November 19, 2015 Docket: PROJ0769

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of "Human Factors Engineering Verification and Validation implementation Plan," Revision 0 (NRC Project No. 0769)

REFERENCES:

1. NuScale Power, LLC Submittal of Human Factors Engineering (HFE) Implementation Plans (NRC Project No. 0769, dated May 6, 2015 (ML15139A214)

2. NuScale Power, LLC Submittal of a Second Set of Human Factors Engineering (HFE) Implementation Plans (NRC Project No. 0769), dated August 6, 2015 (ML15223A042)

3. NuScale Power, LLC Submittal of "Human Factors Engineering Program Management Plan" (NRC Project No. 0769), dated October 5, 2015 (ML15279A168)

NuScale Power, LLC (NuScale) hereby submits Revision 0 of the "Human Factors Engineering Verification and Validation implementation Plan" (RP-0914-8543). This submittal represents the fourth and final set of human factors engineering (HFE) implementation plans and program management plan submitted by NuScale. An initial set of implementation plans was submitted by letter dated May 6, 2015 (Reference 1), and a second set of implementation plans was submitted by letter dated August 6, 2015 (Reference 2). The HFE program management plan was submitted by letter dated October 5, 2015 (Reference 3).

Consistent with recent discussions with the NRC staff regarding pre-application engagement, NuScale requests that the NRC review the enclosed HFE Verification and Validation Implementation Plan within 60 days and provide comments to NuScale.

Enclosure 1 is the nonproprietary version of the implementation plan entitled "Human Factors Engineering Verification and Validation implementation Plan." Enclosure 2 is the proprietary version. NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 3) supports this request. This correspondence includes preliminary and/or conceptual information which reflects the current stage of the NuScale design and may be subject to change."

Please feel free to contact Steven Mirsky at 301-770-0472 or at smirsky@nuscalepower.com if you have any questions.

Sincerely,

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Enclosure 1: "Human Factors Engineering Verification and Validation implementation Plan," RP-0914-8543-NP, Revision 0, nonproprietary version
Enclosure 2: "Human Factors Engineering Verification and Validation implementation Plan," RP-0914-8543-P, Revision 0, proprietary version
Enclosure 3: Affidavit, AF-1115-19226

Enclosure 1:

"Human Factors Engineering Verification and Validation Implementation Plan," RP-0914-8543-NP, Revision 0, nonproprietary version

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Human Factors Engineering Verification and Validation Implementation Plan

November 2015

Revision 0

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NuScale Nonproprietary

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Department of Energy Acknowledgement and Disclaimer

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1.0 Introduction

1.1 Purpose

This document provides the human factors verification and validation (V&V) implementation plan (IP) for the NuScale plant human-system interface (HSI) design including hardware, software, procedures, and training of personnel who operate the HSI. The purpose of human factors V&V is to confirm that the NuScale plant HSI design conforms to human factors design principles and adequately supports plant personnel in the safe and efficient operation of the plant.

Human factors V&V program confirms that the integrated HSI design

- conforms to the specified design
- conforms to appropriate design criteria
- performs within acceptable limits under analyzed operating modes and conditions
- provides the complete set of alarms, controls, indications, and procedures needed to support the personnel tasks as identified in the task analysis (TA)

1.2 Scope

This IP describes the methodology for conducting the four major activities of the human factors V&V element (sampling of operational conditions, design verification, integrated system validation (ISV), and human engineering discrepancy (HED) resolution), including

- identification of sampling dimensions and scenarios used for validation of the integrated HSI
- HSI inventory and characterization
- the criteria used for task support verification and human factors engineering (HFE) design verification
- determination of staffing for and training of the validation team
- determination of validation test objectives
- use of the simulator for validation
- selection and training of personnel used as test crews
- scenario selection and definition for the validation
- performance measures to be used in the validation
- design of testing
- data analysis methods applied to validation data
- detailed example scenarios for integrated system validation (ISV)
- guidance for initiation and evaluation of HEDs to human factors V&V

The human factors V&V scope includes the alarms, controls, indications, and procedures for the HFE program scope described in the Human Factors Engineering Program Management Plan (Reference 8.2.1). Sampling dimensions with regard to locations, HSIs, conditions, types of tasks, and situational factors are further detailed in Section 2.1.

1.3 Abbreviations and Definitions

Table 1-1 Abbreviations

Abbreviation	Definition
CBP	computer-based procedure
DI	design implementation
DV	design verification
HA	human action
HED	human engineering discrepancy
HFE	human factors engineering
HFEITS	human factors engineering issue tracking system
HSI	human-system interface
I&C	instrumentation & control
IHA	important human action
IP	implementation plan
ISV	integrated system validation
MCR	main control room
NRC	Nuclear Regulatory Commission
NUREG	NRC technical report designation (Nuclear Regulatory Commission)
OER	operating experience review
PRA	probabilistic risk assessment
RSF	remote shutdown facility
RSR	results summary report
SA	situation awareness
SME	subject matter expert
SOC	sampling of operational conditions
TA	task analysis
V&V	verification & validation
VDU	visual display unit

2.0 Sampling of Operational Conditions

The purpose of sampling of operational conditions (SOC) is to identify a broad and representative range of operating conditions to be sampled during the task support verification (see Section 3.2), HFE design verification (DV) (see Section 3.0), and ISV (see Section 4.0). The sample is deemed representative if the sample's safety significance, risk significance, and challenges to the operating crew are considered to be within the range of events that the operators could encounter during the plant's life cycle.
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2.1 Sampling Dimensions

A full range of plant conditions, personnel tasks, and situations is considered within the sampling dimensions, including

- conditions
  - normal operating conditions including startup, shutdown, refueling, low-power operation, and significant power changes
  - instrumentation and controls (I&C) and HSI failures and degraded conditions such as
    - single instrument and mechanical component failures (e.g., hardware, transmitters, actuators, pumps, valves, generators)
    - common-mode failures coincident with unrelated accidents and software design defects that initiate transients
    - multiple plant component failures (e.g., station blackout)
    - loss of all nonsafety HSI
    - loss of processing and/or display capabilities for alarms
    - loss of automation
  - transients and accidents, such as
    - abnormal/emergency/transient conditions (e.g., turbine trip, loss of off-site power, station blackout, loss of power to selected buses or main control room (MCR) power supplies, and safety and relief valve transients)
    - accidents (e.g., main-steam-line break, positive reactivity addition, control rod insertion at power, and various-sized loss-of coolant accidents)
    - reactor shutdown and cool down using the remote shutdown facility (RSF)
    - reasonable, risk-significant, beyond-design-basis events that should be determined from the plant-specific probabilistic risk assessment (PRA)
- personnel tasks

- important human actions (IHA) and factors that contribute highly to risk (see Reference 8.2.4):
- protective function initiation by manual means – either planned or as backup to automation
- monitoring of automation sequences
- tasks identified during operating experience review (OER) (Reference 8.2.2) as problematic (defined as those that are identified as such during operator interviews or IHAs identified by review of similar systems and components in current operating plant designs) and those identified as requiring an HED to be generated
- procedure-guided tasks from normal, abnormal, emergency, and alarm response procedures including
  - administrative procedures
  - general plant operating procedures
  - procedures for startup, operations, and shutdown of safety-related systems
  - procedures for abnormal, off-normal, and alarm conditions
  - procedures for managing emergencies and significant events
  - procedures for managing reactivity, control of radioactivity, and radioactive contamination
  - procedures for control of test and measurement equipment used in surveillance tests and calibration
  - procedures for maintenance
  - procedures for chemistry and radiochemistry control
- tasks not well-defined by detailed procedures, (i.e., knowledge-based tasks)
  - tasks identified during TA as complex, requiring knowledge-based decision-making, assuming control from automated systems, or having a high workload or minimal time margin between time required and time available (see Reference 8.2.3).
  - tasks complicated by the addition of secondary and tertiary events or failures
  - tasks that require cognitive judgment, planning, and analytical decision-making
  - beyond-design-basis events based on the functional recovery procedures
  - combinations of failures that can cause potential misdiagnosis
  - secondary side failures that mask primary events and result in distractions
- tasks that require a diverse use of human cognitive abilities
  - detecting and monitoring
  - assessment
  - response planning

    - response implementation
    - obtaining feedback
  - tasks requiring a range of interactions among plant personnel, including tasks performed independently by individual crew members and those undertaken by a team of crew members These interactions include those within the main control room and those between main control room operators and outside personnel (plant and non-plant)
- situational factors, especially those known to challenge human performance
  - high-workload and multi-tasking situations
  - varying-workload or workload transition situations such as
    - sudden alarm waterfalls
    - abrupt decrease in number of alarms or indications needing monitoring
  - fatigue inducing situations
    - repetitive tasks
    - high frequency tasks
    - periods of low stress
    - back shift
  - environmental factors such as
    - normal expected variation in the MCR lighting
    - noise
    - temperature during high personnel loading
  - error-forcing context - situations in which human errors might be expected due to design or situational factors
    - multiple independent failures
    - conflicting indications
    - incorrect information
    - operator trust or lack of trust in automation
    - partial plant/system failures
    - partial HSI and computer-based procedure (CBP) failures

2.2 Identification of Scenarios

HFE V&V scenario developers establish goals and conditions to be included in each scenario selected based on the SOC. Each scenario contains multiple dimensions.

Biases for individual dimensions are possible, but collectively, the scenarios avoid bias by representing scenarios that

- have both positive and negative outcomes
- require varying degrees of administrative burden to run (simulator set-up, instructor input)
- minimize the use of well-known and well-structured sequences (i.e., textbook design-basis accident mitigation)

During identification of scenarios for HFE V&V, the HFE team develops a table to compare the SOC criteria in each scenario; the comparison table helps assure that representative SOC criteria are addressed by the composite set of scenarios. This comparison table is used to document (see Section 6.0) the bases for assurance that the selected scenarios are representative of expected operational conditions.

2.3 Scenario Definition

The scenarios used for DV, task support verification, and ISV selected during the SOC and scenario development process are defined so that they can be performed on a simulator. Scenario definition is used to provide a consistent, objective, and high fidelity environment in which to validate performance of integrated systems. The defined scenarios involve major plant evolutions or transients, reinforce team concepts, and identify the role each individual plays within the team. Tasks performed by operators remote from the MCR are modeled in the ISV scenario to realistically simulate effects on personnel performance due to potentially harsh environments. Effects such as additional time to don protective clothing, set up of radiological access control areas, and employment of damage control, emergency, or temporary equipment are described in scenarios by use of time constraints/additions. Scenarios are defined in detail similar to what will be in the eventual ISV scenarios described by the ISV test plan.

Example scenarios are included in Reference 8.2.10. A scenario has the following attributes

- a synopsis
- objectives
- initial condition of the entire plant
- specific initial conditions pertinent to commencement of the scenario
- a timeline of events to be run including initiating conditions where appropriate
- critical tasks to be conducted
- workplace factors, (e.g., environmental conditions)
- any material or knowledge-based needs to support the task to be tested
- staffing level/qualification
- where specific types of communications are necessary (e.g., an event notification to regulators via dedicated telephone line) details of that expected communication content
- scripted responses for test personnel (both in and out of the MCR)

- data to be collected by observers/instructors (rating scales for administrators are included where appropriate)
- pass/fail criteria for any part of the scenario
- initial simulator set up
- specific criteria for terminating the scenario

The ISV scenarios address the full range of operational conditions determined by SOC as described in Section 2.1. {{

}}[2(a),(c)] Scenarios that lead to only positive outcomes, scenarios that are easy to conduct, and scenarios that are well-structured and often practiced are not selected. Scenarios are selected to confront the crew with challenging normal conditions and abnormal events containing multiple and unanticipated failures. {{

}}[2(a),(c)] The HFE V&V Test Scenario Development Plan (Reference 8.2.10) lists performance measures that may be selected by scenario developers and applied to each scenario; the complete scenario definition includes all performance measures shown in Reference 8.2.10.

Test objectives are discussed in Section 4.2. An individual scenario cannot address all test objectives, but the aggregate ISV includes testing of all objectives. Each scenario tests some portion of the HSI for primary actions (control and verification via the plant response) and secondary actions (navigating the HSI for monitoring of other plant parameters); communication equipment is also verified during scenarios. Time available to perform a task vs. time required (Reference 8.2.3) is validated during scenarios. {{

}}[2(a),(c)] The ISV is also used to confirm the time-required assumptions applied in the TA calculation of workload (Reference 8.2.3).

2.4 Additional Considerations for Reviewing the HFE Aspects of Plant Modifications

After completion of start-up testing and provisional turn over, a licensee institutes a human performance monitoring (HPM) program to evaluate impacts on human

performance going forward. The HPM program evaluates design change proposals for HSI design, procedures, or training against the design bases established for the as-built design. The design change proposal evaluation considers HEDs in HFEITS regardless of the stage of the design in which they were initiated. Human factors V&V activity results that are invalidated by design changes are re-conducted to support plant modification without reducing human performance.

A licensee's design change process is governed by regulatory requirements such as 10 CFR 50.59, "Changes, Tests, and Experiments".

3.0 Design Verification

3.1 Human-System Interface Inventory and Characterization

3.1.1 Scope

The scope of HSI inventory and characterization includes alarms, controls, indications, and procedures for each type of HSI developed for the NuScale plant including: screen-based, room layout/arrangement, and hard-wired panels. Monitoring of automation is an important aspect of HSI that is also included in the scope of HSI inventory and characterization. The list of HSI inventory needed for all tasks is generated during TA (Reference 8.2.3) and developed during HSI design (Reference 8.2.5). In preparation for characterization, the output of TA and HSI design is compared to the HSIs that personnel will need for the tasks in the scenarios developed for SOC. Characterization defines the functionality of each HSI.

3.1.2 Human-System Interface Characterization

HSI design documents such as equipment lists, design specifications, and input/output lists are produced during HSI design (Reference 8.2.5). Characteristics of each HSI component are included in the associated design document. The minimum information set for characterization of each HSI component includes

- a unique equipment identification code that links the HSI component to the associated plant system or subsystem
- associated personnel functions/sub-functions
- type of HSI (indication, control, alarm, procedure, hard-wired, screen-based, etc.)
- HSI characteristics and functionality (unit of measure, accuracy of variable/parameter, format, continuous or discrete (if a control), system response time, etc.)
- HSI control characteristics and functionality (modes, accuracy, precision, format)
- method of use and associated user-aids
- physical or virtual (i.e., on a screen) location of HSI

3.1.3 Inventory Verification

The design simulator is a functional representative of the final plant screen-based HSI but without fully modeled and validated thermal-hydraulic and reactor core simulation, i.e., not the full-scope training simulator. The HSI inventory and characterization information described above is presented in the design simulator. The design simulator also provides displays representing conventional control elements, where necessary. The design simulator advances the HSI characterization by providing the verifier of the inventory with a desktop interface that simulates alarms, controls, indications, and procedures, and control panels as well as the means of navigation between elements. The design simulator is an accurate representation of HSIs in both form and content. Where HSIs are non-screen-based (e.g., voice communication), inventory and

characterization are performed using a mockup, representative hardware, or photographs of specified hardware.

The design simulator allows the verifier to confirm the visual aspects of the HSI during HSI task support verification, including conformance to the HSI style guide (see Reference 8.2.5) during HFE verification. For HSI task support verification related to performance (e.g., accuracy and dynamic response), the design simulator is supplemented by detailed I&C design specifications and databases generated during HSI design (Reference 8.2.5).

3.2 Human-System Interface Task Support Verification

The purpose of HSI task support verification is to assess HSIs as they support the tasks identified in TA. The assessment verifies that HSIs provide the alarms, controls, indications, and procedures, and task support for personnel tasks. HSI task support verification confirms that the HSI design accurately reflects the HSI inventory and characterizations required by TA. The scope includes alarms, controls, indications, and procedures, and supports needed to perform the scenarios selected for ISV through application of the SOC.

3.2.1 Verification Criteria

The task support verification is based on the most recent TA results. The TA defines the inventory and characterization for the alarms, controls, indications, and procedures needed to execute operator tasks for normal and abnormal plant conditions including manual tasks, automation support tasks, and automation monitoring tasks.

3.2.2 General Methodology

Independent HFE team members conduct HSI task support verification, using a verification procedure to control bias and improve consistency. The task support verification entails a detailed comparison of the personnel task requirements identified by the TA with the available alarms, controls, indications, and procedures in the HSI inventory. {{

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Results of the task support verification are based on the criterion that the information, control, and functional characteristics to support the task requirements identified during TA are present in the HSI that is being verified for the task. Results are documented for each task in the V&V results summary report (RSR) (see Section 6.0).

3.2.3 Human Engineering Discrepancy Identification

An HED is written when an HSI

- needed for completion of a task is not identified or not available
- is identified as available but is not needed for any task
- does not meet the established requirements for the task

The HED evaluation process (described in Reference 8.2.1) confirms the need for the HSI. If it is determined by the task support verification that the TA was incomplete, the TA is revised prior to resolution of the HED process for that issue.

3.2.4 Human Engineering Discrepancy Documentation

HEDs (see Reference 8.2.1) are uniquely identified and contain the relevant task criteria and the aspect of the HSI that has been found to not support the task requirements.

Acceptance criteria for task support verification include

- that the task support verification has been performed in compliance with this IP
- that HEDs generated by the task support verification have been treated through the HED process

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}}[2(a),(c)] HED resolutions of task support verification issues are included in the RSR (see Section 6.0).

3.2.5 Additional Methodology Considerations for Plant Modifications

After completion of start-up testing and provisional turn over, a licensee institutes a human performance monitoring (HPM) program (Reference 8.2.7) to evaluate impacts on human performance going forward. The HPM program evaluates design change proposals for HSI design, procedures, or training against the design bases established for the as-built design. The design change proposal evaluation considers HEDs in HFEITS regardless of the stage of the design in which they were initiated. Human factors V&V activity results that are invalidated by design changes are re-conducted to support plant modification without reducing human performance.

A licensee's design change process is governed by regulatory requirements such as 10 CFR 50.59, "Changes, Tests, and Experiments".

3.3 Human Factors Engineering Design Verification

The HFE design verification is conducted to confirm that HSI characteristics conform to HFE guidelines as represented in the style guide (see Reference 8.2.5). The style guide consists of procedures for use, general considerations, and system-specific guidance for screen-based HSIs (the term “system-specific” applies to plant systems as well as HSI systems).

3.3.1 Verification Criteria

The criteria for HFE design verification is provided by the HSI style guide described in Reference 8.2.5. The style guide includes procedural guidance for determining appropriate design criteria when the style guide does not apply to the characteristics of the HSI component being designed. The human factors issues tracking system (HFEITS) (described in Reference 8.2.1) is used to track HFE guidance not found in the style guide at the time of design. The HFEITS record may be referenced during HFE design verification as necessary.

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3.3.2 General Methodology

HFE design verification is conducted in accordance with a written procedure to assure consistency of results and to control analyst bias. The SOC is used to effectively confirm application of HFE design criteria across the entire HSI by ensuring that all HSI components are design-verified.

Procedures describing HFE design verification include

- checklists and guidelines for comparison of the HFE design criteria (style guide) to HSI components (i.e., alarms, controls, indications, procedures, navigation aids)
- a description of the means of comparing HFE design criteria to HSI components in the context of the various environmental conditions or locations of those HSIs (e.g., noise, lighting, ambient temperature/humidity)
- guidelines for determining whether the HSI is "acceptable" or "discrepant" based on the associated HFE design criteria
- methods for preparation and review of the HFE design verification as well as course of action when reviewers do not agree on the results

3.3.3 Human Engineering Discrepancy Identification and Documentation

HEDs (see Reference 8.2.1) are created for HSIs that do not meet the HFE design criteria completely. If an individual HSI does not meet the HFE design criteria, the HED

evaluation determines the extent of the discrepancy and potential indicators of additional issues across the HSI. The sampling based on the SOC is expanded to encompass other display and control formats of the HSI when determined necessary. See Section 5.0 for details of HED analysis and resolution.

3.3.4 Additional Considerations for Reviewing the HFE Aspects of Plant Modifications

After completion of start-up testing and provisional turn over, a licensee institutes a human performance monitoring (HPM) program to evaluate impacts on human performance going forward. The HPM program evaluates design change proposals for HSI design, procedures, or training against the design bases established for the as-built design. The design change proposal evaluation considers HEDs in HFEITS regardless of the stage of the design in which they were initiated. Human factors V&V activity results that are invalidated by design changes are re-conducted to support plant modification without reducing human performance.

A licensee's design change process is governed by regulatory requirements such as 10 CFR 50.59, "Changes, Tests, and Experiments".

4.0 Integrated System Validation

The ISV is the process by which an integrated system design (i.e., hardware, software, and personnel elements) is evaluated using performance-based tests to determine whether it acceptably supports safe operation of the plant. The ISV scenarios are conducted on a fully-developed simulator as a step towards certification of that simulator for scope, fidelity, and accuracy. The ISV is undertaken only after HEDs that were identified in the upstream process, including design verification, have been resolved and the resulting design changes implemented on the simulator.

Scenarios are developed using the guidance described in the implementing procedures. Performance measures used for assessing the results of an ISV are summarized in Section 4.5 and further described in implementing procedures.

4.1 Validation Team

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The MCR crews are selected and qualified as described in Section 4.4.

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4.2 Test Objectives

The objectives of the ISV are to

- validate the role of plant personnel
- validate the acceptability of shift staffing level for all plant conditions, assignment of tasks to crew members, and crew coordination within the MCR
- validate, for each function allocated to a human, that the HSI contains adequate alarms, controls, indications, and procedures, and feedback interface management features during normal plant evolutions, transients, design-basis accidents, and selected beyond-design-basis events to manage applicable critical safety and power production functions
- validate the HSI by demonstrating that personnel tasks can be successfully performed in the time available and within plant performance limits, under normal and degraded HSI conditions
- validate that the HSI supports a high degree of SA and that it allows personnel to achieve work load levels that balance levels of vigilance and operator burden.
- validate that the HSI minimizes human error and confirm that the HSI adequately supports human error minimization and recovery activities
- validate that the HSI supports the management of IHAs (Reference 8.2.4)
- validate the efficiency of the HSI as it supports the crew's ability to transition between the alarms, controls, indications, and procedures in the accomplishment of their tasks and that the HSI does not insert distractions nor present undue burden
- validate that the crew's SA and workload, specifically addressing direct and indirect secondary tasks, are within acceptable limits
- validate that the HSI supports the crew in identifying and managing failures of individual HSI features
- validate that the HSI supports the operating crew in managing plant maintenance, surveillance, and test activities directly affecting the MCR staff
- validate that the ergonomic and environmental design and conditions support safe and efficient operations for expected conditions
- identify aspects of the integrated HSI that are expected to have a negative effect on an aspect of performance (i.e., hardware, software, and personnel qualifications)

4.3 Validation Test Beds

The principal validation test bed for the NuScale ISV is the full-scope simulator. The fidelity of the simulator's model and HSI are verified to represent the current, as-designed NuScale plant prior to use as the test bed for the validation. Validation is based on the simulator design specification, the simulator quality assurance program, and simulator design verification requirements as described in the ISV testing procedure.

Discrepancies found during the simulator verification are corrected prior to starting the ISV. Alternately, if the simulator represents a more recent version of the HSI than was previously verified, the verification is reconfirmed on the simulator.

The validation test bed accurately simulates a NuScale plant MCR environment. Where this is not achievable by the test bed, an exception is taken and documented in the V&V RSR (see Section 6.0). If necessary, changes are also made to the ISV test procedure to reflect the alternate test bed configuration. In some limited cases, the V&V team may consider the test bed discrepancies to affect specific aspects of the validation results. If so, an HED is generated to document the discrepancy and the concern. The HED is resolved in accordance with the HED resolution process described in Reference 8.2.1. The HED resolution may document the need for additional testing in the as-built plant MCR after completion of the ISV.

4.3.1 Interface Completeness

The test bed completely represents the alarms, controls, indications, and procedures of the NuScale MCR and includes samples of elements not specifically required in the test scenarios (e.g., adjacent controls and displays and alternate procedures). The test bed further represents interfaces with other control rooms and local control stations (i.e., communications) to provide an integrated system.

4.3.2 Interface Physical Fidelity

A high degree of physical fidelity in the HSI and procedures is represented, including accurate presentation of alarms, controls, indications, and procedures, job aids, communications, interface management tools, layout, and spatial relationships. The test bed is a replica in form, appearance, and layout of the NuScale MCR design to be implemented in the actual plant. The test bed for the RSF is a derivative of the computer-based displays to be implemented in the actual plant; the RSF test bed, located near but not within the test bed for the MCR simulator, adapts the physical components of the MCR test bed to achieve a representation suitable to achieve the validation objectives.

4.3.3 Interface Functional Fidelity

A high degree of functional fidelity in the HSI and procedures is represented so that all HSI functions are available and the HSI component modes of operation, types of feedback, and dynamic response characteristics operate in the same way as the actual plant.

4.3.4 Environmental Fidelity

The test bed is representative of the actual NuScale plant with regard to environmental features such as lighting, noise, temperature, humidity, and ventilation characteristics. In cases where the test bed cannot accurately simulate the environment, the ISV captures HFEITS entries to confirm additional testing of the as-built during DI (Reference 8.2.6).

4.3.5 Data Completeness Fidelity

In the test bed, information and data provided to personnel represent the complete set of plant systems monitored and controlled from that facility.

4.3.6 Data Content Fidelity

The test bed represents a high degree of data content fidelity. The alarms, controls, indications, and procedures presented are based on an underlying plant model that accurately reflects the NuScale plant.

4.3.7 Data Dynamics Fidelity

The test bed represents a high degree of data dynamic fidelity. The plant model provides input to the HSI in a manner such that information flow and control responses occur accurately and in a correct response time. Information is provided to personnel with the same delays as would occur in the plant.

The test bed is verified and accepted based on an approved simulator design specification and to the required characteristics used for verification before the ISV starts.

4.3.8 Remote HSIs Containing IHAs

The test bed uses simulation or mockup to verify human performance requirements for IHAs conducted at HSIs remote from the MCR. The simulation or mockup considers, for example, transit times, use of personal protective equipment, and delays associated with the need for operator precision (self-checking).

4.3.9 Testbed Conformance

The testbed is verified to conform to its required characteristics before validation tests are conducted.

4.4 Plant Personnel

Operating crews participating in the ISV as test subjects are selected from a pool of experienced U.S. plant staff and NuScale independent design engineering staff. Operating crew personnel participating in ISV are assigned to roles appropriate to their skill and knowledge level within each scenario.

The ISV operating crew is not part of the V&V team. The operating crew selection process is based on the requirement to have an unbiased representative sample of plant personnel. Operating crew makeup is not varied from scenario to scenario and remains consistent throughout the validation (i.e., crew members are not rotated between operating crews).

To control crew bias, a sampling process is employed in crew selection that assures that the plant personnel represent the population of U.S. operating crews. This process

includes a random selection of operators and NuScale design engineers who meet the qualifications and include the following dimensions

- age distribution
- gender distribution
- education level distribution
- experience distribution; generally, industry operators have a minimum of one year of experience while engineers have a minimum of two years experience in addition to NuScale plant systems training

Additionally, the selection process avoids

- individuals who are known to possess a bias that impacts the ISV
- personnel who have supported the ISV test development and pilot test
- personnel involved in design of the HSI

Crew size for the validation tests includes a range of expected sizes to assure that the HSI supports operations and event management. This range includes the minimum operating crew, nominal levels, and maximum levels as defined during the staffing and qualifications program element (Reference 8.2.9) for positions of senior reactor operator, reactor operator, shift technical advisor, etc. for all plant modes. The crew size for each scenario is identified in the ISV test procedure, and scenarios are not repeated with different crew sizes.

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4.5 Performance Measurement

Performance measures for ISV are hierarchical and include measures of plant performance, personnel task performance, SA, cognitive and physical workload, and anthropometric/physiological factors. Both pass/fail and diagnostic measures are applied.

A list of performance measures and criteria for applying them to the ISV is included in Reference 8.2.10. The table uses a unique identifier to track each performance measure followed by a descriptive title and/or description for the performance measure.

4.5.1 Types of Performance Measures

4.5.1.1 Plant Performance Measures

Plant performance resulting from operator action or inaction includes plant process data (e.g., temperature, pressure) and component status (e.g., on/off; open/closed) as a function of time at as many locations in the plant simulation as is possible. These data are obtained from the entire plant: nuclear, fluid, structural, and electrical components. Any component that provides plant process data or component status in the plant is simulated with full fidelity. The test bed has the ability to record all plant process data and component status (including state changes) for the full length of any ISV scenario.

Plant performance measures are delineated in Reference 8.2.10.

4.5.1.2 Personnel Task Performance Measures

For each scenario, tasks that personnel are required to perform are identified and assessed. Primary and secondary personnel tasks are evaluated.

Primary tasks are those involved with function and task completion including detection, assessment, planning, and response. The level of detail to which primary tasks are measured and performance measures selected are assessed based on the complexity of the task. It may only be necessary to measure time and accuracy for a lower level rule-based task to recognize and respond, while tasks that are knowledge-based (e.g., detection, seeking additional data, making decisions, or taking actions) may entail the use of more detailed performance measures.

Secondary task performance measures reflect the workload associated with HSI manipulations associated with maintaining the overall plant. Test personnel evaluate secondary tasks in conjunction with primary tasks to observe effects on overall performance and workload both at individual and operations crew level.

Personnel task performance measurements are selected to reflect those aspects of the task that are important to system performance and used depending on the particular scenario

- time
- accuracy
- frequency
- amount achieved or accomplished
- consumption or quantity used
- subjective report of participants
- behavior categorization by observers

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Personnel performance measures are delineated in Reference 8.2.10.

4.5.1.3 Situation Awareness Performance Measures

To measure SA, ISV applies a combination of objective measures along with subjective post-scenario questionnaire methods.

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4.5.1.4 Cognitive and Physical Workload Performance Measures

To measure cognitive workload, the ISV employs the following methods

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Workload assessment and measurement is discussed in Reference 8.2.3.

4.5.1.5 Anthropometric and Physiological Factor Performance Measures

The primary purpose of anthropometric and physiological performance measures during ISV is to assess those aspects of the design that cannot be evaluated during design verification. Anthropometric and physiological performance measures evaluate how well the HSI supports plant personnel in monitoring and control of the plant. {{

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4.5.2 Performance Measure Information and Validation Criteria

4.5.2.1 Collection Methods

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4.5.2.2 Performance Measure Characteristics and Bases

Each performance measure to be observed during ISV is included in Reference 8.2.10. Performance measures contain the characteristics described in Table 4-1.

Table 4-1 Characteristics of performance measures

Characteristic	Meaning
Construct Validity	A measure should represent accurately the aspect of performance it is intended to measure.
Reliability	A measure should be repeatable; i.e., same behavior measured in exactly the same way under identical circumstances should yield the same results.
Sensitivity	A measure's range (scale) and its frequency (how often data are collected) should be appropriate to that aspect of performance being assessed.
Unobtrusiveness	A measure should minimally alter the psychological or physical processes that are being investigated.
Objectivity	A measure should be based on easily observed phenomena.

The basis for inclusion of a performance criterion in the ISV (or a particular scenario within ISV) used to judge acceptability of that criterion is included in Reference 8.2.10. Bases for performance criteria are described in Table 4-2.

Table 4-2 Basis for performance criteria

Criteria	Basis Meaning
Requirement	The observed performance of the integrated system is compared with a quantified performance requirement; i.e., the requirements for the performance of systems, subsystems, and personnel are defined through engineering analyses.
Benchmark	The observed performance of the integrated system is compared with a criterion established using a benchmark system, e.g., a current system is predefined as acceptable.
Norm	The observed performance of the integrated system is compared with a criterion using many predecessor systems (rather than a single benchmark system).
Expert Judgment	The observed performance of the integrated system is compared with a criterion established by subject-matter experts.

Performance measures are designated as either pass/fail or diagnostic. Diagnostic is measureable and the criteria include both range and unit of measure. The type of performance measurement is included in Reference 8.2.10.

4.6 Test Design

Test design refers to the process of developing scenarios, test plans, and conducting ISV based on the integrated HSI as described in the preceding sections. The goal of test design is to permit the observation of integrated system performance while minimizing bias.

This section describes characteristics of the test design important to supporting ISV validity.

4.6.1 Scenario Sequencing

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4.6.2 Test Procedures

Prior to ISV, detailed test procedures are prepared to manage tests, assure consistency, control test bias, support repeatable results, and focus the test on the specific scenario objectives. The test observers/administrators use the test procedures to set up each scenario, manage the scenario, and analyze the test results. Scenario developers use test procedures to build the scenario set.

ISV test procedures are designed to minimize the introduction of bias by both observer/administrators and test crews. A standardized scenario template, as illustrated in Reference 8.2.10, is part of the test procedure. Test procedures include

- scenario order for each crew and order of crews when running a single scenario multiple times
- detailed and standardized instructions for briefing the test participants before each scenario
- specific instructions and criteria for observer/administrators on conduct of scenarios
- scripted questions and responses for observer/administrators acting as plant staff during the scenario
- guidance on when and how to interact with the operating crew when the simulator encounters difficulties

- specification of unique data to be collected and stored (including what, when, and how) (Section 4.5)
- procedures for documenting
  - operating crews and scenario details
  - deviations from the test procedure, test difficulties, significant unusual events
  - collected plant raw data
  - observer/administrator notes
  - post-scenario and final debriefing notes
  - crew questionnaires
  - observer/administrator questionnaires
  - observer/administrator consensus notes
  - video and audio recordings
  - HEDs
- post-testing instructions for each operating crew that instruct them not to discuss the scenarios and HSI with others

In addition to the test procedure, observer/administrator bias is controlled through the selection process for observer/administrators, a structured training program, a formal consensus process, and independent review of results. Operating crew bias is controlled through qualification, training of test personnel, observer/administrator observations, and cross-crew and scenario data analysis.

4.6.3 Training Test Personnel

Prior to starting ISV, observer/administrators are trained and qualified on NuScale plant systems, the HSI, and ISV test procedures. Training consists of both classroom and simulator time. Training goals include

- assuring familiarity with test procedures and scenarios
- reduction of bias and errors that may be introduced by the observers/administrators due to test-based learning, failure to follow the test procedure, or incorrect interaction with the operating crew
- use of the test procedure
- documentation needs for each test, including
  - where the test did not follow the scenario
  - problems that occur during testing
- the necessity of limiting observer/administrator interaction with test personnel to that which is in the scenario description
- how to conduct post-scenario debriefings

- familiarity with HFE data collection tools and techniques
- familiarity with observation techniques, goals, and responsibilities specific to each observer's role

4.6.4 Training Participants

Test participants are trained in the crew in which they will perform scenarios prior to the start of ISV. Test participants undergo training similar to that which plant operators receive including NuScale plant systems, the HSI, plant events, and operating procedures. Test participants are not trained specifically on the scenarios in which they will participate; scenario briefings are done just prior to commencement of the scenario.

To assure near-asymptotic performance and a consistent level of proficiency between individuals making up the operating crews, only participants who have successfully completed the training program and are judged by the training instructor to have reached a consistent level of performance are considered to be qualified for operating crew assignment.

4.6.5 Pilot Testing

A test crew, which does not participate in ISV, conducts a pilot test (a pre-validation test) to

- confirm the adequacy of the training program for both observer/administrators and test participants
- confirm the test design, performance measures, and test procedure
- give the observer/administrators experience in running the test
- ensure that the ISV runs smoothly and correctly
- identify controllable bias prior to ISV

4.7 Data Analysis and Human Engineering Discrepancy Identification

Test data are analyzed using both quantitative and qualitative methods (Reference 8.2.12). The analysis identifies the relationship between the observed and measured performance and the established acceptance criteria described in Section 4.5.2. Data are analyzed for each scenario across multiple trials. The method of analysis, consistency of measure assessing performance, and criteria used to determine successful performance for a given scenario is provided in the ISV test plan.

The broad-reaching testing and number of performance measures to be evaluated limit the ability to perform statistical analyses. Testing of multiple scenarios with multiple teams (generally, each team will develop a different strategy) makes it impractical to make conclusions based on performance of the population or deviations from a norm. Therefore, observer/administrators, test participants, and the HFE team evaluate any instance where a performance measure is not met to determine causal factors

- Design-related deficiencies determined for alarms, controls, indications, and procedures are documented in an HED. Any previous HFE program element may need to be evaluated to resolve the deficiency. The HSI design is not considered validated until an HED initiated as a result of ISV is resolved.
- Test-related deficiencies are documented in the HFEITS and may result in changes to the test procedure or scenario definition.

HEDs resulting from ISV are prioritized according to importance. The severity of the performance problem is addressed in terms of the degree to which it contributes to human performance problems such as workload, SA, or communication

- Priority 1 HEDs have a potential direct or indirect impact on plant safety and are resolved before HFE V&V is considered complete. HEDs initiated as a result of a performance measure not being met (pass/fail performance measures) are priority 1 HEDs. Cross-cutting issues determined through HED analysis or performance measure analysis are priority 1 HEDs due to their global impact on the HSI design performance.
- Priority 2 HEDs have a direct or indirect impact on plant performance and operability. Priority 2 HEDs are resolved before the plant design is completed.
- Priority 3 HEDs are those that do not fall into priority 1 or priority 2. Priority 3 HEDs do not have to be resolved.

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ISV data analysis is independently reviewed by individuals or groups other than those who performed the original analysis. Data and data-analysis tools (e.g., equations, measures, spreadsheets, expert opinions, resulting HEDs) are documented for the independent review and subsequent audit and application during design integration and/or human performance monitoring HFE program elements. Records of the HFE team independent review are maintained as auditable records.

4.8 Validation Conclusions

ISV conclusions are based on

- a comprehensive testing program performed by an independent ISV team using test procedures covering the scope described above
- a high-fidelity test platform representative of the actual system, model, and HSI in aspects important to the integrated system's performance; variable aspects of the integrated system are adequately sampled
- acceptance criteria are measurable, reflect good operational practices, and are representative of important aspects of performance
- test design minimizes bias or confounding effects so as not to affect the validity of the results
- statistical conclusions, where possible, are based on convergence of multiple measures
- specific pass/fail performance criteria documented as HEDs also identify the extent of the issue

- observer/administrator consensus

ISV conclusions documented in the V&V results summary report include

- the statistical and logical bases for determining that performance of the integrated system is acceptable
- the limitations in identifying possible effects on validation conclusions and that the impact on the design integration HFE program element is considered, including
  - aspects of the tests not well controlled
  - potential differences between the test situation and actual operations such as the absence of productivity-safety conflicts
  - differences between test platform design and the as-built NuScale plant
  - effects of bias and remaining uncontrolled bias identified during testing
  - unforeseen events that occurred during V&V that affect the results

5.0 Human Engineering Discrepancy Resolution

HEDs (see Reference 8.2.1) are identified in the V&V process during

- task support verification
- HFE design verification
- ISV

HEDs resulting from HFE V&V follow the process applied to HEDs described in Reference 8.2.1 with the following additional unique process requirements

- HEDs generated during task support verification are resolved (with resulting design changes completed) prior to completion of task support verification. {{

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- to assure that ISV tests the final HSI design, HEDs resulting from design verification are resolved (and any resulting HSI design changes implemented in the test facility) prior to the start of the ISV
- HEDs resulting from ISV are resolved within ISV whenever practical based on importance level and prior to additional testing. At the point of documenting an ISV HED, completed tests are evaluated to determine the need for retesting.

HEDs may not always be resolved; HEDs may be found acceptable after an evaluation by the HFE team in the context of the integrated design. The decision for accepting an HED without change in the integrated design is based on accepted HFE practices, current published HFE literature, trade-off studies, tests, or engineering evaluations. HED determinations are documented.

5.1 Human Engineering Discrepancy Analysis

HFE V&V HEDs are categorized based on principal impact on

- plant systems
- global HSI feature
- standard HSI feature
- detailed HSI feature
- individual HSI component or operating procedure
- personnel function
- results of an artifact of the V&V program

Extent of condition and causal effect across the various HSI design features/functions are assessed as part of the HED process. Extent of condition determination considers

- cumulative or combined effects of multiple HEDs

- multiple HEDs involving a single system or HSI
- HEDs that may represent a broader issue

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In order to assure a timely and systematic assessment and resolution of the HEDs resulting from the V&V, they are prioritized into three categories described in Section 4.7 and corrected accordingly.

5.2 Human Engineering Discrepancy Evaluation Documentation

As described in Reference 8.2.1, HEDs are documented in HFEITS with

- the basis for not correcting an HED
- related personnel tasks and functions
- related plant systems
- cumulative effects of HEDs
- HEDs as indications of broader issues

6.0 Verification & Validation Results Summary Report

The results of HFE V&V are compiled in a results summary report that contains

- a matrix of HFE V&V team participants and roles
- HFE V&V results overview and principal findings
- HFE V&V execution results
  - verification
    - a description of the application of the verification program
    - verification results based on TA
    - verification results based on the HSI design style guide
    - discussion of HEDs that resulted from the verification, extent of condition, resolution, and any subsequent HSI design changes made prior to validation
    - verification test procedures
    - verification procedure and analysis tools used to draw conclusions and provide assurance that selected scenarios are representative of expected operational conditions (tools may include tables or checklists)
  - validation
    - a description of the application of the validation program
    - validation test procedures
    - ISV procedure, including scenarios
    - a detailed description of the specific scenario sets used in testing as illustrated in Reference 8.2.10, including: test instructions, data collection instruments, SOC versus scenario comparison table, and scenario identification summary table
    - data analysis results and validation conclusions, as compared to the minimum set of test objectives
    - a discussion of pass/fail HEDs that resulted from the validation, extent of condition, resolution, and any subsequent HSI design changes, analyses, or retest
    - a discussion of performance improvement measures
    - a discussion of validation results and conclusions that pass/fail criteria have been met
    - identification of HEDs evaluated for further HSI improvements

7.0 NUREG-0711 Conformance Evaluation

Table 7-1 indicates where each NUREG-0711, Revision 3 criterion is addressed in this IP.

Table 7-1 Conformance with NUREG-0711

Review Criteria	**HFE V&V IP Section No. and paragraph**
11.4.1.1 Sampling Dimensions The following sampling dimensions are addressed below: Plant conditions, personnel tasks, and situational factors known to challenge personnel performance. (1) The applicant should include the following plant conditions: normal operational events including plant startup, shutdown or refueling, and significant changes in operating power I&C and HSI failures and degraded conditions that encompass: - The I&C system, including the sensor, monitoring, automation and control, and communications subsystems; [e.g., safety-related system logic and control unit, fault tolerant controller, local "field unit" for multiplexer (MUX) system, MUX controller, and a break in MUX line] - common cause failure of the I&C system during a design basis accident (as defined by BTP 7-19) - HSIs including, loss of processing or display capabilities for alarms, displays, controls, and computer-based procedures transients and accidents, such as: - transients (e.g., turbine trip, loss of off-site power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or MCR power supplies, and safety and relief valve transients) - accidents (e.g., main-steam-line break, positive reactivity addition, control rod insertion at power, anticipated transient without scram, and various-sized loss-of coolant accidents) - reactor shutdown and cooldown using the remote shutdown system - reasonable, risk-significant, beyond-design-basis events that should be determined from the plant-specific PRA	Section 2.1, bullet 1

Review Criteria	HFE V&V IP Section No. and paragraph
(2) The applicant should include the following types of personnel tasks: Important HAs, Systems, and Accident Sequences – The sample should include all important HAs, as determined in Section 7. Additional factors that contribute highly to risk, as defined by the PRA, also should be sampled: - dominant accident sequences - dominant systems (selected through PRA importance measures, such as Risk Achievement Worth or Risk Reduction Worth) *Manual Initiation of Protective Actions* – The sample should include manual system level actuation of critical safety functions. *Automatic System Monitoring* – The sample should include situations in which humans must monitor a risk-important automatic system. *OER-Identified Problematic Tasks* – The sample should include all personnel tasks identified as problematic during the applicant's review of operating experience. *Range of Procedure Guided Tasks* –The sample should include tasks that are well defined by procedures. Personnel should be able to understand and execute the specified steps as part of their rule-based decision-making. Regulatory Guide 1.33, Appendix A, contains several categories of "typical safety-related activities that should be covered by written procedures." The sample should include appropriate procedures in each category: - administrative procedures - general plant operating procedures - procedures for startup, operation, and shutdown of safety-related systems - procedures for abnormal, off-normal, and alarm conditions - procedures for combating emergencies and other significant events (e.g., reactor accidents, and declaration of emergency-action levels) - procedures for controlling radioactivity - procedures for controlling measuring and test equipment and for surveillance tests, procedures, and calibration - procedures for performing maintenance - chemistry and radiochemical control procedures	Section 2.1, bullet 2

Review Criteria	HFE V&V IP Section No. and paragraph
Range of Knowledge-Based Tasks – The sample should include tasks that are not well defined by detailed procedures. *Additional Information*: A situation may demand knowledge-based decision-making if the procedural rules do not fully address the problem, or when the selection of an appropriate rule is unclear. An example in a pressurized water reactor plant may be the difficulty in diagnosing a steam generator tube rupture (SGTR) with a failure of radiation monitors on the plant's secondary side. This happens because (1) there is no main indication of the rupture (the presence of radiation in secondary side), and (2) the other effects of the rupture (i.e., slight changes in pressures and levels on the primary and secondary sides) may be attributed to other causes. While the operators may use procedures to treat the symptoms of the event, the determination that the cause is a SGTR may call for a situational assessment based on an understanding of the plant's design and the possible combinations of failures that entail the observed symptoms. Errors in rule-based decision-making result from selecting the wrong rule, or incorrectly applying a rule. Errors in knowledge-based decision-making result from mistakes in higher-level cognitive functions, such as judgment, planning, and analysis. The latter are more likely to occur in complex failure events wherein the symptoms do not resemble the typical case, and thus, are not amenable to pre-established rules. *Range of Human Cognitive Activities* – The sample should include the range of cognitive activities that personnel perform, including: - detecting and monitoring (e.g., of critical safety-function threats) - situation assessment (e.g., interpreting alarms and displays to diagnose faults in plant processes and in automated control and safety systems) - planning responses (e.g., evaluating alternatives to recover from plant failures) response implementation (e.g., in-the-loop control of plant systems, assuming manual control from automatic control systems, and carrying out complicated control actions) - obtaining feedback (e.g., feedback of the success of actions taken) *Range of Human Interactions* – The sample should include the range of interactions among plant personnel, including tasks performed independently by individual crew members, and those undertaken by a team of crew members. These interactions among plant personnel should include interactions between: - main control room operators (e.g., operations, shift turnover walkdowns) - main control room operators with auxiliary operators and other plant personnel performing tasks locally (e.g. , maintenance or I&C technicians, chemistry technicians) - main control room operators and the TSC and the EOF - main control room operators with plant management, the NRC, and other outside organizations	Section 2.1, bullet 2

Review Criteria	HFE V&V IP Section No. and paragraph
(3) The applicant should include the following situational factors or error-forcing contexts known to challenge human performance. It also should include situations specifically designed to create human errors to assess the system's error tolerance, and the ability of personnel to recover from any errors, should these occur, for example: High-Workload Situations – The sample should include situations where variations in human performance due to high workload and multitasking situations can be assessed. Varying-Workload Situations – The sample should include situations wherein variations in human performance due to workload transitions can be determined. These include conditions where there is (1) a sudden increase in the number of signals that must be detected and processed after a period in which signals were infrequent, and (2) a rapid reduction in the need for detecting signals and processing demands following a time of high sustained task-demand. Fatigue Situations – To the extent possible, the sample should include situations that may be associated with fatigue, such as work on backshifts and tasks performed frequently with repetitive actions, such as repeated inputs to a touch screen during plant operations or pulling rods. Environmental Factors – To the extent possible, the sample should include environmental conditions that may cause human performance to vary, e.g., poor lighting, extreme temperatures, high noise, and simulated radiological contamination.	Section 2.1, bullet 3
11.4.1.2 Identification of Scenarios (1) The applicant should combine the results of the sampling to identify a set of V&V scenarios to guide subsequent analyses. *Additional Information*: A given scenario may combine many of the characteristics identified by sampling of operational conditions.	Section 2.2, all
(2) The applicant should not bias the scenarios by overly representing the following: scenarios for which only positive outcomes are expected scenarios that, for ISV, are relatively easy to conduct (i.e., scenarios should not be avoided simply because they are demanding to set up and run on a simulator) scenarios that, for ISV, are familiar and well structured (e.g., which address familiar systems and failure modes that are highly compatible with plant procedures, such as "textbook" design-basis accidents)	Section 2.2, all

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.1.3 Scenario Definition (1) The applicant should identify operational conditions and scenarios to be used for HSI Task Support Verification, Design Verification, and ISV. The applicant should develop detailed scenarios suitable for use on a full-scope simulator. The level of detail should be comparable to what one would include in a test plan. For each one, the following information should be defined to reasonably assure that important dimensions of performance are addressed, and to allow the scenarios to be accurately and consistently presented for repeated trials: a description of the scenario and any pertinent prior history necessary for personnel to understand the state of the plant at the start-up of the scenario specific initial conditions (a precise definition of the plant's functions, processes, systems, component conditions, and performance parameters, e.g., similar to that at shift turnover) events (e.g., failures) that will occur during the scenario and their initiating conditions, e.g., based on time, or a value of a specific parameter precise definition of workplace factors, (e.g., environmental conditions, such as low levels of illumination) needs for task support (e.g., procedures and technical specifications) staffing level details of communication content between control room personnel and remote personnel (e.g., load dispatcher via telephone) scripted responses for test personnel who will act as plant personnel in the test scenarios *Additional Information*: Test personnel act as surrogates for personnel outside the control room. To the greatest extent possible, prepare responses to questions that may be asked by operators communicating with the personnel outside the control room. There are limits to the ability to preplan communications because personnel may ask unanticipated questions or make unforeseen requests. However, efforts should be made to detail what information personnel outside the control room can provide, and script the responses to likely questions. the precise specification of what, when, and how data are to be collected and stored (including videotaping, questionnaires, and rating-scale administrations) precise specifications on simulator set up specific criteria for terminating the scenario	Section 2.3, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) The applicant's scenarios should realistically replicate operator tasks in the tests; then, the findings from the test can be generalized to the plant's actual operations. (3) When the applicant's scenarios include work associated with operations remote from the main control room, the effects on personnel performance due to potentially harsh environments (e.g., high radiation) should be realistically simulated (e.g., additional time to don protective clothing, and access radiologically controlled areas).	Section 2.3, all
11.4.1.4 Additional Considerations for Reviewing the HFE Aspects of Plant Modifications In addition to any of the criteria above that relate to the modification being reviewed, the applicant should address the following considerations. (1) The applicant's operational conditions should reflect tasks that involve a modification, rather than the entire range of topics discussed in Section 11.4.1. (2) For ISV, the applicant's operational conditions should encompass the transfer of learning effects on personnel performance when modifying an old HSI or procedure. *Additional Information*: Negative transfer of learning may occur when the new and old components are different and impose different demands on personnel. (3) For ISV, when both old and new versions of the same HSIs are permanently present in the HSI but with different means of presentation and methods of operation, then the applicant's evaluations should reasonably assure that personnel can alternate their use of these HSIs without degrading performance. (4) Where old HSIs are to be deactivated but left in place in the HSI, the applicant should identify conditions for an ISV that would test the potential for their interfering with tasks. *Additional Information*: For example, the presence of deactivated HSIs may cause visual clutter that interferes with the ability of personnel to locate and use other HSIs.	Section 2.4
11.4.2 Design Verification Review Criteria 11.4.2.1 HSI Inventory and Characterization (1) Scope - The applicant should develop an inventory of all HSIs that personnel require to complete the tasks covered in the validation scenarios that were identified by the applicant's Sampling of Operational Conditions. The inventory should include aspects of the HSI used for managing the interface, such as navigation and retrieving displays, as well as those that control the plant.	Section 3.1.1, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) HSI Characterization - The applicant's inventory should describe the characteristics of each HSI within the scope of the verification. The following is a minimal set of information for this characterization: a unique identification code number or name associated plant system and subsystem associated personnel functions and tasks type of HSI, e.g., - computer-based control (e.g., touch screen or cursor-operated button and keyboard input) - hardwired control (e.g., J-handle controller, button, and automatic controller) - computer-based display (e.g., digital value and analog representation) - hardwired display (e.g., dial, gauge, and strip-chart recorder) display characteristics and functionality [e.g., plant variables/parameters, units of measure, accuracy of variable/parameter, precision of display, dynamic response, and display format (e.g., bar chart or trend plot)] control characteristics and functionality [e.g., continuous versus discrete settings, number and type of control modes, accuracy, precision, dynamic response, and control format (method of input)] user-system interaction and dialog types (e.g., navigation aids and menus) location in data-management system (e.g., identification code for information display screen) physical location in the HSI (e.g., control panel section), if applicable The applicant should include photographs, copies of display screens, or similar samples of HSIs in the HSI inventory and characterization.	Section 3.1.2, all
(3) Inventory Verification - The applicant should verify the inventory description of HSIs to ensure that it accurately reflects their current state.	Section 3.1.3, all

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.2.2 HSI Task Support Verification HSI Task Support Verification addresses the availability of items needed to support task requirements. As stated in Section 11.2, the objective of the HSI Task Support Verification review is to ensure that the applicant verified that the HSI provides the needed alarms, information, controls, and task support for personnel to perform their tasks, defined by the task analysis. (1) Verification Criteria - The applicant should base the HSI task support criteria on the alarms, controls, displays, and task support needed by personnel to complete their tasks as identified by the applicant's task analysis.	Section 3.2 Section 3.2.1, all
(2) General Methodology - The applicant should compare the HSIs and their characteristics (as defined in the HSI inventory and characterization) to the needs of personnel identified in the task analysis for the defined sampling of operational conditions, noted in Section 11.4.1.	Section 3.2.2, all
(3) HED Identification - The applicant should identify and document an HED when: An HSI needed for task performance (e.g., a necessary control or display) is unavailable. HSI characteristics do not match the requirements of the personnel task (e.g., a display may show the needed plant parameter but not within the range or precision needed for the task). HSIs are available that are not needed for any task. Additional Information: Unnecessary HSIs introduce clutter, and can distract personnel from selecting the appropriate ones. It is important to verify that the HSI is unnecessary. Appropriate ones may not appear to be needed with personnel tasks for the following reasons: The HSI is essential for a task that the task analysis did not address (i.e., it was not within the scope of the design review). The task analysis was incomplete, overlooking the need for the HSI. The HSI only partially meets the established requirements for the personnel task.	Section 3.2.3, all
(4) HED Documentation – The applicant should document HEDs to identify the HSI, the tasks affected, and the basis for the deficiency (what aspect of the HSI was identified as not meeting task requirements). Additional Information: The analysis and correction of HEDs is detailed in Section 11.4.4, Human Engineering Discrepancy Resolution Review Criteria.	Section 3.2.4, all

Review Criteria	HFE V&V IP Section No. and paragraph
(5) Additional Methodology Considerations for Plant Modifications - In addition to any of the criteria above that relate to the modification being reviewed, the applicant should address the following considerations: HSI Task Support Verification should address all aspects of HSIs described above related to the modification. For modifications to plant systems that do not include modifications of the HSIs, verification of task support should highlight any new demands for monitoring and control, and assess whether the existing HSI design adequately addresses them. HSI Task Support Verification should cover configurations in the modification in which old HSIs are deactivated permanently, but not removed (e.g., abandoned in place). Criterion 4 in this subsection states that the HSIs should not contain any information, displays, or controls that do not support personnel tasks. This verification should identify deactivated HSIs that might negatively affect personnel performance, such as obstructing the view of important information or adding visual clutter that could interfere with monitoring. The applicant should identify deactivated HSIs requiring further evaluation through HFE design verification or ISV. HSI Task Support Verification should address the temporary configurations of the HSIs and plant systems that may be created when establishing the modification, and so used by operations and maintenance personnel when the plant is not shutdown. These configurations may include: - the use of HSIs that differ from the intended final design - combinations of HSIs and system configurations that differ from both the original design and the intended final one For each temporary HSI configuration, the task requirements of personnel should be identified and compared to the information and control capabilities available. *Additional Information*: For example, if a temporary configuration of plant systems introduces special monitoring requirements, the HSIs should provide the necessary information.	N/A. Section 3.2.5

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.2.3 HFE Design Verification HFE Design Verification addresses the suitability of the HSI with regard to human capabilities and limitations. As stated in Section 11.2, the objective of the HFE Design Verification review is to evaluate the applicant's verification that the design of the HSIs conforms to HFE guidelines. (1) Verification Criteria - The applicant should base the criteria used for HFE Design Verification on HFE guidelines. *Additional Information:* The choice of guidelines used in this verification depends upon whether the applicant developed a design-specific style guide. The acceptability of the style guide used by the applicant should be reviewed by the NRC staff using the review guidance in Section 8.4.3, HFE Design Guidance for HSIs. Using an NRC-reviewed style guide affords the criteria for verifying the HFE design. When no style guide is available, the guidelines in NUREG-0700 can be used by the applicant for this purpose. However, because not all of the guidelines therein will be applicable to each review, the applicant should select those based on the characteristics of the HSIs being evaluated. Applicants should identify a subset of guidelines appropriate to a specific design based on the HSI characterization.	Section 3.3 Section 3.3.1, all
(2) General Methodology - The applicant's HFE Design Verification methodology should include the following: Procedures for comparing the characteristics of the HSIs with HFE guidelines for (1) the defined sampling of operational conditions, as noted in Section 11.4.1, and (2) the general environment in which HSIs are sited, including workstations, control rooms, and environmental characteristics (e.g., lighting and noise). *Additional Information:* A single guideline may apply to many HSIs. By verifying all HSIs within the scenarios defined in Section 11.4.1, the consistency of applying a guideline across multiple HSIs can be assessed. Procedures for determining for each guideline whether the HSI is "acceptable" or "discrepant." If discrepant, it should be designated as an HED, tracked, and evaluated (see Sections 2.4.4 and 11.4.4). *Additional Information*: A judgment that an HSI is "acceptable" should be made only if compliance is total, i.e., only if every instance of the item is fully consistent with the criteria established by the HFE guidelines. If there is any noncompliance, full or partial, then an evaluation of "discrepant" should be given, and a notation made as to where it occurs. Procedures for evaluating whether an HED is a potential indicator of additional issues. *Additional Information*: For example, identifying an inappropriate format for presenting data on an individual display should be considered a potential sign that other display formats might be used incorrectly, or that the observed format is employed inappropriately elsewhere. Then, the sampling strategy should be modified to encompass other display formats. In some cases, discovering these discrepancies will warrant further review in the identified areas of concern.	Section 3.3.2, all

Review Criteria	HFE V&V IP Section No. and paragraph
(3) HED Identification - The applicant should identify an HED when a characteristic of the HSI is "discrepant" from a guideline. (4) HED Documentation - The applicant should document HEDs in terms of the HSI involved, and how its characteristics depart from a particular guideline. *Additional Information*: The analysis and correction of HEDs is addressed in Section 11.4.4, Human Engineering Discrepancy Resolution Review Criteria.	Section 3.3.3, all
(5) Additional Considerations for Reviewing the HFE Aspects of Plant Modifications - In addition to any of the criteria above that relate to the modification being reviewed, the applicant should address the following considerations: The scope of HFE design verification may be restricted to the modified HSIs and their interactions with the rest of the HSIs. When both old and new versions of similar HSIs are available, this verification should offer reasonable assurance that their means of presentation and methods of operation are compatible, such that personnel performance will not be impaired when alternating the use of each one. HEDs should be identified for the following: - failure to meet "personnel-identified" functionality in addition to that specified by system designers. When a digital system replaces an existing system, it is important to ensure that all operational uses of the former system were addressed, even those that were not intended in the original design. The replacement system's design should consider the ways in which personnel actually used the former system - poor integration with the rest of the HSI - poor integration with procedures and training Temporary configurations of the HSIs and plant systems that operations and maintenance personnel may use when the plant is not shutdown, should be reviewed to verify that their design is consistent with the principles of good HFE design, including consistency with the rest of the HSIs.	Section 3.3.4

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.3 Integrated System Validation 11.4.3.1 Validation Team (1) The applicant should describe how the team performing the validation has independence from the personnel responsible for the actual design. *Additional Information*: The members of the validation team should have no responsibility for the design; i.e., they should never have been part of the design team. While they may work for the same organization, their responsibilities must not include contributions to the design, other than validating it.	Section 4.0 Section 4.1, all
11.4.3.2 Test Objectives (1) The applicant should develop detailed test objectives to provide evidence that the integrated system adequately supports plant personnel in safely operating the plant, to include the following considerations: Validate the acceptability of the shift staffing level(s), the assignment of tasks to crew members, and crew coordination within the control room, between the control room and local control stations and support centers, and with individuals performing tasks locally. This should encompass validating minimum shift staffing levels, nominal levels, maximum levels, and shift turnover (see Section 6 for definitions). Validate that the design has adequate capability for alerting, informing controlling, and feedback such that personnel tasks are successfully completed during normal plant evolutions, transients, design-basis accidents, and also under selected, risk significant events beyond-design basis, as defined by sampling operational conditions. Validate that specific personnel tasks can be accomplished within the time and performance criteria, with effective situational awareness, and acceptable workload levels that balance vigilance and personnel burden. Validate that the HSIs minimize personnel error and assure error detection and recovery capability when errors occur. Validate the assumptions about performance on important HAs. *Additional Information*: For example, the HRA within the plant PRA contains several assumptions regarding the performance of risk-important HAs. These assumptions should be validated for dominant sequences, such as decision-making and diagnosis strategies, and also for the human actions. This process should be completed before the final quantification stage of the PRA. Validate that the personnel can effectively transition between the HSIs and procedures in accomplishing their tasks, and that interface management tasks, such as display configuration and navigation, are not a distraction or an undue burden.	Section 4.2, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) Additional Considerations for Reviewing the HFE Aspects of Plant Modifications – In addition to any of the criteria above that relate to the modification being reviewed, the test's objectives and scenarios should be developed to encompass aspects of performance affected by the modified design (even when the HSIs are not modified), including personnel tasks.	N/A
11.4.3.3 Validation Test beds A test bed is the HSI representation used to perform validation evaluations. One approach an applicant can use to acceptably meet criteria 1 through 7 in this section is to use a test bed that is compliant with "Nuclear Power Plant Simulators for Use in Operator Training" (ANS, 2009). (1) Interface Completeness - The applicant's test bed should represent completely the integrated system. It should include HSIs and procedures not specifically required in the test scenarios. *Additional Information:* Adjacent controls and displays may affect the ways in which personnel use those addressed by a particular validation scenario.	Section 4.3 Section 4.3.1, all
(2) Interface Physical Fidelity - The test bed's HSIs and procedures should be represented with high physical fidelity to the reference design, including the presentation of alarms, displays, controls, job aids, procedures, communications equipment, interface management tools, layout, and spatial relationships.	Section 4.3.2, all
(3) Interface Functional Fidelity - The test bed's HSI and procedure functionality should be represented with high fidelity to the reference design. All HSI functions should be available. *Additional Information:* High fidelity covers the HSI modes of operation (i.e., the changes in functionality that can be invoked by personnel selecting them), or changes in plant states.	Section 4.3.3, all
(4) Environmental Fidelity - The test bed's environmental fidelity should be represented with high physical fidelity to the reference design, including the expected levels of lighting, noise, temperature, and humidity. Thus, for example, the noise contributed by equipment, such as air-handling units, computers, and communications equipment should be represented in validation tests.	Section 4.3.4, all
(5) Data Completeness Fidelity - Information and data provided to personnel should completely represent the plant's systems they monitor and control.	Section 4.3.5, all
(6) Data Content Fidelity - The testbed's data content fidelity should be represented with high physical fidelity to the reference design. The presentation of information and controls should rest on an underlying model accurately mirroring the reference plant. The model should provide input to the HSI such that the information accurately matches that which is presented during operations.	Section 4.3.6, all

Review Criteria	HFE V&V IP Section No. and paragraph
(7) Data Dynamics Fidelity - The testbed's data dynamics fidelity should be represented with high fidelity to the reference design. The process model should be able to provide input to the HSI so that information flow and control responses occur accurately and within the correct response time; e.g., information should be sent to personnel with the same delays as occur in the plant.	Section 4.3.7, all
(8) For important HAs at complex HSIs remote from the main control room (e. g., a remote shutdown facility), where timely, precise actions are essential, the use of a simulator or mockup should be considered to verify that the requirements for human performance can be met. (For less important HAs, or for non-complex HSIs, human performance may be assessed on analysis, such as task analysis, rather than on simulations.)	Section 4.3.8, all
(9) The applicant should verify the conformance of the testbed to the testbed-required characteristics before validation tests are conducted.	Section 4.3.9, all
11.4.3.4 Plant Personnel (1) Participants in the applicant's validation tests should be representative of plant personnel who will interact with the HSI (e.g., licensed operators, rather than training personnel or engineers). (2) To properly account for human variability, the applicant should use a sample of participants that reflects the characteristics of the population from which it is drawn. Those characteristics expected to contribute to variations in system performance should be specifically identified; the sampling process should reasonably assure that the validation encompasses variation along that dimension. Determining representativeness should include considering the participants' license type and qualifications, skill/experience, age, and general demographics. (3) In selecting personnel for participating in the tests, the applicant should consider the minimum shift staffing levels, nominal levels, and maximum levels, including shift supervisors, reactor operators, shift technical advisors, etc. (4) The applicant should prevent bias in the sample of participants by avoiding the use of participants who: are members of the design organization participated in prior evaluations were selected for some specific characteristic, such as crews identified as good performers or more experienced	Section 4.4, all

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.3.5 Performance Measurement ISV employs a hierarchal set of performance measures including measures of plant performance, personnel task performance, situation awareness, cognitive workload, and anthropometric/physiological factors. Errors of omission and commission also are identified. A hierarchal set of measures provides sufficient information to validate the integrated system design and affords a basis to evaluate deficiencies in performance and thereby identify needed improvements. Pass/fail measures are those used to determine whether the design is or is not validated. Diagnostic measures are used to better understand personnel performance and to facilitate the analyses of errors and HEDs.	Section 4.5, all
11.4.3.5.1 Types of Performance Measures (1) The applicant should identify the specific plant performance measures applicable to each ISV scenario. *Additional Information*: They may address the performance of functions, systems, or component.	Section 4.5.1.1, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) The applicant should identify the primary task measures applicable to each ISV scenario. For each scenario, the applicant should identify the primary tasks operators must perform to accomplish scenario goals, so that such measures can be developed. *Additional Information*: The primary tasks are those involved in carrying out the functional role of the operator in supervising the plant; i.e., monitoring, detection, situation assessment, response planning, and response implementation. Primary tasks should be assessed at a level of detail appropriate to the task's demands. For example, for some simple scenarios, measuring the time to complete a task may suffice. For complicated tasks, especially those described as knowledge-based, it may be appropriate to undertake a fine-grained analysis, such as identifying the task's components, viz., seeking specific data, making decisions, taking actions, and obtaining feedback. The measures chosen to evaluate personnel task performance should reflect those aspects of the task that are important to system performance, such as: - time - accuracy - frequency - amount achieved or accomplished - consumption or quantity used - subjective reports of participants - behavior categorization by observers The analysis of primary tasks will support the identification of errors of omission (primary tasks not performed). Also, any actions and tasks that operators *actually* perform that deviate from the primary tasks should be identified and noted. These actions should be used to identify errors of commission.	Section 4.5.1.2, all
(3) The applicant should identify the secondary task measures applicable to each scenario. *Additional Information*: Secondary tasks are those personnel must perform when interfacing with the HSI, such as navigating through computer screens to find a needed display and to configure HSIs. The measurement of secondary task performance should reflect the demands of the detailed HSI implementation, e.g., time to configure a workstation, navigate between displays, and manipulate them (e.g., changing display type and scale settings).	Section 4.5.1.2, paragraph 3

<table>
<tr><th>Review Criteria</th><th>HFE V&V IP Section No. and paragraph</th></tr>
<tr><td>(4) The applicant should identify the measures of situation awareness applicable to each scenario.

Additional Information: Situation awareness is the degree to which personnel’s perception of plant parameters and understanding of the plant's condition corresponds to its actual condition at any given time and influences predictions about future states.</td><td>Section 4.5.1.3, all</td></tr>
<tr><td>(5) The applicant should identify the workload measures obtained for each scenario.
Additional Information: Workload is comprised of the physical, cognitive, and other demands that tasks place on plant personnel. The impact of one or many of these aspects of workload should be considered in the performance measures.</td><td>Section 4.5.1, all;
Section 4.5.1.4</td></tr>
<tr><td>(6) The applicant should identify the anthropometric and physiological measures obtained for each scenario.
Additional Information: Anthropometric and physiological factors include such concerns as visibility of displays, accessibility of control devices, and ease of manipulating the control device. Many of these design aspects are assessed as part of verifying the HFEs design. Therefore, attention should focus on those areas of the design that only can be addressed by testing the integrated system, e.g., the ability of personnel effectively to use the various controls, displays, workstations, or consoles while performing their tasks.</td><td>Section 4.5.1.5, all</td></tr>
<tr><td>11.4.3.5.2 Performance Measure Information and Validation Criteria
(1) The applicant should describe the methods by which these measures are obtained, e.g., by simulator data recording, participant questionnaires, or observation by subject-matter experts.</td><td>Section 4.5.2, all;
Section 4.5.2.1</td></tr>
<tr><td>(2) The applicant should specify when each measure is obtained (recorded), such as continuously, at specific points during the scenario, or after the scenario ends.</td><td>Section 4.5.2.2, paragraph 3</td></tr>
<tr><td>(3) The applicant should describe the characteristics (see Table 11-1) of the performance measures.
Characteristics of Performance Measures
<table>
<tr><th>Characteristic</th><th>Meaning</th></tr>
<tr><td>Construct Validity</td><td>A measure should represent accurately the aspect of performance it is intended to measure.</td></tr>
<tr><td>Reliability</td><td>A measure should be repeatable; i.e., same behavior measured in exactly the same way under identical circumstances should yield the same results.</td></tr>
<tr><td>Sensitivity</td><td>A measure's range (scale) and its frequency (how often data are collected) should be appropriate to that aspect of performance being assessed.</td></tr>
<tr><td>Unobtrusiveness</td><td>A measure should minimally alter the psychological or physical processes that are being investigated.</td></tr>
<tr><td>Objectivity</td><td>A measure should be based on easily observed phenomena.</td></tr>
</table></td><td>Section 4.5.2.2, Table 4-1</td></tr>
</table>

<table>
<tr><th>Review Criteria</th><th>HFE V&V IP Section No. and paragraph</th></tr>
<tr><td>(4) The applicant should identify the specific criterion for each measure used to judge the acceptability of performance and describe its basis.
Additional Information: Table 11-2 describes the different bases for performance criteria.
Basis for Performance Criteria
<table>
<tr><th>Criteria</th><th>Basis Meaning</th></tr>
<tr><td>Requirement</td><td>The observed performance of the integrated system is compared with a quantified performance requirement; i.e., the requirements for the performance of systems, subsystems, and personnel are defined through engineering analyses.</td></tr>
<tr><td>Benchmark</td><td>The observed performance of the integrated system is compared with a criterion established using a benchmark system, e.g., a current system is predefined as acceptable.</td></tr>
<tr><td>Norm</td><td>The observed performance of the integrated system is compared with a criterion using many predecessor systems (rather than a single benchmark system).</td></tr>
<tr><td>Expert Judgment</td><td>The observed performance of the integrated system is compared with a criterion established by subject-matter experts.</td></tr>
</table></td><td>Section 4.5.2.2, Table 4-2</td></tr>
<tr><td>(5) The applicant should identify whether each measure is a pass/fail one or a diagnostic one.</td><td>Section 4.5.2.2, final paragraph</td></tr>
<tr><td>11.4.3.6 Test Design
11.4.3.6.1 Scenario Sequencing
(1) The applicant should balance scenarios across crews to provide each crew with a similar, representative range of scenarios.
Additional Information: Random assignment of scenarios to crews for ISV is undesirable. The value of using random assignment to control bias is effective only when the number of crews is quite large.</td><td>Section 4.6
Section 4.6.1, all</td></tr>
<tr><td>(2) The applicant should balance the order of presentation of scenarios to crews to provide reasonable assurance that the scenarios are not always presented in the same sequence (e.g., the easy scenario is not always used first).</td><td>Section 4.6.2, bullet 1</td></tr>
</table>

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.3.6.2 Test Procedures (1) The applicant should use detailed, unambiguous procedures to govern the conduct of the tests. These procedures should include the following: the identification of which crews receive which scenarios, and the order in which they should be presented detailed and standardized instructions for briefing the participants *Additional Information:* The type of instructions given to participants can affect their performance on a task. This source of bias is minimized by developing standard instructions. specific directions for the testing personnel on conducting the test scenarios, as elaborated in Scenario Definition (Section 11.4.1.3) guidance on when and how to interact with participants when difficulties occur in simulation or testing *Additional Information:* Even when a high-fidelity simulator is used, the participants may encounter artifacts of the test environment that detract from their performance of the tasks that are the focus of the evaluation. Guidance should be available to the test conductors to help resolve such conditions. instructions on when and how to collect and store data. These instructions should stipulate which data are to be recorded by: - simulator computers - special-purpose instruments and devices for collecting data (such as situation awareness- and workload-questionnaires, or physiological measures) - video recorders (locations and views) - test personnel and subject-matter experts (such as via observational checklists) procedures for documentation: - identifying and maintaining files of test records including details of the crew and scenarios - data collected - logs created by those who conducted the tests The procedures should detail the types of information that should be logged (e.g., when the tests were performed, deviations from the test procedures and why they occurred, and any unusual events that may be important to understanding how a test was run or for interpreting the findings from it). The procedure also should state when the types of information should be recorded.	Section 4.6.2, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) The applicant's test procedures should minimize the opportunity for bias in the test personnel's' expectations and in the participant's responses. *Additional Information*: The expectancies of test personnel may introduce a bias if the expectations of the testers systematically influence the collection of data. Expectancies can influence performance in many ways (e.g., test personnel may, by giving subtle cues or communications, provide direction to participants, or they may tend to evaluate the performance of participants in ways that reflect more favorably upon the design than would an objective observer). Participant response bias means that the design of the test itself affects the data obtained from participants. It is not necessarily implied that a response bias represents any deliberate attempt by the participants to be untruthful. The test environment can influence participants in ways that have little to do with the tests objectives. Response bias can occur in four ways. First, participants may wish to influence outcomes and so be biased toward producing data consistent with their desired result. Second, participants may want to provide data that they think the test personnel want to obtain. Third, participants may try to figure out how performance should vary under different conditions, and then influence data to be consistent with such differences. Fourth, participants may want to excel because they know that they are being observed. See NUREG/CR 6393 (O'Hara et al., 1997) for additional information.	Section 4.6.2, final paragraph
11.4.3.6.3 Training Test Personnel (1) The applicant should train test personnel (those who conduct or administer the validation tests) on the following: the use and importance of test procedures bias and errors that test personnel may introduce into the data through failures to follow test procedures accurately or to interact with participants properly the importance of accurately documenting problems arising during testing, even if they were due to an oversight or error of those conducting the test	Section 4.6.3, all
11.4.3.6.4 Training Participants (1) The applicant's training of participants should be very similar to the training plant personnel receive. It should reasonably assure that the participants' knowledge of the plant's design, and operations, and the use of the HSIs and procedures represent that of experienced plant personnel. Participants should not be trained specifically to carry out the selected validation scenarios.	Section 4.6.4, paragraph 1
(2) To assure that the participants' performance is representative of plant personnel, the applicant's training of participants should result in near asymptotic performance (i.e., stable, not significantly changing from trial to trial) and should be tested for such before conducting the validation.	Section 4.6.4, paragraph 2

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.3.6.5 Pilot Testing (1) The applicant should conduct a pilot study before the validation tests begin to offer an opportunity for the applicant to assess the adequacy of the test design, performance measures, and data-collection methods. (2) The applicant should not use participants in the pilot testing who will then be participants in the validation tests.	Section 4.6.5, all
11.4.3.7 Data Analysis and HED Identification (1) The applicant should use a combination of quantitative and qualitative methods to analyze data. The analysis should reveal the relationship between the observed performance and the established performance criteria.	Section 4.7, paragraph 1
(2) The applicant should discuss the method by which data is analyzed across trials, and include the criteria used to determine successful performance for a given scenario.	Section 4.7, paragraph 1
(3) The applicant should evaluate the degree of convergence between related measures (i.e., consistency between measures expected to assess the same aspect of performance). *Additional Information:* For example, if situation assessment is measured by both a participant questionnaire, and an observer rating scale, the results should be consistent with each other. If they do not converge, the reason for this should be identified.	Section 4.7, all
(4) When interpreting test results, the applicant should allow a margin of error to reflect the fact that actual performance may be slightly more variable than observed validation-test performance.	Section 4.7, paragraph 6
(5) The applicant should verify the correctness of the analyses of the data. This verification should be done by individuals or groups other than those who performed the original analysis, but may be from the same organization.	Section 4.7, paragraph 7
(6) The applicant should identify HEDs when the observed performance does not meet the performance criteria. *Additional Information*: The analysis and correction of HEDs is addressed in Section 11.4.4, Human Engineering Discrepancy Resolution Review Criteria.	Section 4.7, paragraph 3
(7) The applicant should resolve HEDs identified by pass/fail measures before the design is accepted.	Section 4.7, paragraph 3

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.3.8 Validation Conclusions (1) The applicant should document the statistical and logical bases for determining that performance of the integrated system is, and will be acceptable. (2) The applicant should document the limitations in the validation tests, their possible effects on the conclusions of the validation, and their impact on implementing the design. *Additional Information:* Examples of possible limitations include: aspects of the tests that were not well controlled potential differences between the test situation and actual operations, such as the absence of productivity-safety conflicts potential differences between the validated design and the as-built plant or system (if validation is directed to a plant under construction where such information is available, or to a new design using the validation findings from a predecessor)	Section 4.8, all

Review Criteria	HFE V&V IP Section No. and paragraph
11.4.4 Human Engineering Discrepancy Resolution Review Criteria (1) HED Analysis The applicant's HED analyses should include the following: *Personnel Tasks and Functions* – The impact of HEDs on personnel tasks and the functions supported by those tasks. *Additional Information:* The potential effects of HEDs is determined, in part, by the importance of the personnel function to plant safety (e.g., consequences of failure), and their cumulative effect on personnel performance (e.g., degree of impairment and types of potential errors). *Plant Systems* – The impact of HEDs on plant systems, considering the safety significance of that system(s), their effect on accident analyses, and their relationship to risk-significant sequences in the plant's PRA. *Additional Information:* The potential effects of these HEDs on the plant's safety and personnel performance are determined, in part, by the safety significance of the plant system(s) related to the particular component. *Cumulative Effects of HEDs* – The analysis of HEDs should identify the cumulative effects that multiple HEDs may have on plant safety and personnel performance. *Additional Information*: Although an individual HED might not be considered sufficiently severe to warrant correction, the combined effect of several of them on a single aspect of the design could significantly degrade plant safety, and therefore, necessitate corrective action. Likewise, when a single plant system with multiple associated HEDs affects several HSIs, then their possible combined effect on the operation of that plant system should be considered. *HEDs as Indications of Broader Issues* – As well as addressing specific HEDs, the applicant's analysis should determine whether the HEDs point to potentially broader problems. *Additional Information*: For example, identifying multiple HEDs associated with one particular aspect of the HSI design, such as the remote shutdown panel, also might suggest other problems with that aspect of the design, such as inconsistent use of design procedures and style guides. In some cases, findings from evaluating HEDs could warrant further review in the identified areas of concern, e.g., when multiple cases of mislabeling are found, the reviewers may wish to do a more complete examination of labeling.	Section 5.0 Section 5.1, all

Review Criteria	HFE V&V IP Section No. and paragraph
(2) Selection of HEDs to Correct The applicant should conduct an evaluation to identify which HEDs to correct. The evaluation should identify those HEDs that are acceptable as is (The *Additional Information* below provides examples). The remaining discrepancies should be denoted as HEDs to be addressed by the HED-resolution process. HEDs the applicant should correct are those with direct safety consequences, namely, those that could adversely impact personnel performance such that the margin of plant safety may be reduced below an acceptable level. Unacceptability is indicated by such conditions as violations of Technical Specification safety limits, operating limits, or limiting conditions for operations, or failing an ISV pass/fail criterion. HEDs with potential safety impact, not as severe as those described above, also should be corrected unless the applicant justifies leaving the condition as is. The applicant should correct HEDs that may adversely impact personnel performance in a way that has potential consequences to plant performance or SSC operability, and personnel performance or efficiency. This may include failing to meet personnel information needs or violating HFE guidelines for tasks associated with plant productivity, availability, and protecting investment. *Additional Information:* HEDs could be acceptable within the context of the fully integrated design. The technical basis for such a determination could include an analysis of recent research literature, current practices, tradeoff studies, or design engineering evaluations.	Section 5.1, final paragraph
(3) Development of Design Solutions The applicant should identify design solutions to correct HEDs. As part of the design solution, the application should evaluate the interrelationships of individual HEDs. *Additional Information*: HEDs should not be considered in isolation and to the extent possible, their potential interactions should be considered when developing and implementing solutions. For example, if the HSI for a single plant system is associated with many HEDs, then the set of design solutions should be coordinated to enhance overall performance and avoid incompatibilities between individual solutions. Similarly, if a single plant system is associated with multiple HSIs associated with HEDs, then the design of individual solutions should be harmonized so that the outcome enhances rather than detracts from that system's operation. Approaches that develop design solutions to some HEDs before all are identified in a particular V&V activity are acceptable provided that the potential interactions between HEDs are specifically considered before implementing the design solutions.	Section 5.1, all Also described in Reference 8.2.1.

Review Criteria	**HFE V&V IP Section No. and paragraph**
(4) Design Solution Evaluation The applicant should evaluate design solutions to demonstrate the resolution of that HED and to ensure that new HEDs are not introduced. Generally, the evaluation should use the V&V method that originally detected the HED. *Additional Information*: For example, if the HED was identified using HFE Design Verification, then that verification should be employed to evaluate the solution. However, there may be reasons for documenting a satisfactory resolution using other methods. For example, if an aspect of the HSI was significantly changed from the resolution of multiple HEDs, the final HSI design may be validated to ensure that the net effect of all the changes is acceptable.	Section 5.1, all Also described in Reference 8.2.1.
(5) HED Evaluation Documentation The applicant should document each HED, including: the basis for not correcting an HED related personnel tasks and functions related plant systems cumulative effects of HEDs HEDs as indications of broader issues *Additional Information*: Some, or all, of this documentation may be included in the issues tracking system (Section 2.4.4). Other information, such as cumulative effects or indications of broader issues, may be documented separately.	Section 5.2, all

8.0 References

8.1 Source Documents

8.1.1 U.S. Nuclear Regulatory Commission, “Human-System Interface Design Review Guidelines,” NUREG-0700, Rev. 2, May 2002.

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

8.1.3 U.S. Nuclear Regulatory Commission, “Guidance for the Review of Changes to Human Actions,” NUREG-1764, September 2007.

8.1.4 U.S. Nuclear Regulatory Commission, “Accident Sequence Evaluation Program Human Reliability Analysis Procedure,” NUREG/CR-4772, February 1987.

8.1.5 U.S. Nuclear Regulatory Commission, “Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications,” NUREG/CR-1278, August 1983.

8.2 Referenced Documents

8.2.1 NuScale Human Factors Engineering Program Management Plan, RP-0914-8534.

8.2.2 NuScale Human Factors Engineering Operating Experience Review Implementation Plan, RP-0914-8535.

8.2.3 NuScale Human Factors Engineering Task Analysis Implementation Plan, RP-0914-8537.

8.2.4 NuScale Human Factors Engineering Treatment of Important Human Actions Implementation Plan, RP-0914-8539.

8.2.5 NuScale Human Factors Engineering Human-System Interface Design Implementation Plan, RP-0914-8540.

8.2.6 NuScale Human Factors Engineering Design Implementation Implementation Plan, RP-0914-8544.

8.2.7 NuScale Human Factors Engineering Human Performance Monitoring Implementation Plan, RP-0914-8545.

8.2.8 Nuclear Power Plant Simulators for Use in Operator Training and Examination, ANSI/ANS 3.5-2009, American National Standards Institute.

8.2.9 NuScale Human Factors Engineering Staffing and Qualifications Implementation Plan, RP-0914-8538.

8.2.10 NuScale Human Factors Engineering Verification and Validation Testing Scenario Development Plan, Pending.

8.2.11 NuScale Human Factors Engineering Verification and Validation Testing Plan, Pending.

8.2.12 U.S. Nuclear Regulatory Commission, “Integrated System Validation: Methodology and Review Criteria,” NUREG/CR-6393, January 1997.

Enclosure 2:

"Human Factors Engineering Verification and Validation Implementation Plan," RP-0914-8543-P, Revision 0, proprietary version

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvallis, Oregon 97330 Office 541.360-0500 Fax 541.207.3928
www.nuscalepower.com

Enclosure 3:

Affidavit, AF-1115-19226

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvallis, Oregon 97330 Office 541.360-0500 Fax 541.207.3928
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NuScale Power, LLC

AFFIDAVIT of Thomas A. Bergman

I, Thomas A. Bergman , state as follows:

(1) I am the Vice President of Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale

(2) I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:

(a) The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.

(b) The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.

(c) Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

(d) The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.

(e) The information requested to be withheld consists of patentable ideas.

(3) Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying implementation plan reveals distinguishing aspects about the process, method, or other trade secrets by which NuScale develops and implements its Human Factors Engineering Verification and Validation.

NuScale has performed significant research and evaluation to develop a basis for this process, method, or trade secret and has invested significant resources, including the expenditure of a considerable sum of money.

The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

(4) The information sought to be withheld is in the enclosed implementation plan entitled Human Factors Engineering Verification and Validation Implementation Plan.The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.

(5) The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).

(6) Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:

(a) The information sought to be withheld is owned and has been held in confidence by NuScale.

(b) The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.

(c) The information is being transmitted to and received by the NRC in confidence.

(d) No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.

(e) Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on November 18, 2015.

Thomas A. Bergman