration Task Load Index (NASA-TLX) used to assess workload.
    - SA questionnaire administered via real-time probe (i.e., at predetermined times during the scenarios) to collect self-report information about the scenario events from memory (i.e., an explicit SA metric).
    - Post-scenario critiques.
- Stopwatch
    - Used to assess timing of operator actions.

NUREG/CR-7190 identifies acceptable methods for measuring workload and SA, including NASA-TLX and explicit SA methods administered via real-time probe. Thus, the NRC staff confirmed that the data collection tools conformed to guidance in NUREG/CR-7190 and NUREG-1791.

NuScale staff also presented preliminary results from each scenario for total crew workload, individual operator workload and SA to the NRC staff. Self-assessment of workload was found, generally, to be below 50 on a 100 point scale indicating the operators perceived the workload to be low. In addition, SA was found to range from approximately 88 to 100 percent depending

on the scenario and the individual operator. These preliminary results indicate the operators had a high level of situational awareness.

The NRC staff noted that the strength of the data collection approach was that the measurement tools used were many and varied. Measuring the same construct (e.g., workload) via multiple methods allows for a more holistic analysis and provides confidence that the entire "picture" will be captured with regard to the adequacy of the level of staffing.

Objective 11: Observe the displays and control room layout in the simulator and compare to guidance in NUREG-0700, "Human-System Interface Design Review Guidelines," about font size; accessibility of displays; and spatially dedicated, continuously visible indications.

The NRC staff made the following observations about how the control room and HSI design conformed to the HFE design guidelines in NuScale's Style Guide, which uses NUREG-0700 as a basis:

- Screen navigation is simple, and information is retrievable.
- The HSI displays the safety function status in a location that is readily viewable and using a method of indication that is unambiguous.
- Symbols and titles are used consistently on HSI displays.
- Computerized alarm response procedures (ARP) are displayed for use when the operator selects (i.e., clicks) the alarm line item on one of multiple workstation screen displays.
- A dedicated phone was not available for the STA at the STA's desk. The STA shared a phone with the CRS, which eliminated the ability for the CRS and the STA to use the phone at the same time.
- The NRC staff observed that the operators were able to navigate from one display screen to another with minimal mouse clicks.
- The font size on the display screens at the sit-down operator workstations appeared to be smaller than the font sizes recommended in NUREG-0700, and it was somewhat difficult to read even when sitting at the sit-down operator workstations. The NRC staff observed some operators leaning over to read some of the information displays while seated at their workstations.
- The table height for the stand-up common systems panel is too low; the NRC staff observed operators bending excessively while working with this panel.
- Trend indication on the central panel creates a potentially confusing pattern when multiple parameters are displayed. Aligning arrows with parameter titles listed on the bottom of the screen is made more difficult by the current design. However, the NRC

staff noted two instances where the operating crew used the trend indication to quickly diagnose a plant status change. The staff concluded the trend indication provided a valuable trending tool but could be made more user friendly with a revised HFE design.

Objective 12: Observe use of unique HSI design features and any impacts on human performance.

The NRC staff identified the following unique HSI design features and related operator responsibilities for interfacing with the design:

- Because the plant design is simpler compared to operating reactors, the amount of information operators need to safely monitor and control 12 NuScale units is considerably less than what would typically be required for an operating reactor. As a result, the amount of indications and controls displayed to the operators for each NuScale unit is less than what operators need at an operating reactor. The NRC staff observed that the displays for each unit contained information that was easy to locate and presented logically.

- Dedicated stand-up unit workstations are provided for 12 units. Each standup workstation provides the full set of controls and indications for it respective unit as the sit down stations. There is also a stand-up common systems panel that can be used for operating common systems and shows trends and indications for key parameters associated with common plant systems. In addition, there are three sit-down operator workstations that each have the capability of controlling any of the 12 units. The STA and CRS also have their own operator workstations that have the same capability as the sit-down operator workstations. The NRC staff observed the operators moving between the sit-down operator workstations and the dedicated stand-up unit workstations with ease.

- The unit overview displays located above each dedicated stand-up unit workstation display key indications to the operators about the status of each unit. Having three sit-down operator workstations positioned evenly between the 12 dedicated stand-up unit workstations ensures that US1, US2, and US3 each have at least 6-8 of the unit overview displays within the recommended viewing angle of 95 degrees on either side of straight ahead line of sight. The CRS' operator workstation is placed behind the three sit-down operator workstations, and all 12 unit overview displays are within the 95 degree guidance.

  The NRC staff noted that when US2 and US3 were operating at any of the dedicated stand-up unit workstations, the unit overview displays were beyond the recommended viewing angle for US1. The NRC staff did not observe any impacts on human performance.

- The NuScale HSI utilizes a specific geometrical shape with a numerical identifier to provide indication of an operator who has active control of a unit. The NRC staff observed the operators used this tool to track the responsibilities and workload assigned to each operator so that when new tasks needed to be assigned, the tasks could be assigned to the operator who could most readily manage the additional workload. This

indication also helps the operators to maintain SA of the unit(s) they are assigned to at any given time.

- In a number of cases, the NRC staff observed that US1 was able to identify adverse trends and conditions using the unit overview displays prior to receiving alarms for those conditions.

- The NRC staff observed the operators' interactions with the CBP system. The NRC staff observed that the CBPs have not been dynamically integrated into the HSI. Specifically, the operators had to manually perform some place-keeping using the mouse pointers, and, at times, it was necessary for the operators to scroll up and down to steps applicable to their unit in the procedures before performing actions. The NuScale staff stated that it intends to improve the CBP system prior to the ISV.

Objective 13: Determine the extent to which automation is used and observe impacts on human performance.

The NRC staff observed the operators' interaction with the automated HSI features during the scenarios. Under certain circumstances, the HSI prompted the operator to permit the plant control system to perform a routine task. For example, the NRC staff observed the plant control system automatically requested to perform routine dilutions. US1 received the request and "peer checked," or validated, the dilution request was appropriate. US1 also informed the CRS that he had received the request, and the CRS also confirmed the validity of the request. Once US1 and the CRS determined that performing a dilution was an appropriate action, US1 allowed the plant control system to automatically perform the dilution. The time between receiving the request and initiating the dilution took approximately 1-3 minutes, which is a relatively short period of time when compared to an operating reactor.

In the staffing plan validation scenarios, the staff observed automation to be a significant factor in enabling the independent operation of multiple units. The operator workload is largely cognitive in that he/she is maintaining situational awareness of the status of each unit and validating automation requests. Where physical action is needed, there were no restrictive time limits. For the scenarios observed the margins associated with controlling the plant safety functions (e.g. reactivity, heat removal) were sufficient that operator errors, inexperience, complicating factors, communications, and administrative responsibilities could be addressed as needed without exacerbating the conditions on the units not being directly attended.

The NRC staff noted that automating certain routine plant evolutions changes the role of the operator from performing an action to overseeing or monitoring the performance of an action by the control system. This results in the operator at a NuScale plant having to perform fewer total tasks to complete a plant evolution as compared to an operating reactor.

Additionally, safety-related protective actions occur automatically when plant parameters reach a threshold value, which is comparable to operating reactors.

Objective 14: Observe how the lead operator turns over responsibility for a module to other operators and determine whether he/she is "directing" the activities of the other operators, which

requires a senior reactor operator license, or informing the other operators. If the latter, determine the role of the control room supervisor in this process.

During the March/April 2016 audit, the NRC staff questioned whether US1 operator responsibilities included directing the activities of other licensed operators, which requires a senior operator license rather than the operator license assumed in the current staffing configuration. Of particular concern to the NRC staff were the decisions being made about which work responsibilities were transferred to US2 and US3.

During this audit the NRC staff observed that the CRS, which is a control room staff position that requires a senior operator license, was clearly coordinating control room activities, providing oversight, and making command and control decisions. The US1 position implemented responsibilities that generally aligned with those stated in the Concept of Operations. For example, US1's primary responsibility was to monitor all 12 modules, and the Concept of Operations lists a specific, limited set of tasks US1 may perform that do not significantly challenge the ability to monitor the units. The NRC staff observed that US1 would turn over control actions that would challenge his ability to monitor all units to US2 and US3 through the CRS: US1 informed the crew or just the CRS of the action that needed to be performed, and then the CRS would direct US2 or US3 to perform the action. This interaction was conducted using formal communications, and the HSI changed to indicate which operator was responsible for controlling the unit(s). These actions provided for status controls that were easily and continuously visible to the entire control room operating crew.

Overall, the NRC staff observed that US1 performed duties commensurate with the (reactor) operator license level, which included monitoring, informing the other crew members when abnormal conditions existed, and acknowledging alarms. The NRC staff observed that the CRS assigned control of units to operators when it was required and directed all of their activities. The NRC staff observed that the role of the CRS is the same as it is in operating reactors.

Objective 15: Observe the extent and nature of the interconnection of the protection and control systems to assure that this interconnection supports or enhances plant operations as related to operator interface.

During the scenarios, the NRC staff observed the operators using hardwired, manual initiation pushbuttons at the dedicated stand-up unit workstations to manually initiate system-level protective actions (i.e., engineered safety features actuation signals and reactor trip signals). The NRC staff inquired about the use of these switches and whether safety-related equipment could be operated from the operator workstations. NuScale staff presented an overview of the I&C system to address these questions.

During the presentation, NuScale staff described that operators can manually actuate system-level protective actions only by using the hardwired controls at the dedicated stand-up unit workstations. When directed by procedure(s), the operators may control safety-related components via the nonsafety-related Module Control System (MCS) using the soft controls at the operator workstations only if (1) the conditions that resulted actuation of a protective action no longer exist and (2) the operator has changed the position of the hardwired enable nonsafety control switches that allow the MCS and MPS to communicate.

Operators will need to operate safety-related components during performance of periodic

surveillances or as part of the process of restoring normal operations following actuation of a protective action. Plant procedures govern the performance of these activities. The enable nonsafety control switches allow for this via the nonsafety-related MCS and the soft controls at the operator workstations. Alternatively, the design could have included hardwired, safety-related controls (e.g., switches) for each safety-related component for all 12 units. Such a design would require the operators to use a HSI that is different from the HSI at the operator workstations, which is what they normally use, to operate safety-related components. If these activities are performed infrequently, then it is possible that operators may be less familiar with use of the separate HSI, which may potentially introduce the opportunity for human performance errors.

VI. Conclusion

NRC staff conducted an audit exit brief with NuScale staff on August 19, 2016. During the exit brief, NRC staff stated they were able to address all of the audit objectives by observing the staffing plan validation and by having discussions with NuScale staff. The NRC staff also stated that observing the staffing plan validation allowed them to gain a better understanding of the novel aspects of the NuScale plant system, control room and HSI design. The NRC staff shared the observation that the control room simulator and concept of operations had matured since the March/April 2016 audit. The NRC staff also stated that continued development of the alarm inventory and alarm prioritization strategy must occur to determine the impact of the alarm system on workload.

In summary, NRC staff determined the following:

- The staffing plan validation was conducted in accordance with the applicable NuScale procedures.

- The staffing plan validation included a wide range of challenging operational conditions to produce high workload scenarios for the operators, and the simulator ran all of the planned events in these scenarios.

- Preliminary analysis of the test results demonstrated that the goals for workload, situation awareness, and timed operator actions were satisfied.

VII. References

1. NRO Office Instruction NRO-REG-108, “Regulatory Audits,” Revision 0, April 2009.

2. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Chapter 18, “Human Factors Engineering,” Draft Revision 3, July 2015.

3. NUREG-0711, “Human Factors Engineering Program Review Model,” Revision 3, November 2012.

4. NUREG-1791, “Guidance for Assessing Exemption Requests from the Nuclear Power

Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m),” July 2005.

5. NUREG/CR-6838, “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),” February 2004.

6. NUREG/CR-7190, “Workload, Situation Awareness, and Teamwork,” March 2015.