Human Factors Engineering Analysis Phase Implementation Plan:

Operating Experience Review Implementation Plan
Functional Requirements Analysis and Function Allocation Implementation Plan
Task Analysis Implementation Plan
Staffing and Qualification Implementation Plan
Human Reliability Analysis Implementation Plan

October 2010

Revision 0

NuScale Non Proprietary

NuScale Power, Inc.

Suite 10310

1000 NE Circle Blvd

Corvallis, Oregon 97330

www.nuscalepower.com

© Copyright 2010 NuScale Power, Inc.

This page intentionally blank

NUSCALE POWER PROPRIETARY INFORMATION NOTICE

This document does not contain proprietary information.

COPYRIGHT NOTICE

This document bears a NuScale Power, Inc., copyright notice. No right to disclose, use, or copy any of the information in this document, other than by the U.S. Nuclear Regulatory Commission (NRC), is authorized without the express, written permission of NuScale Power, Inc.

The NRC is permitted to make the number of copies of the information contained in these reports that is needed for its internal use in connection with generic and plant-specific reviews and approvals, as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by NuScale Power, Inc., copyright protection notwithstanding. Regarding nonproprietary versions of these reports, the NRC is permitted to make the number of additional copies necessary to provide copies for public viewing in appropriate docket files in public document rooms in Washington, DC, and elsewhere as may be required by NRC regulations. Copies made by the NRC must include this copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

CONTENTS

1.0 Definitions / Abbreviations 8

2.0 HFE Analysis Phase Implementation Plan 10

2.1 Background 10

2.2 HFE Analysis Phase Implementation Plan Scope 10

2.3 HFE Analysis Phase Implementation Plan Structure 10

3.0 Operating Experience Review Implementation Plan 11

3.1 OER Purpose 11

3.2 OER Scope 11

3.2.1 Reviews of Related Systems 11

3.2.2 Reviews of Issues from NUREG/CR-6400 HFE Insights For Advanced Reactors Based Upon Operating Experience 12

3.2.3 Reviews of Issues of Proposed HFE Technology 12

3.2.4 Personnel Interview Input 13

3.2.5 Issues Associated with Risk-Important Human Actions 14

3.3 OER Team 14

3.4 OER Method 14

3.4.1 OER Process and Procedures 14

3.4.2 OER Tool 16

3.5 OER Process Outputs 17

4.0 Functional Requirements Analysis and Function Allocation Implementation Plan 20

4.1 FRA&FA Purpose 20

4.2 FRA&FA Scope 20

4.3 FRA&FA Team 21

4.4 FRA&FA Method 22

4.4.1 FRA&FA Process and Procedures 22

4.4.2 FRA&FA Tools 27

4.5 FRA&FA Process Outputs 30

5.0 Task Analysis Implementation Plan 33

5.1 TA Purpose 33

5.2 TA Scope 34

5.3 TA Team 35

5.4 TA Method 35

5.4.1 TA Process and Procedures 35
5.4.2 TA Tools 39
5.5 TA Process Outputs 40
6.0 Staffing and Qualifications Implementation Plan 41
6.1 S&Q Purpose 41
6.2 S&Q Scope 42
6.3 S&Q Team 45
6.4 S&Q Method 45
6.4.1 S&Q Process and Procedures 45
6.4.2 S&Q Tools 47
6.5 S&Q Process Outputs 48
7.0 Human Reliability Analysis Implementation Plan 50
7.1 HRA Purpose 50
7.2 HRA Scope 50
7.3 HRA Team 51
7.4 HRA Method 51
7.4.1 HRA Process and Procedures 51
7.4.2 HRA Tools 54
7.5 HRA Process Output 54
8.0 References 56
Appendix A. NuScale Cognitive Work Analysis Process 59
Appendix B. NuScale Function Allocation Process 69

TABLES

Table 1-1 Definitions / Abbreviations 8

Table A-1. Mapping of NuScale CWA process to HFE element implementation plans 60

FIGURES

Figure 3-1 Typical HFE OER database 17
Figure 4-1 Typical FRA&FA database 29
Figure 4-2 Typical operational conditions list 30

Figure A-1. Typical ADS template 62
Figure A-2. Typical decision ladder template 64

Figure A-3. Typical task summary template with columns for data entry during strategies 65
Figure A-4. Typical task summary details added during function allocation 65
Figure A-5. Typical task summary details added during TA process (input review, information requirements) 66
Figure A-6. Typical task summary details added during TA process (decision, response requirements)... 66
Figure A-7. Typical task summary details added during TA process (communications, work load, factors, hazards) 67
Figure A-8. Typical details of task summaries (situation awareness, worker competencies) 67
Figure B-1. NuScale function allocation process diagram 71

Abstract

NuScale Power, Inc. (NuScale) is the designer of the NuScale nuclear power plant. This power plant design is based on using twelve independent modular reactor units to generate electric power. The Human Factors Engineering (HFE) program at NuScale will be done in four phases. These phases are analysis; design; verification and validation; and implementation and operation. This Human Factors Analysis Phase Implementation Plan describes how NuScale will implement the five analysis technical elements of the Human Factors Engineering (HFE) Program. These five analysis technical elements are part of what is described as the planning and analysis general activity in NUREG-0711 Rev. 2 (Reference 1). These technical elements are Operating Experience Review (OER); Functional Requirements Analysis and Function Allocation (FRA&FA); Task Analysis (TA); Staffing and Qualification (S&Q); and Human Reliability Analysis (HRA).

This plan (HFE Analysis Phase Implementation Plan (IP)) will be one of a set of submittals for HFE program technical element implementation plans. These implementation plans support and provide direction for the implementation of the NuScale HFE Program in support of the design and development of the NuScale nuclear power plant as defined in the HFE program management plan (PMP) (Reference 2). The five analysis phase technical elements are included in this plan to support the preparation of the Design Certification Document (DCD) and work needed in support of a staffing exemption request from 10 CFR 50.54 (Reference 3).

The technical elements of the NuScale HFE program that are not covered in this HFE Analysis Phase IP will have implementation plans that will be included in future submittals. The plans to be addressed in future submittals include the Human-System Interface (HSI) Design Plan, the Procedure Development Plan, the Training Program Development Plan, the HFE Verification & Validation Plan, the HFE Design Implementation Plan, and the Human-Performance Monitoring Plan.

The HFE process begins with OER providing information to be used to support multiple other HFE technical elements. Functional Requirements Analysis defines functions at the plant and system levels for the operation of the plant. Function Allocation determines whether a human, machine, or a combination of both human and machine completes actions accomplished in the performance of functions. TA follows FRA&FA and will establish the information and control requirements as an input to the design of the human-systems interface (HSI), standard plant procedures and training program development. S&Q will be determined using a systematic methodology that takes into consideration task and regulatory requirements. An HFE Human Reliability Analysis (HRA) process will interact with the safety analysis group responsible for the Probabilistic Risk Assessment (PRA) and HRA. The results from the HRA and input to subsequent HRA revisions will be coordinated with all appropriate HFE program technical elements. The HFE design process and products will be evaluated in the Verification and Validation (V&V) process with implementation checked in the HFE Design Implementation and Human Performance Monitoring processes.

1.0 Definitions / Abbreviations

Table 1-1 Definitions / Abbreviations

Term	Definition
ADS	Abstraction-Decomposition Space
ASEP	Accident Sequence Evaluation Program
ATHEANA	A Technique for Human Event Analysis
CFR	U.S. Code of Federal Regulations
COL	Combined License
CWA	Cognitive Work Analysis
DCD	Design Control Document
DI&C	Digital Instrumentation and Controls
EID	Ecological Interface Design
FRA&FA	Functional Requirements Analysis and Function Allocation
FV	Fussell-Vesely
HA	Human Action
HEP	Human Error Probability
HFE	Human Factors Engineering
HFEITS	Human Factors Engineering Issues Tracking System
HMI	Human Machine Interface
HRA	Human Reliability Analysis
HSI	Human-System Interface
I&C	Instrumentation and Control
IEEE	Institute of Electrical and Electronic Engineers
IP	Implementation Plan
ISG	Interim Staff Guidance
LWR	Light Water Reactor
MCR	Main Control Room
NRC	United States Nuclear Regulatory Commission
NUREG	Technical Report of the United States Nuclear Regulatory Commission
OER	Operating Experience Review
OSU	Oregon State University
PMP	Program Management Plan

PRA	Probabilistic Risk Assessment
PSF	Performance Shaping Factor
QAP	Quality Assurance Program
RAW	Risk Achievement Worth
RO	Reactor Operator
RSR	Results Summary Report
RSS	Remote Shutdown Station
SA	Situation Awareness
S&Q	Staffing and Qualification
SPAR-H	Standardized Plant Analysis Risk- Human Reliability Analysis Method
SRO	Senior Reactor Operator
SSC	Structures, Systems, and Components
STA	Shift Technical Advisor
TA	Task Analysis
THERP	Technique for Human Error Rate Prediction
TSC	Technical Support Center
V&V	Verification and Validation
WDA	Work Domain Analysis

2.0 HFE Analysis Phase Implementation Plan

2.1 Background

This Human Factors Engineering (HFE) Analysis Phase Implementation Plan (IP) is part of the NuScale HFE Program and is implemented under the HFE Program Management Plan (PMP) (Reference 2) which is under the NuScale Quality Assurance Program (QAP). The HFE program at NuScale will be done in four phases. These phases are analysis; design; verification and validation; and implementation and operation. NuScale will prepare 11 implementation plans. One for each technical element described in NUREG-0711. This HFE Analysis Phase IP describes how NuScale will implement the five analysis technical elements of the Human Factors Engineering (HFE) Program. These five analysis technical elements are part of what is described as the planning and analysis general activity in NUREG-0711 Rev. 2 (Reference 1). These technical elements are Operating Experience Review (OER); Functional Requirements Analysis and Function Allocation (FRA&FA); Task Analysis (TA); Staffing and Qualification (S&Q); and Human Reliability Analysis (HRA).

The technical elements of the NuScale HFE program that are not covered in this HFE Analysis Phase IP will have implementation plans that will be included in future submittals. The plans to be addressed in future submittals include the Human-System Interface (HSI) Design Plan, the Procedure Development Plan, the Training Program Development Plan, the HFE Verification & Validation Plan, the HFE Design Implementation Plan, and the Human-Performance Monitoring Plan.

2.2 HFE Analysis Phase Implementation Plan Scope

The HFE Analysis Phase IP covers the main control room (MCR) (including multi-modular monitoring and control), remote shutdown station (RSS), emergency operations facility (EOF), technical support center (TSC), and local control stations (LCSs).

2.3 HFE Analysis Phase Implementation Plan Structure

Each analysis phase HFE program technical element implementation plan will be a separate section of this submittal. Each section includes subsections covering the purpose, scope, team, method, and output for each technical element. Information and data exchange between the HFE program technical elements will be referenced in the scope and output sections of each HFE program technical element implementation plan.

3.0 Operating Experience Review Implementation Plan

3.1 OER Purpose

The purpose of conducting an operating experience review (OER) is to identify HFE-related issues identified in other similar applications. These will be used throughout the HFE process to capitalize on lessons learned. The NuScale HFE OER draws from multiple industries such as nuclear, petrochemical, pharmaceutical, and military. The selection of items for review will be based on similarities with the NuScale design, technologies, or concept of operations. The concept of operations for the NuScale plant includes the use of advanced automation to support the changing role of the operator in the main control room (MCR) including multi-modular monitoring and control. The objective of the OER is to inform the plant design processes, plant layout, plant support systems, operator training, operational procedures, and operations.

3.2 OER Scope

This section of the HFE Analysis Phase Implementation Plan covers the process for performing OER for the NuScale HFE Program.

OER includes

- reviews of related systems.
- reviews of issues from NUREG/CR-6400 HFE Insights For Advanced Reactors Based Upon Operating Experience (Reference 4).
- reviews of issues concerning the HFE technology proposed for the NuScale design.
- input from interviews with appropriate personnel.
- issues associated with any identified risk-important human actions (HAs).

This process follows the NUREG-0711 Rev. 2 (Reference 1) review criteria. The content analysis, tracking, and review criteria for each OER item is covered in the OER Method section, supported by the OER Process and Procedures subsection and the OER Process Output section below.

3.2.1 Reviews of Related Systems

The OER team, to determine whether these systems provide operating experience pertinent to HFE issues related to the NuScale nuclear power plant, will screen and review related systems. This will address criterion 3.4.1(1) from NUREG-0711. The OER team will organize searches for similar plants and systems within the nuclear industry, based on the NuScale system list, with guidance from the engineering representative in the OER team. Review of systems having similarities to the NuScale nuclear power plant, but not represented in the nuclear industry, will be organized and processed by the OER team. In particular, this may include systems dealing with multi-modular monitoring and control, highly automated control, use of mainly video display units for monitoring and control, digital instrumentation and control (I&C), and monitoring and control of multiple identical systems in the same control room. These features will be used as screening criteria for which similar systems need a full OER review.

There are no operating predecessor plants for the NuScale nuclear power plant. However, the Oregon State University's (OSU's) NuScale test facility may provide some operating experience to be reviewed by the OER process and will be captured in this section or the section covering personnel input by interviews.

3.2.2 Reviews of Issues from NUREG/CR-6400 HFE Insights For Advanced Reactors Based Upon Operating Experience

All of the issues from NUREG/CR-6400 will be entered in the OER database as OER items, screened for applicability to the NuScale design, and if applicable, will be reviewed by the OER team using the method outlined. Items that are not applicable to the NuScale HFE program are summarized in the OER database with an explanation for why the item does not apply. Review of all the NUREG/CR-6400 OER items addresses criterion 3.4.1(2) from NUREG-0711. The NuScale OER approach to each of the six areas covered by NUREG/CR-6400 is listed below.

1. Each item identified in the section of NUREG/CR-6400 covering the unresolved safety issues (USIs) and generic safety issues (GSIs) from NUREG-0933 (Reference 5) will be screened and reviewed by the OER team. The OER team will screen and review any new items contained in supplements to NUREG-0933 (from the time covered in NUREG/CR-6400 until the end of the calendar year prior to the year in which the OER is being performed).

2. Each item identified in the section of NUREG/CR-6400 covering Three Mile Island Issues from, 10 CFR 50.34(f) (Reference 6), NUREG-0933, and NUREG-0737 (Reference 7) will be screened and reviewed by the OER team.

3. In addition to the OER items listed in Section 4 of NUREG/CR-6400, the OER team will screen and review for OER items in the NRC Generic Letters and Information Notices (from the time covered in NUREG/CR-6400 until the end of the calendar year prior to the year in which the OER is being performed).

4. NUREG-1275, Vol. 8 (Reference 8) will be screened by the OER team to determine which of the human performance issues in that report will be considered OER items and need to be added to the OER database.

5. Each item in the section of NUREG/CR-6400 covering low power and shutdown operations will be screened and reviewed by the OER team.

6. Each item in the section of NUREG/CR-6400 covering the operating plant event reports issues will be screened and reviewed by the OER team.

3.2.3 Reviews of Issues of Proposed HFE Technology

HFE technology being reviewed by NuScale that is considered new or unproven, will go through the OER process, and be reviewed by the OER team. Unproven HFE technologies are those for safety-related systems have less than a year of successful operation at a light water reactor (LWR). Unproven HFE technologies for non-safety systems are those that have less than one year of successful operation in LWRs, fossil power plants, military, or industry process plants prior to startup date of the NuScale plant. Review of NUREG/CR-6947 (Reference 9) for examples of new and emerging technology and any HFE issues will be done by the OER team.

Some of the HFE technology proposed in the NuScale design that might fall in this category includes digital monitoring and control of most functions, use of computerized procedures, possible use of touch screens, and task management software for multi-modular monitoring and control. Reviews will include literature reviews, trade study evaluations, or operator interviews to collect the appropriate level of detail needed. The OER team will determine if the OER information provided for these technologies is adequate and will have the authority to request further information. The structures, systems and components (SSC) or function in the NuScale design that will apply the HFE technology will also be considered by the team to determine the amount of information necessary to complete the review of the OER item. This part of the OER process will address criteria 3.4.1(3) from NUREG-0711.

3.2.4 Personnel Interview Input

Issues identified by plant or system operators will be obtained by the use of personnel interviews where practical and feasible. The interviews will focus on design features applicable to the NuScale nuclear power plant HFE.

The OER team will conduct interviews with personnel capable of providing design input regarding all features including the unique features of the NuScale power plant. These interviews will be with operators with both nuclear and other industrial process experience. Interviews will cover topics as listed in criteria 3.4.1(4) of NUREG-0711. These topics include:

- plant operations, which include
  - normal plant evolutions (e.g., startup, full power, and shutdown)
  - instrument failures
  - HSI equipment failures and processing failures
  - transients
  - accidents
  - reactor shutdown and cool down using remote shutdown system
- HFE design topics
  - alarm and annunciation
  - display
  - control and automation
  - information processing and job aids
  - real-time communications with plant personnel, real time communications with other organizations
  - procedures, training, staffing/qualifications and job design

In addition to the items identified above from NUREG/CR-6400, items unique to the NuScale design will also be included. This encompasses multi-modular monitoring and control, multi-module control rooms,

highly automated control systems, module refueling coincident with other module power operation, and personnel interaction with highly automated systems.

3.2.5 Issues Associated with Risk-Important Human Actions

Risk-important human actions identified in the Probabilistic Risk Assessment / Human Reliability Analysis (PRA/HRA) process will be added as OER items into the database. The bases that were used to add human actions to the PRA or HRA will be included in the description or reference of the OER items. Note that any risk-important human actions that have been identified in previous or similar systems and documented in the OER database will be provided to the HRA process for consideration in the NuScale HRA and PRA. These steps will address criteria 3.4.1(5) from NUREG-0711.

The OER database will be used to document these items as requiring special attention during the design process. The priority of these OER items will be tracked using the HFE issue tracking system (HFEITS). The HFEITS process provides a means to capture resolution of issues.

3.3 OER Team

The OER team will include a representative from HFE (who will be the OER team lead and report to the HFE lead), engineering, safety analysis group, operations and a customer representative if one is available. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. A member of the HFE team will be assigned as the OER coordinator. The OER coordinator will be responsible for the quality and timeliness of the OER to support the HFE program plan and schedule.

The OER team will screen, review, and document OER items. The OER coordinator will be responsible for the database and organizing resources for reviews and documentation.

3.4 OER Method

The OER process includes the use of an OER team, OER coordinator, and OER database. This process provides the important first step in the HFE process for NuScale while addressing review criteria established by the Nuclear Regulatory Commission (NRC).

The OER method for the NuScale HFE program will follow a process outlined in this plan in conformance with NuScale procedures. NuScale procedures will include a procedure for the HFE issue tracking system (HFEITS) process.

Input to the OER process will follow the NRC review model in NUREG-0711 and include documented operating experience and operator interviews when appropriate. The OER items considered for screening and review will be documented in the OER database. The output from the OER process will be based on the OER database or periodic evaluation reports to support the HFE program schedule. An OER results summary report (RSR) will be prepared when the OER process is completed.

3.4.1 OER Process and Procedures

The OER process involves screening, reviewing, providing recommendations, and documenting OER items considered. The OER process includes the following steps:

1. developing an OER database for tracking and documentation

2. screening items for applicability to NuScale design
3. reviewing OER items for human performance issues, sources of human error and design elements
4. creating HFEITS issues for OER items that have not been addressed in the current NuScale design for tracking and resolution
5. signing off OER items

3.4.1.1 OER Database Development

The OER process will begin with developing an OER database described in the Operating Experience Review Tool section below. The OER database will guide and capture the data from the subsequent steps in the OER process.

3.4.1.2 Populate and Screen Items in OER Database

The OER team will use examples from sections of NUREG/CR-6400 as guidance on types of OER items to screen in the screening step. Further screening criteria are delineated in the Operating Experience Review scope section of this document.

3.4.1.3 Review of OER Items

The process includes reviewing OER items that have passed screening for human performance issues, sources of human error, and design elements that support and enhance human performance. Each item will be considered for how it affects the HFE program technical elements FRA&FA, TA, S&Q, HRA, HSI design, procedure development, training program development, and verification and validation. This review process addresses OER process criteria 3.4.2 (1) from NUREG-0711.

The OER items will be classified for safety significance as follows and may be one of four values: safety, non-safety, not classified, or other. Safety and non-safety will follow the NuScale quality program definitions while “not classified” is a placeholder to indicate that a classification has not yet been designated for the system that the OER item applies to. Finally, the “other” classification provides for currently undefined classification and, if used, must have justification provided in the comment text box of the database.

The OER item will be examined for the following

- completeness of OER item information in OER database.
- screening applicability to NuScale design. (If not applicable an explanation will be entered in the review as to why it is not applicable).
- classification of OER item.
- current incorporation and documentation in the NuScale design and if so supporting reference.
- recommendation(s) for how the operating experience item may be applied to NuScale design if not currently incorporated.
- complete comments as necessary to capture state of review (if left open) or to clarify item in the database.

Any missing information will be captured in the comments text field and the OER item is to remain with an open status.

3.4.1.4 Create HFEITS Issues

Any item that is identified as an issue requiring tracking in the HFEITS process will be input into the HFEITS database. The OER database will indicate that the issue has been transferred to the HFEITS database and tracking will be done by the HFEITS process. This allows for the OER item to be completed but still allows for searching the database to find items that are being addressed by the HFEITS process.

Items may also be identified and submitted to the OER process through use of the HFEITS process by any team or NuScale staff member.

3.4.1.5 Sign off OER Items

Sign off on each OER item from all OER team representatives will be documented in the OER database. The final sign off is by the OER team lead.

3.4.2 OER Tool

The OER database will be maintained as an electronic database. Revision control of the database and changes will be the responsibility of the OER database coordinator. The database will have at a minimum the following fields:

- OER Identifier – This field is a unique identifier for each OER item in OER database.
- Input Date – This field is a database input date of OER item.
- Review Date – This field is the date that the item was reviewed by the OER team.
- Review Status – This field indicates status of OER item (“Open” indicates that the review or documentation for the item is incomplete and “Complete” indicates that the review and documentation is complete.)
- Classification – This field is used to indicate the safety classification of the OER item (will have one of the following four values: “safety”, “non-safety”, “not classified”, or “other.”
- Description/Title – This is a text field for short description or title to provide clarification for sorting, for ease of discussion, or searching the database.
- Summary – This is a text field for summary of OER item including enough detail to either summarize experience item to support documentation or provide all detail if no reference/source documentation is available. Information will be provided as to why this item is an HFE-related safety issue.
- Reference/Source – This is a text field to capture OER item reference information in order to provide traceability for further review or basis of item. This will be a document title with revision and date information. In addition, document numbers and page numbers will be included if needed for clarity. Interview and individual accounts will contain all information in the summary text field or provide reference to documentation.
- Reference Plant/System – This is a text field to identify name of reference plant or system that operating experience item draws from.

- NuScale Applicable Process/System – If the applicable process or system in the NuScale plant is known it will be captured in this text field.
- NuScale Component – If the applicable component in the NuScale plant is known it will be captured in this text field.
- Review of how item is addressed – This is a text field to capture documentation of results of applicability screening, incorporation into current design documents or any recommendation(s) as to how the OER item could be addressed in the NuScale design.
- HFEITS Reference (if applicable) – This is a text field for HFEITS issue number if OER item is not currently addressed and documented in the design. The status of the HFEITS issue will also be included.
- OER Item Owner – This is a text field for the name of individual and their organization assigned to address open OER items.
- Comments – This field provides free text input for clarification of item or other OER database fields.

The OER database will be maintained by the OER coordinator. The OER coordinator will also coordinate any communication and action items associated with an OER item. A typical database will resemble the example in Figure 3-1.

HFE Operating Experience Review (OER) Revision A

OER Identifier	Input Date	Review Date	Review Status	Classification	Description /Title	Summary	Reference /Source	Reference Plant/System	NuScale applicable Process/ System	NuScale Component	Review of How item is addressed	HFEITS Reference (if applicable)	OER Item Owner	Comments
OER-xxxx	YYYYMMDD	YYYYMMDD	Open/ Complete	Safety/ Non Safety/ Not Classified /Other	text	text	Reference & # of OE source	Name of reference plant or system	Identifier	Identifier if applicable	Text description & reference to NuScale documentation	#/status	Name of Organization	text
OER-0001														

Figure 3-1 Typical HFE OER database

An OER item is considered complete when it has supporting documentation that it is complete (including sign off from owner) and the item has been approved by the OER team as complete.

3.5 OER Process Outputs

The output of the OER process will be documented in the form of OER database data or OER report(s). The OER report(s) will be created to support the HFE program as necessary. The report(s) will be used as the basis for other technical elements of the HFE program and will be provided to other organizations within NuScale as requested. The complete and current database will be reviewed each time any HFE program technical element iterates through a design cycle. HFE program technical elements using output from the OER process include the following:

- Function Requirements Analysis and Functional Allocation (FRA&FA)

The OER provides inputs to ensure that functions that have had HFE-related issues will be captured in enough detail. This includes developing sub-functional levels to the degree necessary to capture issues identified in the OER process. Any items requiring changes for specific systems or components will be addressed through the engineering change process. The FRA&FA process may identify functions that need to be modified. This would be done working with engineering and the engineering change process. OER also highlights the lessons learned on the distribution of functions between human and machine, thereby informing function allocation.

- Task Analysis (TA)

  The OER database is an input to the TA process and will provide risk-important human actions identified during OER and any errors in similar systems that will need to be analyzed during TA. The individual OER items also provide guidance on what level of detail of TA is required in order to include the OER identified issues.

- Staffing and Qualifications (S&Q)

  Any OER items dealing with staffing and qualifications will be examined as part of the scope for the S&Q plan. The S&Q process will look for items identified that have risk-important human actions or errors, indicate problematic operations and tasks, and may indicate staffing shortfalls in the past. A review of the OER database will need to be done as an input to the S&Q process.

- Human Reliability Analysis (HRA)

  The OER will provide a list of risk-important human actions that will need to be considered when performing the HRA and may provide guidance on what level of detail the HRA analysis will need to be done to include the OER identified items. These items may include risk-important human actions or errors not already identified in the PRA or HRA along with problematic operations. The HRA process will need to incorporate the identified OER items in calculations and in support of the PRA effort. In addition, any risk-important human actions that have been identified in previous or similar systems and documented in the OER database will be provided to the HRA process for consideration for input to the NuScale HRA and PRA.

- Human-System Interface (HSI)

  The OER provides a list of items that require attention during the HSI design process. The items identified in the OER process may include trade study evaluations, or potential design solutions or issues. A review of the OER item list and recommendations will be done by the HSI design team.

- Procedure Development

  OER provides a list of items that require attention during the procedure development. The items identified in the OER process may include potential design solutions or issues with procedure implementation. A review of the OER item list and recommendations will be done by the HFE team member assigned to support the procedure development.

- Training Program Development

  The OER provides a list of items that require attention during training development. The items identified in the OER process may include potential design solutions or issues that may be provided to the utility companies that will own and operate a NuScale nuclear power plant and maintain a

training program for their trained operators. A review of the OER item list and recommendations will be done by the HFE team member assigned to support training development.

- HFE Verification and Validation (V&V)

  The OER database will be one input for the planning of the V&V of the HFE process. The identified OER items may contribute to the criteria for system or design element V&V along with the extent of V&V. This may include effectiveness of some design features, tasks to be evaluated, scenario selection, and performance measure selection. It will also provide support for issue resolution verification. The V&V team will review the OER database for items that need to be considered by the V&V process.

Output from the OER process will fulfill the Operational Experience requirement of the exemption request that NuScale will file in support of the MCR design concept.

An OER Results Summary Report (RSR) will be prepared when the OER process is complete. This report will contain the scope of operating experiences reviewed and documentation of OER item review analysis. The report will also contain a list of items input to the HFEITS process including status of those issues with respect to the review criteria in NUREG-0711 Section 3.4. The RSR fulfills review criteria 3.4.2 (2) from NUREG-0711. The OER database will capture the necessary details for each OER item. A listing from the HFEITS database may also be included in the OER RSR if it provides additional information. The connection to the HFEITS process fulfills review criteria 3.4.2 (3) from NUREG-0711.

4.0 Functional Requirements Analysis and Function Allocation Implementation Plan

4.1 FRA&FA Purpose

The FRA&FA technical element of the HFE Analysis Phase Implementation Plan identifies the process for defining the plant's functional requirements, allocating those requirements that take advantage of human strengths of the operators, and avoiding allocation of functions to operators that would be negatively affected by human limitations.

Functional Requirements Analysis is the identification of those functions that must be performed to satisfy the plant's objectives (e.g., to prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public). This analysis establishes the objectives, performance requirements, high-level functions, relationships between functions, and constraints of the plant. In doing so, the analysis also provides a framework for understanding the role of controllers (whether personnel or system) in regulating plant processes. High-level functions, plant systems, and components are addressed, as necessary, along with parameters appropriate for the function level.

Function Allocation is the analysis of the functional requirements for plant control and the assignment of control functions to plant personnel, automation (including passive), or shared control between operator and automation. Selection of shared control requires further analysis based on the nature of the sharing, ranging from automation assisted decisions to personnel approved actions. Guidance for allocation will be drawn from NUREG/CR-3331 (Reference 10).

Plant safety and reliability are enhanced by exploiting the strengths of both personnel and system elements, including improvements achieved by assigning control to these elements with overlapping and redundant responsibilities. Function Allocation will be based on HFE principles and use a structured, well-documented methodology that provides personnel with logical, coherent, meaningful tasks as presented in Appendix B.

NuScale will also use the FRA&FA process to develop and analyze the concept of operation of multi-module monitoring and control. The results of this analysis will help fulfill the requirements for an exemption request from the staffing requirements in 10 CFR 50.54(m) (Reference 3). The staffing exemption request will be developed using NUREG-1791, and NUREG/CR-6838 as guidance (Reference 11 and Reference 12).

4.2 FRA&FA Scope

The FRA&FA is an iterative process that supports the design of the NuScale nuclear power plant. This includes control functions and function allocation based on changes in design specifics, OER input or other studies. NuScale will maintain the analysis in a current state over the life cycle of design development through decommissioning to provide a suitable design basis when modifications are considered. This addresses criteria 4.4(2) from NUREG-0711 Rev. 2 (Reference 1) with the limitation of the responsibility of updating the analysis being dependent on the commercial relationship of the designer and any end user of the HFE process.

The following will be inputs to the FRA process:

- OER Report or output from the OER database

  This provides inputs to ensure that functions that have had a safety-related issue will be captured in enough detail. That includes developing sub-functional levels to the degree necessary to capture issues identified in the OER process. These may be translated into requirements for specific systems or components and will be addressed through the engineering change process and using the HFEITS process when necessary. The FRA&FA process may identify Structures, Systems and Components (SSC) functions that need to be modified. This will be done working with engineering and the engineering change process. Function allocation guidance in general or for specific functions may be based on OER items that indicate successful or less than successful allocations in similar systems.

- System functional specification and other system design documents as needed for reference in order to examine details of plant and system required functions

- Risk Report from the safety analysis group covering identified human actions from PRA along with HRA results

After the initial FRA&FA determination, the iterative design process will incorporate information from the HSI design process through inclusion in the FRA&FA inputs for the next iteration of the FRA&FA process. One input from the HSI design process is the concept of operation (from the HSI process) for both control room and entire plant that is developed in more detail in support of the HSI design process.

Another input source that may be incorporated is from any combined license (COL) applicant referencing the NuScale nuclear power plant design. The HFE program will work with the engineering group from the COL applicant.

Input to the function allocation part of the FRA&FA process will be directly from the function requirements analysis part of the process.

The FRA&FA process and analysis results will help fulfill the requirements for an exemption request from the requirements of 10 CFR 50.54(m) with regard to the monitoring and control of12 NuScale modules in one control room. In addition, the process will provide the analysis to support the proposed multi-modular monitoring and control done by a staff of less than that called out in 10 CFR 50.54(m) . This will provide input to the exemption request process following guidance from NUREG-1791.

NuScale will maintain the FRA&FA analysis as a suitable basis for future plant modifications. When and if these modifications take place, the FRA&FA analysis will be referenced, updated, and used to support the modifications. A review and analysis will be conducted to ensure that modifications likely to change existing safety functions are addressed. The analysis will also address function allocation between human and machine along with the operator role due to a modification including task demands. This addresses criteria 4.4(11) from NUREG-0711.

4.3 FRA&FA Team

The FRA&FA team will include a representative from HFE (who will be the OER team lead and report to the HFE lead), engineering, safety analysis group, operations and a customer representative if available. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. The FRA&FA process is supported by the NuScale Cognitive Work Analysis (CWA) process as described in Appendix A. The HFE engineers conducting the analyses are

responsible for coordinating the FRA&FA database and reporting requirements in support of the HFE program plan and schedule.

4.4 FRA&FA Method

4.4.1 FRA&FA Process and Procedures

This section of the HFE Analysis Phase Implementation Plan covers the process for performing FRA&FA for the NuScale nuclear power plant HFE Program.

The FRA&FA process will be based on the CWA methodology (Reference 13) outlined in Appendix A. The CWA process has proven useful for analysis of complex systems (Reference 14). The CWA process includes the following five phases:

- Work domain analysis

  This phase will include a physically accurate and psychologically relevant model of the NuScale nuclear power plant using the abstraction-decomposition space (ADS) that captures both the plant purpose relevant affordances and constraints.

- Control task analysis

  This analysis will be done using decision ladder task analysis methodology to understand work tasks within the constraints of the work domain while defining what needs to be accomplished. This will be in terms of information-processing activities and states of knowledge.

- Strategies analysis

  This analysis will be used to explore how the control task analysis information-processing activities are actually performed.

- Social organization and cooperation analysis will support the function allocation part of FRA&FA along with supporting the S&Q process.

- Worker competencies analysis will support the S&Q process and will be discussed in more detail in the TA and S&Q plan sections of the HFE Analysis Phase Implementation Plan.

The CWA process will be used to determine the functions and the scope of functions to be considered for functional requirements analysis. The FRA&FA team will review the plant functions that cover the operational conditions to ensure all functions have been included in the analysis.

The CWA process has three phases that provide for a means of identifying functions and the information requirements associated with those functions. These three phases are work domain analysis (WDA), control task analysis and strategies analysis. The details of these phases are described in Appendix A. The use of CWA as a means to perform functional requirements analysis and provide guidance on function allocation addresses criteria 4.4(1) from NUREG-0711.

Function allocation is supported by the fourth CWA phase of social organization and cooperation analysis. This phase will provide the initial input and framework to support function allocation and documentation. The NuScale function allocation process is described in Appendix B.

The FRA&FA process covers the categorizing, structuring, data collection, and documentation of functions for analysis and allocation. The FRA&FA process includes the following steps:

1. Develop an FRA&FA database for tracking and documentation of functions, systems, and components as defined in the NuScale CWA process.
2. Perform a work domain analysis using ADS diagrams.
3. Populate the database with information requested in Section 4 of NUREG-0711 and supporting documentation.
4. Create a list of operational conditions.
5. Develop a list of goals for control task analysis to apply to the ADS for all applicable operational conditions.
6. Perform control task analysis (as defined in the NuScale CWA process that is delineated in Appendix A) using decision ladders.
7. Create task summaries for goals analyzed using decision ladders.
8. Perform strategies analysis and capture strategy options and classes of options in a revised set of task summaries.
9. Perform social organization and cooperation analysis in order to allocate functions and develop integrated personnel roles across functions. This is done using NuScale function allocation rules, called out in Appendix B, that direct the decision of how to apply level of automation during function allocation.
10. Create high level function decomposition diagram for human performed functions with supporting documentation using strategies or strategy classes to show success paths or configurations for different operating conditions.

After the initial FRA&FA determination, the iterative design process will incorporate information from the HSI design process through inclusion in the FRA&FA inputs for the next iteration of the FRA&FA process. In particular, the concept of operation for both control room and entire plant developed during the HSI design process will be subjected to the iterations of the analysis specified in the FRA&FA method above.

4.4.1.1 Develop FRA&FA database

The FRA&FA database will be developed using the outline provided in the FRA&FA tools section below. The database will be coordinated and updated by a CWA team member assigned by the HFE team representative who is responsible for the CWA process (see Appendix A).

4.4.1.2 Work Domain Analysis (ADS Methodology)

A work domain analysis will be performed using the ADS methodology described in Appendix A. It addresses the why, what, and how questions for the means-ends hierarchal abstraction. The part-whole decomposition will use engineering functional specifications, systems requirements documents, engineering drawings and engineering diagrams. The HFE team member(s) working on the ADS will work with the engineering team member representative to ensure that the engineering input is accurate and

current. The ADS process is iterative during development and will be revised with changes to the plant design and updates from other HFE program technical elements as required.

4.4.1.3 Populate Database

The team members performing the ADS phase of CWA will be responsible for populating the database as the ADS is being developed and revised. This will include the abstraction level and the decomposition level for the ADS. Other important fields for high-level functions include a description of the function and any differences compared with predecessor functions or systems. The descriptive information collected shall also include purpose, conditions indicating need, parameters for the availability, operating, achieving purpose, and termination conditions for the function. The FRA&FA database will be used to capture and store this information for high-level and other appropriate functions. This step addresses part of criterion 4.4(3) and all of criterion 4.4(4) from NUREG-0711.

4.4.1.4 Operational Conditions

A list of operational conditions will be created covering operational tasks (normal, abnormal, and emergency), plant maintenance, and plant surveillance and testing. The list will contain operational conditions to be analyzed, which present the greatest potential challenges to the effective and safe performance of control personnel under the NuScale power plant highly automated multi-modular monitoring and control design concept.

Multiple dimensions will be considered when creating the list of operational conditions. The following list of factors is derived from NUREG-0711 and contains some of the sampling from the dimensions (plant conditions, personnel tasks, and situational factors) for V&V operational conditions sampling:

- normal operational events including plant startup, plant shutdown or refueling, and significant changes in operating power
- failure events
  - instrument failures including I&C failures that exceed the design basis
  - HSI failures (e.g., loss of processing and/or display capabilities for alarms, displays, controls, and computer-based procedures)
- transients and accidents
  - transients (e.g., turbine trip, loss of off-site power, station blackout, loss of feed 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 small break loss-of-coolant accidents)
  - reactor shutdown and cool down using the remote shutdown system
- reasonable, risk-significant, beyond-design-basis events, which will be determined from the plant specific PRA
- consideration of the role of equipment in achieving plant safety functions and the degree of interconnection with other plant systems. A system that is interconnected with other systems could

cause the failure of other systems because the initial failure could propagate over the connections. This consideration is especially important when assessing non-class 1E electrical systems.

- Regulatory Guide 1.33, Appendix A (Reference 15) contains several categories of "typical safety-related activities that will be covered by written procedures." The following activities are included:
  - 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
  - procedures for control of radioactivity
  - procedures for control of measuring and test equipment and for surveillance tests, procedures, and calibration
  - procedures for performing maintenance
  - procedures for chemistry and radiochemical control
- range of human interactions – This involves human interactions among plant personnel, including tasks that are performed independently by individual crewmembers and tasks that are performed by crewmembers acting as a team. These interactions among plant personnel may include interactions between the following personnel:
  - main control room operators (e.g., operations, and shift turnover walkdowns)
  - main control room operators and auxiliary operators
  - main control room operators and support centers (e.g., the technical support center and the emergency offsite facility)
  - main control room operators with plant management, NRC, and other outside organizations
- environmental factors – Factors such as poor lighting, extreme temperatures, high noise, and simulated radiological contamination.

All inputs into the FRA&FA process will also be reviewed for other conditions that need to be considered in operational conditions list development. This includes items from OER and HRA/PRA. Any problematic OER issues identified will be transferred and documented in the task summary in the comments and recommendation fields. This will include justification of the function analysis and function allocation. This addresses criteria 4.4(7) from NUREG-0711.

In addition to factors listed above, operational conditions unique to the NuScale nuclear power plant proposed design will be considered. These include operational conditions related to a multi-modular power plant with shared systems, up to 12 modules being monitored and controlled in a single control room and multi-modular monitoring and control by staffing different than that called out in 10 CFR

50.54(m). The list of operational conditions will be documented in an operational conditions document and revisions will be controlled using the NuScale documentation process and procedures.

4.4.1.5 List of Goals for Control Task Analysis

A list of goals, as defined in the NuScale CWA process, will be developed for use in the control task analysis phase of CWA. The operational conditions will be used extensively when developing the list of goals to analyze in this step to ensure that goals are considered for combinations of operational conditions that cover the range of important actions. This list will identify goals for control task analysis and may contain similar information as the functions documented in the ADS phase of the CWA. The FRA&FA database will be used to capture the list of goals that will be used for control task analysis. Each of these goals will be added to the FRA&FA database along with any pertinent details to clarify the goal.

4.4.1.6 Control Task Analysis

Control task analysis will be performed using the decision ladder template and the process in Appendix A. The control task analysis is a process of creating generic tasks in the sense that function allocation (human or machine) has not been done. This step encompasses what is to be done within the constraints captured in the ADS for a given goal. The ADS will guide the control task analysis by specifying available system capabilities and constraints. The resulting decision ladders for the list of goals will provide a way of using the ADS diagram to identify the information-processing activities and states of knowledge that need to be used in completion of the goal. The details of the decision ladder will be tabulated in the next step using task summaries.

4.4.1.7 Task Summaries from Control Task Analysis

Task summaries will capture the steps of the goals (information-processing activities and states of knowledge) specified in the decision ladders used during the control task analysis. An example of a typical task summary can be seen in Figure A-3 of Appendix A. The steps of the goals (used for control task analysis) documented in the task summaries will not be allocated to an actor (human or machine). The advantage of this is that multiple strategies and staffing arrangements may be explored to optimize and ensure the most efficient and safe operation in the workspace. The task summaries may be used to collect data similar to a traditional hierarchical task analysis and will be used in later FRA&FA steps along with the TA, and S&Q processes that use input from FRA&FA.

4.4.1.8 Strategies Analysis

Strategies analysis will use the task summaries and may use information flow maps to document the different strategies (how the goal is achieved) that are available to satisfy the goal used to develop the decision ladders. The alternative strategies identified will be represented in information flow maps.

The strategies analysis is also the phase of analysis where enough details will be available to support the description of the connection between high-level functions down to critical end-item requirements in support of plant functions. The list of strategies and the information flow maps will allow for a set of plant system configurations or success paths responsible for carrying out the function to be defined and documented. The team will review configurations for completeness and accuracy. The documentation will be completed on a representation of the ADS diagram or similar representation. This addresses part of criteria 4.4(3) from NUREG-0711. Strategies analysis phase is outlined in the NuScale CWA process in Appendix A. Results of this analysis will be appended onto the task summaries.

4.4.1.9 Social Organization and Cooperation Analysis Along with Function Allocation

Function allocation will occur after completion of strategies analysis. The control task analysis creates tasks that may be performed by either human or machine and have yet to be allocated. Tasks that end up being allocated to humans will then be analyzed in the TA process covered by the TA Implementation Plan to ensure all needed information for further analysis and design is captured.

The information flow maps from the strategies analysis step will be used to evaluate different allocations of actors (human or machine) to actions. The criteria used will include the objective of keeping the operator engaged in meaningful decision making and control of the systems. The resulting allocation options will be the starting point for the team in applying the function allocation method in Appendix B.

The CWA social organization and cooperation analysis phase along with information learned during the control task analysis and strategies analysis phases of CWA will be used in conjunction with the function allocation guidance called out in Appendix B. The NuScale function allocation process called out in Appendix B will also apply to the multi-modular monitoring and control design that is proposed. This is part of the social organization and cooperation analysis phase of CWA where the unique nature of monitoring automation for multi-modular monitoring and control will be emphasized. This addresses part of criteria 4.4(8) from NUREG-0711.

4.4.1.10 Create High Level Function Decomposition Diagram

A high-level function decomposition diagram with supporting descriptions will be used in multiple ways. The development of a description of the integrated personnel role across functions and systems will be provided in terms of personnel responsibility and level of automation. This will be done by restating the level of automation scheme (from function allocation) with any exceptions. Graphing of personnel responsibilities onto the ADS will also be used to provide another qualitative representation of personnel roles. This addresses criteria 4.4(9) from NUREG-0711.

The first use of the high-level decomposition diagram will be to communicate the results of the CWA process up to this point in the FRA&FA process. The next use will be support of verification of the functional requirements analysis to ensure that all high-level functions are identified along with the requirements for those high-level functions. This. along with mapping of operator roles onto the ADS diagram, will also be used to verify that function allocation resulted in a coherent role for the plant personnel. This addresses criteria 4.4(10) from NUREG-0711. Verification, of the high-level decomposition diagram, will be done by a panel composed of HFE, engineering, and operations personnel.

4.4.2 FRA&FA Tools

The FRA&FA process shares tools with the TA process. This includes data collection, processing, and reporting. This section also describes the tools and how the tools are to be used to support FRA&FA. The supporting details of the tools and supporting processes are contained in Appendices A and B.

The first tool in preparing for functional requirements analysis is a work domain analysis. NuScale will use an abstraction-decomposition space (ADS) process to document the work domain. An example of the ADS is shown in Appendix A.

An FRA&FA database will capture the details that cannot be conveniently documented in the ADS diagram. The database and ADS diagrams will capture the high-level functions and descriptions. This documentation will include how those high-level functions (and systems supporting the functions)

compare to any reference plant or systems identified in the OER results. This will also include any technical basis for modification compared with predecessor design and addresses criterion 4.4(5) and part of criterion 4.4(3) from NUREG-0711.

The FRA&FA database will capture information about functions considered for review in the functional requirements analysis process. These include parameters for high-level functions and addresses criterion 4.4(4) from NUREG-0711 and are listed in the database fields list below:

- FRA&FA identifier – This is a unique number for function, affordance, or goal (used in preparation for control task analysis phase).
- Title – This is a text identifier to assist in tracking of entry (optional).
- Description – this field is a text entry capturing nature of entry and any changes from predecessor.
- Status – This field indicates status of entry. “Open” indicates that the review or documentation for the entry is incomplete, “Complete” indicates that the analysis, allocation, and documentation is complete.
- Predecessor function or system – This field is a reference for predecessor function or system if one exists including name, revision, and documentation.
- Purpose – This field indicates the purpose of function, system, or component. This may be in the form of a means-ends connection associated with the ADS.
- Condition(s) indicating function is needed – This field indicates either an operating condition or event (planned or unexpected) that requires the function to maintain high-level functions or goals of the plant.
- Parameter(s) indicating function is available – This field contains alarms, sensor values, calculated values, component status, plant mode or combination needed to allow the allocated actor (man or machine) to know if the function is available.
- Parameter(s) indicating function is operating – This field contains alarms, sensor values, calculated values, component status, plant mode or combination needed to allow the allocated actor (human or machine) to know if the function is operating. This may require monitoring of a value or set of values over time.
- Parameter(s) indicating function is achieving required purpose – This field contains alarms, sensor values, calculated values, component status, plant mode, or combination needed to allow the allocated actor (human or machine) to know if function is achieving the purpose. This may require monitoring of a value or set of values over time.
- Parameter(s) indicating that function can or should be terminated – This field contains alarms, sensor values, calculated values, component status, plant mode, or combination needed to allow the allocated actor (man or machine) to know if function can be terminated.
- Abstraction level – This field is the level in the abstraction hierarchy (means-ends) in the ADS structure and will be functional purpose, abstract function, generalized function, physical function, or physical form. This will reference any links to other functions by referencing the unique identifiers for those functions.

- Decomposition level – This field contains the level in the decomposition hierarchy (part-whole) in the ADS and will be total system, subsystem, function unit, subassembly, or component.
- Function Owner – This field is the name of individual and their organization who has design authority over function.
- Comments – This field provides free text input for clarification of item or other FRA&FA database fields.

An example of a typical FRA&FA database is shown in Figure 4-1 Typical FRA&FA database.

HFE Functional Requirements Analysis and Function Allocation (FRA&FA)Database Revision A																
Identifier	Title	Description	FRA Status	Predecessor Function or System	Purpose	Conditions Indicating Need	Availability Parameter(s)	Operating Parameter(s)	Function Achievement Parameter(s)	Termination Parameter(s)	Abstraction Level	Decomposition Level	Function Owner	Function Allocation	Allocation Status	Comments
F-xxxxxx or G-xxxxxx (F for function in support of ADS, G for goal in suppers of control task analysis)	YYYY MMDD	text	Open/ Complete	Name of reference plant or system	text	text	text	text	text	text	text	text	Name and Organization	Human/ Shared/ Machine/ not yet allocated	Open/ Complete	text
F-000001																
F-000002																
G-000001																
G-000002																
G-000003																

Figure 4-1 Typical FRA&FA database

Goals compiled for use in the control task analysis phase of the CWA using decision ladders will be entered and stored in the FRA&FA database. A list of operational conditions will be kept. An example of a typical operational conditions list is shown in Figure 4-2.

Operational Conditions							**Revision A**
Identifier	**Title**	**Class**	**Description**	**References**	**Procedures**	**Environmental Factors**	**Comments**
Unique number identifier	**text title for condition**	**Normal/ Abnormal/ Transient/ Failure/ Accident/ Emergency**	**text summary of condition**	**text listing references for condition**	**list of procedures that apply to condition**	**text describing any**	**text field for clarifying details**
OP-001	Plant Startup	Normal					
OP-002	Plant Shutdown	Normal					
OP-003	Refueling	Normal					
OP-004	Low Power	Normal					
OP-005	Shutdown	Normal					
OP-006		Abnormal					
OP-007	Instrument failure	Failure					

Figure 4-2 Typical operational conditions list

Documentation of the strategies analysis phase of the CWA will be captured by revising and appending results onto task summaries that were originally created during the control task analysis phase.

The tool used to perform and document the control task analysis is the decision ladder. An example of the typical decision ladder is shown in Appendix A. Summaries will be created from the decision ladders to capture the informational requirements for each information-processing activity and state of knowledge. An example of a typical representation of this is also in Appendix A.

Function allocation information is appended onto task summaries. This addresses criterion 4.4(6) from NUREG-0711 and includes the following:

- technical basis for function allocation
- allocation criteria
- allocation rationale

The analysis method used for function allocation (social organization and cooperation analysis from the CWA process in Appendix A) uses the information gathered in earlier steps of the FRA&FA. The function allocation process also uses the NuScale function allocation method detailed in Appendix B. The allocation decision, level of automation, basis, and criteria used will be added to the task summaries.

The functional decomposition representation will be performed as a graphic hierarchal representation. That allows for sufficient detail to verify all high-level functions necessary for achievement of safe operation and will be identified along with requirements of each high-level function. The functional decomposition will also provide a description of the integrated personnel role across functions and automation.

4.5 FRA&FA Process Outputs

The output for the FRA&FA process will be ADS diagrams, task summaries, information flow maps, the functional decomposition diagram, and FRA&FA report(s). The FRA&FA report(s) will be created to support the HFE program as necessary. The report(s) will be used as the basis for other technical

elements of the HFE program along with any other areas within NuScale. A version of the report will be created for the verification of the High-level functions at the end of the FRA&FA process. HFE program technical elements using output from the FRA&FA process include the following:

- Task Analysis (TA)

  The function allocation will identify human tasks for detailed task analysis and will be documented in task summaries from the control task analysis phase of the CWA process. The FRA&FA process will be directly linked to the TA process and will share data on a continual basis during analysis. As necessary in the HFE process a set of reports may be created that distinguish the data and analysis in separate reports or forms for documentation purposes.

- Staffing and Qualifications (S&Q)

  The function allocation output along with the task summaries containing results from the social organization and cooperation analysis will provide input to the S&Q process. This input will be used in the fifth phase of the CWA process which is worker competencies analysis.

- Human Reliability Analysis (HRA)

  If any risk-important human actions are identified in the FRA&FA process then these will be documented and provided to the HRA process directly or by use of the HFEITS process and then directed to the PRA.

- Human-System Interface (HSI)

  The function list from the ADS diagrams (FRA&FA database) and information in the task summaries will provide requirements to the HSI design process. The informational requirements identified will provide guidance and requirements.

- HFE Verification and Validation (V&V)

  The operational conditions list will be used to develop conditional sampling for V&V. The output from FRA&FA will also be used to build scenarios for validation testing. The V&V plan will also use the list of functions, functional structure, and function allocation to build scenarios

- Inputs to maintenance concept

  The specific allocation of functions to human and machine will also affect responsibilities of control room and maintenance personnel during maintenance. Any FRA&FA results affecting details or procedural information for maintenance will be provided to the developer of the maintenance concept for the NuScale nuclear power plant.

Operational conditions will be created for use during the FRA&FA but also to support other HFE program technical elements.

Output from the FRA&FA process will fulfill the Operational Conditions and FRA&FA report requirements of the exemption request that NuScale will file in support of the MCR design concept.

A FRA&FA Results Summary Report (RSR) will be prepared when the FRA&FA process is complete. This will include a summary of review criteria for NUREG-0711 Section 4.4. This report may also contain

examples from the FRA&FA process and will have a summary of the high-level verifications that was performed during the FRA&FA process. A copy of the operational conditions will also be included.

5.0 Task Analysis Implementation Plan

5.1 TA Purpose

Task Analysis is the identification of task requirements for accomplishing the functions allocated to plant personnel. This adds to the information gathered in the control task analysis performed in the FRA&FA process. The Task Analysis process is iterative in nature and supports the plant design as it matures. The Task Analysis method will use the databases and diagrams from the FRA&FA process and the NuScale CWA process outlined in Appendix A. The HFE Analysis Phase Implementation Plan describes how Task Analysis will be used to provide the following:

- one of the bases for making decisions about HSI design including specifying the design requirements for the displays, data processing, and controls needed to carry out tasks
- basic input for developing procedures
- basic information for developing the staffing, qualifications, training, and communication requirements of the plant
- task topics (as appropriate) including
  - information requirements
  - decision making requirements
  - response requirements
  - communication requirements
  - workload
  - task support requirements
  - workplace factors
  - situational and performance shaping factors
  - hazard identification

Task Analysis encompasses a range of plant operating conditions, including startup, normal operations, abnormal operations, transient conditions, low power, shutdown, and refueling conditions. The Task Analysis process also extends to the tasks required for maintenance of the plant. The operational conditions developed in the FRA&FA process will be used to verify that task analysis looks at representative human tasks from multiple operational conditions and human processing steps.

The output of the Task Analysis will be Task Analysis Report(s) for use as input by several of the other HFE program technical elements. The Task Analysis results are also used to define a minimum inventory of alarms, displays, and controls. In addition, Task Analysis supports changes over the life cycle of the NuScale nuclear power plant design and implementation, including a process for addressing tasks resulting from or required for modification of the plant.

5.2 TA Scope

The TA is an iterative process that increases in detail as the design of the NuScale nuclear power plant progresses through the engineering design phases. This process includes enough details to provide requirements to the HSI design process, which in turn will enable specification of HSI details including alarms, displays, controls, and data processing to support human tasks. This addresses criteria 5.4(3) from NUREG-0711 Rev. 2 (Reference 1)

This section of the HFE Analysis Phase Implementation Plan covers the process for performing TA for the NuScale nuclear power plant HFE Program.

The TA process will be directly linked to the FRA&FA process and will share data on a continual basis during analysis.

HFE program technical elements have input into the TA and are listed below:

- OER Report or output from the OER database

  This provides a list of risk-important human actions and errors that will be included in the TA and provides guidance on the level of detail analysis that will be performed in order to include the OER identified issues. A review of the OER item list will be accomplished by the TA team as part of their input review.

- FRA & FA Database/report(s)

  Input from FRA&FA will be direct in the form of FRA&FA reports, databases, or diagrams from the process with an emphasis on task summaries. The task summaries will have detailed information about the human tasks that need to be further detailed. The decision ladders, ADS, and function decomposition representation will be used for orientation and organizing human task within the work domain. The operational conditions list created during the FRA&FA process will be used to ensure that selected representative and important tasks are included in the TA. These include operations, maintenance, test, inspection, and surveillance and the full range of operating modes called out in Section 4.4.1.4 in the FRA&FA IP. The function allocation results will be used to select tasks that require monitoring of automation and execution of backup actions when automation fails. This addresses part of criterion 5.4(1) from NUREG-0711.

- PRA through the HFE HRA report

  The HRA input through the HFE HRA process will allow identification of risk-important human actions in the task summaries and ensure that those human actions are fully analyzed including ensuring that the detailing of the task hierarchy has enough depth to capture the level of detail provided by the HRA report. This addresses part of criterion 5.4(1) from NUREG-0711. Any HRA inputs are identified by noting in the task summary HRA field.

After the initial TA determination, the iterative process dictates review of information from other HFE program technical elements.

Modification to the plant in the future will reexamine the TA process reports, and diagrams including updated task summaries. This is done to ensure any design modifications have not created modifications in the nature of the human actions identified as risk-important. This will require the FRA&FA results, database, and analysis diagrams. If a modification affects HSI features, the existing characteristics will be

considered in the modification including input regarding adjustments made by operators. Finally, any new OER information will be considered. NuScale will maintain the analysis in a current state over the life cycle of design development through decommissioning to provide a suitable design basis when modifications are considered. This addresses criteria 5.4(7) from NUREG-0711 with the limitation of the responsibility for updating the analysis being dependent on the commercial relationship of the designer NuScale and any end user of the HFE process.

5.3 TA Team

The TA team will include a representative from HFE (who will be the OER team lead and report to the HFE lead), engineering, safety analysis group, operations and a customer representative is one is available. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. The TA process is supported by the NuScale CWA process. The TA process coordinator will use the task summaries for reporting requirements in support of the HFE program plan and schedule.

5.4 TA Method

5.4.1 TA Process and Procedures

The TA process will leverage the work done in the NuScale CWA process described in Appendix A and used during the FRA&FA process. The process will use task summaries from the FRA&FA as the data collection and documentation tool. The TA process adds more detail to the tasks allocated to humans. This includes the human tasks of monitoring the automated system and providing backup to automated actions when automation fails. The TA process will be performed in the following steps:

1. Gather and review FRA&FA database and documentation inputs.
2. Organize the decision ladders and task summaries into task sequences for analysis.
3. Detail task summaries with further task information.
4. Use task summary items allocated to personnel to create a narrative description of what personnel have to do.
5. Create definitions of minimum inventory (alarms, displays, and controls necessary to perform crew tasks based on both task and instrumentation and control requirements) for the main control room and remote shutdown station (RSS).

After the initial TA determination, the iterative process dictates review of information from other HFE program technical elements.

5.4.1.1 Review Inputs

All input listed in the scope section of this plan will be reviewed by the TA team. The review will make sure the TA performer is familiar with all input content.

5.4.1.2 Organize Decision Ladders

The task analysis will start at a high level to organize the decision ladders in a meaningful way and to ensure that all appropriate work sequences are addressed. A high level sequencing of tasks may be

created using operational sequence diagrams if the organization of the decision task ladders does not provide an adequate top-level description to begin analysis.

5.4.1.3 Detail Task Summaries

The types of information to be considered when detailing the human task are based on Table 5.1 from NUREG-0711 and covers the following task considerations:

- information requirements
  - alarms and alerts
  - parameters (units, precision and accuracy)
  - feedback needed to indicate adequacy of actions taken
- decision making requirements
  - decision type (relative, absolute, probabilistic)
  - evaluations to be performed
- response requirements
  - type of action to be taken
  - task frequency, tolerance and accuracy
  - time available and temporal constraints (task ordering) physical position (stand, sit, squat)
  - biomechanics
    - movement (lift, push, turn, pull, crank)
    - forces needed
- communication requirements
  - personnel communication for monitoring information or control
- workload
  - cognitive
  - physical
  - overlap of task requirements (serial vs. parallel task elements)

- task support requirements
  - special and protective clothing
  - job aids or reference materials needed
  - tools and equipment needed
- workplace factors
  - ingress and egress paths to the worksite
  - workspace envelope needed by action taken
  - typical and extreme environmental conditions, such as lighting, temperature, noise
- situational and performance shaping factors
  - stress
  - reduced manning
- hazard identification
  - identification of hazards involved, e.g., potential personal injury

A copy of the table will be used to guide the HFE team member performing the analysis through the fields of the task summary. These steps address criteria 5.4(2) from NUREG-0711. In addition to these task considerations, the number of crewmembers along with crew skills will be addressed. The crew allocation of monitoring and control tasks will be done in a way that a meaningful job is created. This job will be within the physical and cognitive workload limits of the crewmember. The job will be evaluated as part of the narrative description review and will be done in the description of personnel narratives step. Support for the review may be in the form of time lines displaying workload if the detail level was captured in the detailing of the human tasks. This addresses criteria 5.4(4) from NUREG-0711. The situation awareness (SA) information and level will be identified for any human task that supports decision making. Finally, any task timing information will be added to the task summaries.

5.4.1.4 Description of Personnel Narratives

Narrative descriptions of personnel activities will be developed and used to perform walkdowns of the product as well as providing a verification of the analysis. Details and text will be extracted from the task summaries and all task summaries used will be referenced as part of these narrative descriptions. The narratives will be reviewed by representatives from the operations group with experience in operating nuclear power plants.

5.4.1.5 Preliminary Minimum Inventory

The process for defining a minimum inventory of alarms, displays, and controls for the main control room and remote shutdown station (RSS) is done in the following steps (this addresses criteria 5.4(5) from NUREG-0711. These steps also use guidance from section 2 of DI&C-ISG-05 (Reference 16).

- Review input from the HRA process for any of risk-important human actions from the PRA. This includes credited manual actions to bring and maintain reactor to safe shutdown condition.
- Review input from the FRA&FA process covering the operator actions necessary to bring the reactor to a safe shutdown when the primary instrumentation is available and when it is unavailable.
- Review any defense-in-depth and diversity credited human actions.
- Review engineering reports and analysis that affect the minimum inventory. These may include post accident monitoring and other similar reports.
- Review any inputs from simulator use during development or testing including a full scope simulator that meets ANSI/ANS 3.5. (Reference 17)
- Review HFEITS database for any human action or HSI issues.
- Use the inventory inputs from previous steps along with the following lists to identify functions, systems, and tasks that have been allocated to the human. This information will be added to the task summaries created during the FRA&FA process and updated during the earlier TA process steps.
  - Minimum inventory for the main control room will consider the following:
    - Monitor the status of fission product barriers.
    - Perform and confirm a reactor trip.
    - Perform and confirm a controlled shutdown of the reactor using the normal or preferred safety means.
    - Actuate safety related systems that have the critical safety function of protecting the fission product barriers.
    - Analyze failure conditions of the normal human system interfaces, while maintaining the current plant operating condition and power level until the human-system interfaces are restored in accordance with applicable regulatory requirements.
    - Implement the plant's emergency operating procedures.
    - Bring the plant to a safe condition.
    - Carry out those operator actions shown to be risk-important by the applicant's probabilistic risk assessment (PRA).

  - For the remote shutdown station (RSS) all inventory inputs collected in previous steps will be added to HSIs for the following:
    - Perform and confirm a reactor trip.
    - Place and maintain the reactor in a safe condition using the normal or preferred safety means.

- Apply minimum inventory criteria.

  The criterion will be conservative and add all items to the list that have been identified in referenced input from previous steps. These items are represented on the task summaries and will provide the information requirements for these actions.

  The minimum inventory will be reviewed and revised by the TA team to ensure that support indications required to carry out safety functions will be listed for inclusion into the HSI design. If the activity was identified and documented in enough detail to identify a subset of the information to support the human task (such as only 1 of 3 indicators are needed for the risk-important human action) then the subset may be used instead of keeping the whole information set for the task in the inventory.

  As the design progresses this will be an area of iterative HSI design providing more detailed information requirements (e.g., only one range of liquid level is needed to support risk-important human action instead of the full level range). Any changes to the minimum inventory such as removing an inventory item will be documented with the basis for removal.

- Document minimum inventory for main control and minimum inventory for remote shutdown station (RSS). Documentation will be created that references the task summaries and transfers the information into the two inventories.

The definition of minimum inventory will need to be updated during other HFE program processes, specifically HSI design, procedure development, training program development, and V&V. Finally, the HSI design implementation plan will use the defined minimum inventory list to verify implementation. Procedure development will update the minimum inventory when considering guidelines for developing emergency operating procedures.

The fields used to capture the individual minimum inventory items will include parameter description, function/task, minimum HSI accessibility criteria, alarm, control, display, and applicable regulatory/industry requirements/guidance. HSI accessibility criteria will include spatially dedicated, continuously visible, self revealing, and one-step accessible.

The V&V process or the HFE design implementation process will verify that the defined minimum inventory will have been implemented and the completeness of the implementation in the plant simulator and actual as-built plant.

5.4.2 TA Tools

Task summaries from the FRA&FA process will be used to collect, review and document data gathered in the TA process. Revised versions of the task summaries will be the main output of the process. An example of the typical task summary is shown in Figure A-3 found in Appendix A.

5.5 TA Process Outputs

The output of the TA process will be TA report(s). The TA report(s) will be created to support the HFE program as necessary. The report(s) will be used as the input to other technical elements of the HFE program and other NuScale organizations. HFE program technical elements using output from the TA process include the following:

- Staffing and Qualifications (S&Q)

  Timing and workload level along with initial crew work description will be used as S&Q input. The allocation and timing information if detailed will be used for input into the staffing plan. Crew requirements will be inputs into job descriptions

- Human-System Interface (HSI)

  Information requirements will be provided to the HSI design process in the form of descriptive narratives of the human task groupings and information details captured in the task summaries and addresses criteria 5.4(6) from NUREG-0711.

- Procedure Development

  Task summaries along with decision ladders from the FRA&FA process will provide initial input into procedure development. The decision ladders that were developed in the FRA&FA process and that the task summaries were derived from will be used to illustrate the inputs to procedure development recommendations and addresses criteria 5.4(6) from NUREG-0711.

- Training Program Development

  The crew requirements and crew work descriptions will be an initial input to the training program development recommendations and addresses criteria 5.4(6) from NUREG-0711.

- HFE Verification and Validation (V&V)

  The human tasks identified in the task summaries will be used to develop conditional sampling for V&V along with being used to build scenarios for validation testing.

Output from the TA process will fulfill the task analysis reports requirement of the exemption request that NuScale will file in support of the staffing levels for the MCR design concept.

A minimum inventory of alarms, displays, and controls for the main control room and remote shutdown station (RSS) will be an output from the TA process. This inventory will be used for HSI design and V&V and will be iterated as the design and HFE process progresses. A TA Results Summary Report (RSR) will be prepared when the TA process is complete. This will include a summary of review criteria for NUREG-0711 Section 5.4. This report will also contain examples from the TA and TA process.

6.0 Staffing and Qualifications Implementation Plan

6.1 S&Q Purpose

Plant staffing and qualifications (S&Q) are important considerations throughout the design process and provide input to many of the HFE program technical elements. Initial staffing levels will be established based on staffing of existing operating plants, staffing goals (such as staffing reductions), initial analyses, government regulations (including an exemption request), and the NuScale philosophy of plant operation. However, the acceptability of the staffing goals and assumptions will be examined as the design of the plant proceeds.

The S&Q Implementation Plan describes the methodology for systematically analyzing the requirements for the number and qualifications of personnel. This analysis includes a thorough understanding of task requirements and regulatory requirements. This analysis will be provided in the form of Staffing and Qualifications Report(s) and will be iteratively reviewed based on changes in other HFE program technical elements and engineering design changes that affect Staffing and Qualifications.

The key differences between staffing for current power reactors and that proposed for staffing the NuScale power plant are based on the simple robust design, passive safety systems, and greater use of automation. Another very important point is that the operator is not expected to have any required actions post accident for 72 hours.

The initial concept for the NuScale power plant consists of twelve NuScale Power Modules of 45 MWe each. Each module consists of a reactor, turbine, and generator that can operate independently of the other modules. The concept is that the displays and controls for individual modules will be organized into clusters so that one reactor operator (RO) can monitor and control multiple modules from a control station within the main control room. Each cluster will have panels for each of the reactors. The Control Room Supervisor (CRS), a senior reactor operator (SRO), will oversee the ROs. The CRS will be responsible for all of the modules in the control room, and will be assisted by a shift technical advisor (STA) as well as the shift supervisor. The CRS, SRO, and STA will have SRO licenses.

With the NuScale design, although the tasks and function allocation will be different, the envisioned primary role of the operator does not change from that of the reactor operator in current nuclear power stations. The licensed operator will maintain responsibility for plant safety and operation by selecting operating state, monitoring and verifying parameters, and initiating manual trip of a module, if trends indicate that auto trip is imminent.

The concept assumes the HSI provides the operator with the information required to monitor and control multiple modules while preventing information overload during an event. Automation is intended to reduce the burden on the operator by performing routine tasks. Operator tasks will be reduced in this concept compared to current designs because of higher levels of automation for all control functions, fewer components in each module, passive decay heat removal based on two diverse natural circulation systems, and a large volume of water capable of providing passive heat removal for three days without operator action.

Final staffing and qualification requirements are the responsibility of the COL applicant and will depend on the actual plant operation. The purpose of the S&Q plan is to provide minimum and maximum requirements for the NuScale nuclear power plant as designed and presented in the DCD.

6.2 S&Q Scope

The S&Q process is an iterative process that supports the design of the NuScale nuclear power plant. This includes a staffing plan and job definitions. NuScale will maintain the analysis in a current state over the life cycle of design development through decommissioning to provide a suitable design basis when modifications are considered. This addresses criteria 6.4(3) from NUREG-0711 Rev. 2 (Reference 1).

The S&Q plan will address the applicable plant personnel called out in Section 2.4.1(5) of NUREG-0711 and determine the required number and background of these personnel. This addresses criteria 6.4(2) NUREG-0711 in considering the following list of personnel:

- licensed control room operators as defined by 10 CFR 55 (Reference 18)
- personnel defined by 10 CFR 50.120 (Reference 19)
  - nonlicensed operators
  - shift supervisor
  - shift technical advisor
  - instrument and control technician
  - electrical maintenance personnel
  - mechanical maintenance personnel
  - radiological protection technician
  - chemistry technician
  - engineering support personnel
- Any other plant personnel who perform tasks that are directly related to plant safety

The number and background for the recommended personnel will be evaluated for the full range of plant conditions and tasks:

- plant operational
  - normal
  - abnormal
  - emergency
- plant maintenance
- plant surveillance
- testing
- plant refueling

Items in NUREG-0800, Sections 13.1.1 through 13.1.3 (Reference 20) will be reviewed and applied to the S&Q process. However, the combined license (COL) applicant has the ultimate responsibility for these items. This also applies to 10 CFR 50.54(m) (Reference 3) which will be addressed in this plan as well as an exemption request from some of the staffing requirements. This addresses criteria 6.4(1) NUREG-0711.

The HFE program technical elements that will have input to staffing and qualification requirements are operating experience review (OER), functional requirements analysis and function allocation (FRA&FA), task analysis (TA), and human reliability analysis (HRA). After the initial S&Q determination, the iterative design process information from other HFE program technical elements will be reviewed for input into the S&Q requirements. In addition to those previously listed, the HFE program technical elements of human-system interface (HSI) design, procedure development, and training program development will be considered in the iterative process.

Information considered as the basis for staffing and qualifications will be reviewed and modified, as necessary, to address the following issues listed by HFE program technical element (this addresses criteria 6.4(4) NUREG-0711):

- Operating Experience Review
  - operational problems and strengths that resulted from staffing levels in predecessor systems
  - initial staffing goals and their bases including staffing levels of predecessor systems and a description of significant similarities and differences between predecessor and current systems
  - staffing considerations described in NRC Information Notice 95-48, "Results of Shift Staffing Study" (Reference 21).
  - staffing considerations described in NRC Information Notice 97-78, "Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times" (Reference 22)
- Functional Requirements Analysis and Function Allocation
  - mismatches between functions allocated to personnel and their qualifications
  - changes in the roles of personnel due to plant system and HFE modifications (e.g. NuScale use of multi-modular supervisory monitoring and control for control room)
- Task Analysis
  - the knowledge, skills, and abilities needed for personnel tasks addressed by the task analysis (in the form of crew requirements from TA, and knowledge, skills, and abilities addressed in other steps of the S&Q process)
  - personnel response time and workload
  - personnel communication and coordination, including interactions between them for diagnosis, planning, and control activities, and interactions between personnel for administrative, communications, and reporting activities

  - job requirements that result from the sum of all tasks allocated to each individual both inside and outside the control room
  - decreases in the ability of personnel to coordinate their work due to plant and HFE modifications
  - availability of personnel considering other activities that may be ongoing and for which operators may take on responsibilities outside the control room (e.g., fire brigade)
  - actions identified in 10 CFR 50.47 (Reference 23), NUREG-0654 (Reference 24) and procedures to meet an initial accident response in key functional areas, as identified in the emergency plan
  - staffing considerations described by the application of ANSI/ANS 58.8-1994 (Reference 25), "Time Response Design Criteria for Safety-Related Operator Actions"
- Human Reliability Analysis
  - the effect of overall staffing levels on plant safety and reliability
  - the effect of overall staffing levels and crew coordination for risk-important HAs
  - the effect of overall staffing levels and the coordination of personnel on human errors associated with the use of advanced technology
- HSI Design
  - staffing demands resulting from the locations and use (especially concurrent use) of controls and displays
  - coordinated actions between individuals
  - decreases the availability or accessibility of information needed by personnel due to plant system and HFE modifications
  - the physical configuration of the control room and control consoles
  - the availability of plant information from individual workstations and group-view interfaces
- Procedure Development
  - staffing demands resulting from requirements for concurrent use of multiple procedures
  - personnel skills, knowledge, abilities, and authority identified in procedures
- Training Program Development
  - crew coordination concerns that are identified during the development of training

The current requirements for control room staffing are contained in 10 CFR 50.54(m) (2) (i), (ii), (iii), and (iv). These requirements are based on large LWR designs and require exemptions for the proposed NuScale design and concept of multi-modular monitoring and control. The following requirements and assumptions will need to be evaluated for exemption for the NuScale proposed design concept.

- 50.54 (m) (2) (i) contains a table that addresses minimum requirements for RO and SRO shift staffing. There is no provision for more than three nuclear power units operating on a site, and the table shows a maximum of two units operating from a single control room.
  - A NuScale design will have 12 operating nuclear power modules operated from a single control room. Therefore, this would need to be addressed by an exemption.
- 50.54 (m) (2) (iii) requires a licensed RO or SRO to be present at the controls at all times for each fueled nuclear power unit.
  - A NuScale plant would have a licensed RO present at the controls at all times for a cluster of multiple fueled nuclear power modules. Therefore, this would need to be addressed by an exemption.
- It is expected that a NuScale plant design would meet or exceed the other staffing requirements contained in 10 CFR 50.54 (m).

An exemption request will be prepared for these sections of 10 CFR 50.54 following guidance from NUREG-1791 (Reference 11). The NuScale design is expected to meet all other requirements from 10 CFR 50.54. This addresses part of criteria 6.4(1) NUREG-0711.

6.3 S&Q Team

The S&Q team will include a representative from HFE (who will be the OER team lead and report to the HFE lead), engineering, safety analysis group, operations and a customer representative if one is available. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. The S&Q process is supported by the NuScale CWA process (worker competencies analysis) as described in Appendix A. The HFE engineers conducting the analyses will support the coordinator of the S&Q process. The S&Q process coordinator will use the task summaries, job definitions, and the staffing plan for reporting requirements in support of the HFE program plan and schedule.

6.4 S&Q Method

6.4.1 S&Q Process and Procedures

This section of the HFE Analysis Phase Implementation Plan covers the methods for performing S&Q. The S&Q process covers the systematic development of a staffing plan and a set of job definitions. The S&Q process will be performed in the following steps:

1. Review input sources for issues or human actions with unique or new requirements including input from other HFE program technical elements along with items listed in the S&Q scope section.
2. Perform worker competencies analysis.
3. Create job definitions.

4. Create staffing plan (baseline then iterative revisions).
5. Review staffing plan against PRA.
6. Use the simulator for staffing plan evaluation.
7. Perform a validation analysis of staffing plan (actual validation will be done during V&V).

6.4.1.1 Review Input Sources

The review of inputs to the S&Q process include items listed in the S&Q scope section of this document including reports and analysis from other HFE program technical element processes. These include the role of plant personnel from the FRA&FA process and the narrative description of what personnel activities from the TA process. The comments and any field in the task summaries needing adjustment will be documented by the S&Q team.

6.4.1.2 Perform Worker Competencies Analysis

Perform worker competencies analysis using the skill, rule, and knowledge taxonomy called out in Appendix A. This is the fifth and final phase of the CWA process. This data will be added to the task summaries and then written to match descriptions of the knowledge and abilities catalog from NUREG-1122 (Reference 26). The worker competency analysis goes through every human action identified in the TA along with other input sources and looks at the information-processing activities and states of knowledge (that were identified on the decision ladders during control task analysis) to capture the behaviors at a skill-based, rule-based, and knowledge–based level (as defined in the CWA methodology). This is done by the S&Q team for each step in the human action. The behavior descriptions for each of the skill, rule, and knowledge levels will provide more input into the design for HSIs to support the human actions. This process captures references to the supporting databases and diagrams artifacts from the FRA&FA and TA processes and is deterministic.

6.4.1.3 Job Definitions

Job definitions will be developed based on the current industry job definitions and the current catalog of knowledge and abilities for a pressurized LWR by referencing NUREG-1122 as appropriate. Any new knowledge and abilities not in the catalog will be created for the support of the NuScale job definitions. The job definitions will use the crew requirement descriptions from the TA process along with responsibility mapping onto ADS diagrams if this was done during the work domain phase of CWA used in the FRA&FA process. The job definitions will be captured in the S&Q report.

The objective is to develop job definitions for the personnel who will be responsible for monitoring the plant and for any control decisions for the proposed NuScale plant design.

Job definitions will be created to support the NuScale concept of operation for multi-modular supervisory monitoring and control and the NuScale team concept. The number of modules under an individual RO and the details for the monitoring and control of those modules will be developed for at least two multi-modular monitoring and control concepts. Other concepts may emerge and will be analyzed, evaluated, and validated using the S&Q process and iteratively through any of the other HFE program technical elements as necessary. The team concept will be developed as a narrative and may use an operational sequence diagram for added clarity of communications and data exchange. This may be done for each team concept of operations and job definition variation considered. If used, these will be provided along

with the job definitions, for review by the operations team. A walkdown of each team concept and set of job definitions will also be provided.

6.4.1.4 Staffing Plan

The staffing plan will be developed to support the NuScale reference plant. The staffing of the plant will be similar in most ways to existing LWRs. The NuScale reference plant consists of 12 modules and produces 540 MWe. As a framework, the plant staff is assumed to be organized in Operations, Maintenance, Technical, and Administrative divisions. Since the resources required to accomplish specific functions are essentially independent of the plant organization structure, other organizational alignments may be acceptable.

The main difference in staffing is expected in the number of reactor operators per reactor. Otherwise a NuScale plant is expected to be staffed similar to existing industry standards. Therefore, NuScale plants will be able to capitalize on industry experience and existing programs.

The staffing plan along with job definitions will be reviewed against the current version of the PRA in a risk-informed manner to ensure that the PRA details do not change any risk-important human actions or credited actions and to provide input if these have changed. This will be coordinated through the HFE team member responsible for the HRA interaction with the NuScale safety analysis team responsible for the PRA. Any changes will require an iterative revision of the areas of the S&Q process that are affected.

6.4.1.5 Simulator Use

Job definitions and the staffing plan will be evaluated using the engineering simulator and control room mockups. This provides another method for verifying and validating the staffing plan analysis. A simulation model that includes a replicated HSI and I&C platform representation will fully address the various contexts that the operators see within scenarios. This will be documented as the HFE program is conducted with NuScale simulation facilities.

In addition, the assumed concept of one operator monitoring and controlling multiple modules will be tested using the simulator to provide challenging scenarios. Scenario development will be supported by the PRA for plant events that include (1) external events such as fires, floods, and seismic events, and (2) system events such as plant/grid instability, and station blackout. These scenarios will be modeled in the simulator to verify that the NuScale design concept protects against both errors of omission and errors of commission.

6.4.1.6 Validation Analysis

A validation analysis of the staffing plan will be performed during preparation for the 10 CFR 50.54m exemption request and will be performed during the HFE V&V process. This will include development of preliminary scenarios including reference to operational conditions to be used in the staffing plan validation. Descriptions of key system and plant parameters relevant to the scenarios along with relevant criteria will be addressed when creating and performing validation.

6.4.2 S&Q Tools

The S&Q tool used will be updated task summaries that will capture the skill-based, rule-based, and knowledge-based behaviors to support steps in the human actions analyzed. The job definitions and staffing plans will be tables with supporting documentation or references. If operational sequence diagrams are used, a standard methodology will be chosen, referenced, followed, and documented.

The engineering simulator will be used to support staffing plan and job definition evaluation. This will be done using multiple HFE measuring tools that will be identified in the HSI design implementation plan and will include work load measurements. These tools will be used during HSI development and evaluation and S&Q simulator evaluation may be coordinated with the HSI design development process supporting the iterative nature of the design. Depending on the schedule, the full scope simulator may also be used in conjunction with each of the phases of the engineering simulator. The supplementary use of the full scope simulator is not necessary but will benefit the process if available by providing another resource.

6.5 S&Q Process Outputs

The output for the S&Q process will be in the form of one or more S&Q report. The S&Q report(s) will be created to support the HFE program as necessary. The report(s) will be used as the basis for other technical elements of the HFE program along with any other areas within NuScale. HFE program technical elements using output from the S&Q process include the following:

- Human-System Interface (HSI)

  Information required per personnel type will be provided to the HSI design process. Also, job definitions will provide input for high level grouping of HSI components.

- Procedure Development

  Output from S&Q will provide input into the organization of procedures based on job definitions. It will also be used to verify if the staffing levels called for are adequate to carry out the procedures.

- Training Program Development

  Outputs from S&Q to the training program development recommendations will be taken from the job definitions and list of qualifications (crew requirements) in the revised task summaries. This will ensure that the crew will be able to understand, communicate, and coordinate successfully using HSI.

- V&V

  The simulator will be used to validate the staffing plan. This will provide timely information at critical locations for a staffing baseline level adequate to meet operational and accident conditions. The physical configuration of the control room will also be evaluated for proposed staffing levels.

The staffing plan and supporting documentation will also be an output to the utility customer in order to establish the baseline recommended staffing requirements.

Job definitions will have clear and rational details for personnel responsible for controlling the plant and will be an independent document or set of documents. This will include modified roles, responsibilities, and qualifications for licensed control room personnel from the current requirements. The input from each of the other HFE program technical elements to the job definition will be referenced. This includes the knowledge, skills, and abilities analysis. Finally, any job definitions of personnel working in crews will be coordinated.

The staffing plan will have multiple versions that are iteratively developed based on engineering development, other HFE program technical element processes iterations. A final version will be created after validation as part of the V&V process. The plan will include the operational conditions identified as

applicable to the staffing plan and will provide adequate numbers of qualified personnel integrated across shifts. Response times will also be considered in the development of the staffing plan.

Output from the S&Q process will fulfill the job definitions and staffing plan requirements of the exemption request that NuScale will file in support of the MCR design concept. Additional data, most likely in the form of knowledge, skills, and abilities, may also be used from the S&Q process to support the exemption request.

An S&Q Results Summary Report (RSR) will be prepared when the S&Q process is complete. This will include a summary of review criteria for NUREG-0711 Section 6.4. This report will contain the scope of S&Q process along with the staffing plan and job definitions. The report will also contain any new knowledge and abilities unique to the NuScale plant.

7.0 Human Reliability Analysis Implementation Plan

7.1 HRA Purpose

HRA seeks to evaluate both the potential for and the mechanisms of human error that may affect plant safety. Thus, HRA is an essential element in achieving the HFE goal of providing operator interfaces that minimize personnel errors, allow their detection, and provide recovery capability.

HRA is conducted as an integrated activity to support both the HSI design and PRA. PRA and HRA are performed early in the design process to provide insights and guidance for both systems design and HFE purposes.

The robustness of the HRA largely depends on the analysts' understanding of personnel tasks, the information related to them, and the factors that influence human performance. Accordingly, HRA is an iterative process throughout the design process. By developing an understanding of the causes, modes, and probabilities of human error, HRA can provide valuable insights into the desirable characteristics of the HSI design. Consequently, special attention will be paid to those scenarios, risk-important human actions, and HSI components that were identified by HRA and PRA analyses as important to the plant's safety and reliability. The effect of advanced technology on human performance will be considered when performing the HRA.

The HFE Analysis Phase Implementation Plan describes the detailed methodology for implementing HRA. IEEE Standard 1082 (Reference 27) will be used in informing the method by which HRA is performed. The HRA is intended to ensure the following:

- The NuScale design has addressed human-error mechanisms in the design of the HFE aspects of the plant to minimize the likelihood of personnel error.
- The NuScale design has addressed human-error mechanisms in the design of the HFE aspects of the plant to ensure that, should errors occur, they are detected and recovery is ensured.
- The HRA activity effectively integrates the HFE Program with the PRA and risk analysis.

The main purpose of the HFE HRA effort is to ensure that the results from the PRA process as detailed in the Risk Report are applied to the HFE program technical elements that affect design.

7.2 HRA Scope

The main inputs to the HRA process will be identified as part of the PRA and may include input from the OER processes. Summary of those inputs are listed below:

- PRA report

  This input provides the list of human actions considered in the initial design input. These will be used to inform the other HFE program technical element processes

- OER process output

  The OER may provide risk-important human actions from predecessor plants or systems. These may come directly from the OER process or may have been entered into HFEITS during the OER process. These items will be considered when performing the HRA and may determine the level of detail of the

HRA analysis. These items may include risk-important human actions or errors not already identified in the PRA or HRA along with problematic operations

After the initial HFE HRA determination, iterative design process information from other HFE program technical elements (HSI design, procedure development, training program development, and the HFE V&V) will be reviewed for input into the HRA.

Another potential input source is any customer that decides to build/construct a NuScale nuclear power plant. The HFE program would then collaborate with the PRA/HRA group from the utility.

7.3 HRA Team

The HRA team will have at least one person from the HFE team (who will be the OER team lead and report to the HFE lead) and will interact with the safety analysis group representative who is responsible for the PRA and HRA. Input from a customer representative, if one is available, will also be included in the team. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. The HFE representative will be responsible for review of the PRA report and, in particular, the sections that address the HRA and risk-important human actions. The HFE representative will also be responsible for providing the list of identified risk-important human actions to the other HFE program technical elements and getting feedback from HFE program technical elements for input to the HRA/PRA process to the safety analysis group. Finally, the HFE representative assigned to the HFE HRA process will be responsible for the HFE HRA Results Summary Report.

7.4 HRA Method

7.4.1 HRA Process and Procedures

This section of the HFE Analysis Phase Implementation Plan covers the methods for performing HRA for the NuScale nuclear power plant HFE Program.

The HFE HRA process will include the following steps:

1. Safety analysis group performs PRA and HRA analysis.
2. HFE HRA team reviews PRA report and HRA analysis for risk-important human actions.
3. HFE HRA team coordinate with other HFE program technical elements to ensure that risk-important human actions are identified in their process. This may include creating a HFEITS issue if it is warranted.
4. HFE HRA tam review output from HFE program technical elements (including HFEITS) to determine if additional risk-important tasks need to be added to the HRA and PRA analysis. Also, this step will inform the safety analysis group of any changes to the details of risk-important human actions based on design changes or analysis results from the HFE program.

7.4.1.1 Safety Analysis Group Performs PRA and HRA

NuScale uses a risk-informed design process to keep the design staff cognizant of PRA and Severe Accident results, insights, human actions, and the SSCs that are significant contributors to plant safety while considering the effect of potential design changes on PRA and Severe Accident evaluation results. This iterative process encompasses the HRA process and uses the Risk Report as the main tool for risk-

informing the design process. Information contained in the Risk Report will be used by the other engineering disciplines, including HFE, for design guidance and risk-informed decisions.

The safety analysis group uses a multi-step process that includes initiating event analysis, success criteria analysis, accident sequence development analysis, systems analysis, HRA, risk quantification, sensitivity/uncertainty analysis, importance figures, severe accident progression, quantification, and source term analysis. Iterations to design may bring new input back to the systems analysis step of this process, and this is where output from the HFE HRA process will be considered.

The safety analysis group follows a similar process to that in IEEE 1082, which covers the following general steps:

1. select and train team (including team lead)
2. familiarize team
3. build initial plant model
4. screen human actions
5. characterize human interactions
6. quantify human interactions
7. update plant model
8. review results

The HRA will use the Standardized Plant Analysis Risk- Human Reliability Analysis Method (SPAR-H) (Reference 28) as a basic HRA method for all human failure events. Either the Technique for Human Error Rate Prediction (THERP) (Reference 29) or Accident Sequence Evaluation Program (ASEP) (Reference 30) method will be used if it is deemed necessary for more detailed analysis of pre-initiator human failure events. A Technique for Human Event Analysis (ATHEANA) (Reference 31) method will be performed if errors of commission need to be analyzed.

When using the SPAR-H methodology and considering human error events the performance shaping factors (PSFs) that are considered are available time, experience/training, and ergonomics/HMI (human-machine interface or HSI). These are then applied to the nominal human error probability (HEP) to determine the modified HEP based on the chosen levels of PSFs.

The PRA/HRA output will be provided in the Risk Report that will be used for input to FRA&FA, TA, HSI design, procedure development, and training program development.

7.4.1.2 Review input from PRA and HRA

The HFE team member will review and identify from the Risk Report risk-important human actions. These are actions that are identified in or developed as part of the Level 1 (core damage) PRA and Level 2 (release from containment) PRA including both internal and external events. The PRA process that the safety analysis group uses includes generation of importance measures. The importance measures (e.g., risk achievement worth (RAW), Fussell-Vesely (FV)) provide risk insights on the importance of each human action required to prevent or mitigate core damage or release from containment. These are applied at four levels of risk significance ranking and action: high (must re-design), medium-high

(designer-PRA analyst decision), medium-low (designer-PRA analyst decision only if SSC or human action involves high uncertainties), and low (no action). The process also entails a sensitivity analysis.

The HFE team member will also review the design basis accidents analysis for risk-important timing data assumed.

The review will include capturing the risk-important actions identified from the PRA/HRA process and classifying which HFE elements need them as input. These include the FRA&FA, TA, HSI design, procedure development, and training program development processes. This addresses part of criteria 7.4(1) from NUREG-0711 Rev. 2 (Reference 1).

The review will also encompass the assumptions that determine the level chosen for the PSF when modifying the nominal HEP values to ensure that there is a match between the assumptions and the current HSI design.

7.4.1.3 Coordinate with other HFE program technical elements

The limitation of human performance will be considered in the analysis and design processes of the HFE program. By identifying and prioritizing risk-important human actions provided to the HFE program technical elements of the NuScale HFE program, the tracking and verification of these human actions ensure that they will be addressed. The functional requirements analysis will use the identified human actions from the PRA/HRA process to ensure that the analysis covers the actions in enough detail that further analysis and design will have necessary information and traceability. The function allocation may be influenced by the details of the information provided by the HRA. This may be in the form of the NuScale assumptions about how the human and machine interact and the level of automation. TA will use a field in the task summaries to identify and allow searching for risk-important human actions. The coding and prioritization in the task summaries will ensure that the data collection for the supporting tasks is done in a manner to provide task requirements such as informational requirements, decision types, crew requirements, workload, and any time issues to the HSI design process. HSI design, procedure development, and training program development will use these requirements to guide development and place prioritized emphasis on the HSI, procedure, or training support for the operator to be able to perform within their human limitations. This addresses part of criteria 7.4(2) from NUREG-0711.

In order to minimize operator error, provide for error detection, and ensure easy error recovery, the risk-important human actions identified in the PRA/HRA process will be prioritized to ensure consideration during analysis and design HFE steps. These results will drive the prioritization and iteration of the functional requirements. The prioritization will ensure that enough detail is captured for further analysis and design. This also applies to the function allocation with special emphasis on the level of automation when functions are being allocated between human and machine. The HSI design process will iterate design options to reduce error probability, enhance error detection, and improve error recovery. This process will use the engineering simulator to evaluate design options and may be used to collect data to support or modify PSF multiply values. The results of the PRA/HRA will be applied to procedure development to ensure that any error prone operations are thoroughly analyzed and well documented. Also, training program development will ensure that knowledge and abilities affecting risk-important human actions relating to human errors will be included and prioritized. This addresses criteria 7.4(3) from NUREG-0711.

As part of the HFE HRA process, walkdowns will be used to validate dominant sequences that address HRA assumptions such as decision making and diagnosis strategies. The walkdowns will use personnel with operating experience and be performed in the NuScale control room mockup or simulator. The

walkdowns will use a guided checklist for the reviewers with a list of HRA assumptions and other appropriate items to review. These walkdowns will be conducted before the final quantification stage of the PRA. This addresses criteria 7.4(4) from NUREG-0711.

The V&V process will plan V&V evaluations to ensure that human performances for risk-important human actions are addressed. These will include scenarios that encompass all human actions identified in the HRA as risk significant and will include operating procedures and training material. The validation covers all of the HSI design and will be conducted with operators trained using the recommendations from the HFE program. The validation will capture and analyze performance data and may include task completion, workload, and situation awareness measures.

7.4.1.4 Review HFE program technical element outputs

The HFE HRA team will review any modifications to the HSIs, procedures and training program to assess whether the HRA analysis scope covers any human action changes. This will be done in conjunction with a safety analysis group representative and will consider the following possible effects on the existing HRA:

- whether the original HRA assumptions are valid for the modified design
- whether the human errors analyzed in the existing HRA are still relevant
- whether the probability of errors by operators and maintenance personnel may change
- whether errors may be introduced that are not modeled by the existing HRA and PRA
- whether the consequences of errors, established in the existing HRA, may change

This addresses part of criteria 7.4(1) from NUREG-0711.

7.4.2 HRA Tools

The HRA will use the reports and databases from other processes. This includes reports from the safety analysis group covering PRA and HRA.

7.5 HRA Process Output

The output for the HFE HRA process will be in the form of one or more report. The HFE HRA report(s) will be created to support the HFE program as necessary. The analysis and HFE HRA Results Summary Report(s) will be updated to support the iterative nature of the HSIs and plant design. The report(s) will be used as the basis for other technical elements of the HFE program along with any other design areas within NuScale. Processes using output from the HRA process include the following:

- Probabilistic Risk Assessment (PRA)

  HFE program technical element design changes and input from analysis will be provided to the PRA process for consideration in updating the HRA model for any changes to risk-important human actions.

- Functional Requirements Analysis and Function Allocation (FRA&FA)

  The FRA&FA uses the PRA and HRA identified risk-important human actions and ensures that the FRA analysis highlights the functions affected and that function allocation considers the human actions when making function allocations and applying level of automation choices.

- Task Analysis (TA)

  The TA will use the human actions identified to highlight the human tasks in order to prioritize the analysis and develop the analysis to the appropriate detail.

- Human-System Interface (HSI) Design

  Any identified human actions will be candidates for prioritized design. This will be done to reduce the probability of error and increase error recovery possibilities. Improvements to the HSI may also be the basis for changes in PSF multiplier values.

- Procedure Development

  Procedure development will use the identified risk-important human actions to prioritize the procedure development that contain these human actions. The input will also provide a way to prioritize which procedures are incorporated into scenario development for validation.

- Training Program Development

  Training program development will use the identified risk-important human actions to prioritize the training program development to ensure the appropriate knowledge and abilities are contained for training on these human actions.

- HFE Verification and Validation (V&V)

  The identified human actions will be used during conditional sampling when creating V&V plans

- HFE Design Implementation

  The list of human actions from the HRA process may be used to ensure that the HFE process and results were implemented in the completed plant

- Human performance monitoring

  Recommendations to the operating utility may include consideration of the human actions identified in the HRA process.

An HRA Results Summary Report (RSR) will be prepared when the HFE HRA process is complete. This will include a summary of review criteria from NUREG-0711 Section 7.4. This report will contain the scope of HRA, outputs to other HFE program technical elements, along with a list of risk-important human actions being tracked in HFEITS.

Output from the HRA process may also be used to support the optional additional data for the exemption request that NuScale will file in support of the MCR design concept.

8.0 References

1. U.S. Nuclear Regulatory Commission, “Human Factors Engineering Program Review Model,” NUREG-0711, Rev. 2, 2004, Agencywide Document Access and Management System (ADAMS) Accession No ML040770540.

2. NuScale Power, Inc., “Human Factors Engineering (HFE) Program Management Plan (PMP),” NP-TR-0610-290-NP, Rev. 0, Corvallis, Oregon, 2010.

3. *U.S. Code of Federal Regulations,* “Conditions of licenses, “Domestic Licensing of Production and Utilization Facilities,” Part 50, Chapter I, Title 10, "Energy," (10 CFR 50.54(m)).

4. U.S. Nuclear Regulatory Commission, “HFE Insights For Advanced Reactors Based Upon Operating Experience,” NUREG/CR-6400, 1997, Agencywide Document Access and Management System (ADAMS) Acession No 9704100181.

5. U.S. Nuclear Regulatory Commission, “A Prioritization of Generic Safety Issues,” NUREG-0933, June 2001, Agencywide Document Access and Management System (ADAMS) Accession No.ML012190431.

6. *U.S. Code of Federal Regulations*, “Contents of applications, technical information,” Part 50.34, Chapter I, Title 10, “Energy,” (10 CFR 50.34).

7. U.S. Nuclear Regulatory Commission, “Clarification of TMI Action Plan Requirements,” NUREG-0737, 1980, Agencywide Document Access and Management System (ADAMS) Accession No. ML102560051.

8. U.S. Nuclear Regulatory Commission, “Operating Experience Feedback Report – Human Performance in Operating Events,” NUREG-1275, Volume 8, December 1992, Agencywide Document Access and Management System (ADAMS) Accession No. 9301080202.

9. U.S. Nuclear Regulatory Commission, “Human Factors Considerations with Respect to Emerging Technology in Nuclear Power Plants,” NUREG/CR-6947,. October 2008, Agencywide Document Access and Management System (ADAMS) Accession No. ML083090338.

10. U.S. Nuclear Regulatory Commission, “A Methodology for Allocation of Nuclear Power Plant Control Functions to Human and Automated Control,” NUREG/CR-3331, August 1983, Agencywide Document Access and Management System (ADAMS) Accession No. 8309080015.

11. U.S. Nuclear Regulatory Commission, “Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m), Final Report,” NUREG-1791, July 2005, Agencywide Document Access and Management System (ADAMS) Accession No. ML052080125.

12. U.S. Nuclear Regulatory Commission, “Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m),” NUREG/CR-6838, February 2004, Agencywide Document Access and Management System (ADAMS) Accession No. ML040580289.

13. Bisantz, A. M. and Vicente, K. J. 1994, “Making the abstraction hierarchy concrete,” *International Journal of Human-Computer Studies*, 40, 83 – 117.

14. Vicente, K. J,. *Cognitive work analysis: toward safe, productive, and healthy computer-based work,* Mahwah, N.J., Lawrence Erlbaum Associates, 1999

15. U.S. Nuclear Regulatory Commission, "Quality Assurance Program Requirements," Regulatory Guide 1.33, Revision 2, February 1973, Agencywide Document Access and Management System (ADAMS) Accession No. ML003739995.

16. Nuclear Regulatory Commission, “Task Working Group #5: Highly-Integrated Control Rooms—Human. Factors Issues (HICR—HF) Interim Staff Guidance,” Rev. 1, (DI&C-ISG-05), 2008, Washington D.C

17. ANSI/ANS-3.5-2009, “Nuclear Power Plant Simulators for Use in Operator Training and Examination”.

18. *U.S. Code of Federal Regulations*, "Operator's Licenses," (revised periodically), Part 55, Chapter I, Title 10, "Energy," (10 CFR 55).

19. *U.S. Code of Federal Regulations,* "Training and Qualification of Nuclear Power Plant Personnel," (revised periodically), Part 50.120, Title 10, "Energy."

20. U.S. Nuclear Regulatory Commission, “Standard Review Plan, Chapter 18 - Human Factors Engineering,” NUREG-0800, Chapter 18, Section 18.0, Revision 2, March 27, 2007, Agencywide Document Access and Management System (ADAMS) Accession No. ML070670253.

21. NRC Information Notice 95-48, “Results of Shift Staffing Study,” October 10, 1995

22. NRC Information Notice 97-78, “Crediting of Operator Actions in Place of Automatic Actions and Modification of Operator Actions, Including Response Times,” October 23, 1997

23. *U.S. Code of Federal Regulations,* "Emergency Plans,” (revised periodically), Part 50.47, Title 10, "Energy”

24. U.S Nuclear Regulatory Commission, “Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants (FEMA-REP-1),” NUREG-0654, November 1980, Agencywide Document Access and Management System (ADAMS) Accession No.8012020653.

25. ANSI/ANS-58.8-1994, “Time Response Design Criteria for Safety-Related Operator Actions”.

26. U.S. Nuclear Regulatory Commission, “Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Pressurized Water Reactors,” NUREG-1122 Rev. 2, Supp. 1 DFC, May 2007, Agencywide Document Access and Management System (ADAMS) Accession No. ML071580631.

27. Institute of Electrical and Electronics Engineers Standard 1082-1997, “A Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations,” 2008, New York: Institute of Electrical and Electronics Engineers.

28. U.S. Nuclear Regulatory Commission, “The SPAR-H Human Reliability Analysis Method,” NUREG/CR-6883, August 2005, Agencywide Document Access and Management System (ADAMS) Accession No. ML051950061.

29. U.S. Nuclear Regulatory Commission, “Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications,” NUREG/CR-1278, October 1983, Agencywide Document Access and Management System (ADAMS) Accession No. 8310200388.

30. U.S. Nuclear Regulatory Commission, “Accident Sequence Evaluation Program Human Reliability Analysis Procedure,” NUREG/CR-4772, February 1987, Agencywide Document Access and Management System (ADAMS) Accession No. 8706120044.

31. U.S. Nuclear Regulatory Commission, “Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis (ATHEANA),” NUREG-1624, Rev. 1, 2000, Agencywide Document Access and Management System (ADAMS) Accession No. ML003719212 and ML003719239.

32. Bisantz, A.M., Burns, C.M., *Applications of Cognitive Work Analysis,* Boca Raton, FL, CRC Press, 2008

33. Hugo, J., Engela, H, “Function Allocation for Industrial Human-System Interfaces,” *In: 4th. International Cyberspace Conference on Ergonomics*, Johannesburg: International Ergonomics Association Press, 2005.

34. Cummings, M.L., Bruni, S., Mercier, S., Mitchell, P.J., “Automation Architecture for Single Operator, Multiple UAV Command and Control,” *The International C2 Journal*, Vol. 1, No 2, 1-24, 2007.

35. Proud, R. W., and Hart, J. J., “FLOAAT, A Tool for Determining Levels of Autonomy and Automation, Applied to Human-Rated Space Systems,” in *Proceedings of Infotech@Aerospace*, AIAA 2005-7061, Arlington, VA, Sept. 2004.

Appendix A. NuScale Cognitive Work Analysis Process

The NuScale HFE process will use a cognitive work analysis (CWA) framework and process to support the FRA&FA, TA, S&Q, HSI design (supporting the use of ecological interface design (EID) practices), procedure development, and training program development processes and implementation plans.

A.1 CWA Connection to HFE program and HFE Analysis Phase IP

The CWA process supports the HFE program technical elements. This is shown below in Table A-1, which maps the phases of CWA process to the NuScale HFE program technical element implementation plans.

Table A-1. Mapping of NuScale CWA process to HFE element implementation plans

NuScale implentation plans for NUREG-0711 Rev 2.	NuScale CWA Process
00 Program plan	NA
01 Operating Experience Review	NA
02 Functional Requirements Analysis	CWA1 - ADS with Functional Structure CWA2- Control Task Analysis (Decision Ladders and Control Task Analysis Summaries) CWA3 - Strategies Analysis
02 Function Allocation	CWA4 - Social Organization and Cooperation Analysis (including automation as cooperation agents) CWA1 - ADS(iterative with mapping of responsiblities)
03 Task Analysis	CWA2 - Control Task Analysis (Decision Ladders and Control Task Analysis Summaries) CWA4 - Social Organization and Cooperation Analysis (including automation as cooperation agents)
04 Staffing and Qualification	CWA4 - Social Organization and Cooperation Analysis (including automation as cooperation agents) CWA5 - Worker Competencies Analysis CWA1 - ADS(iterative with mapping of responsiblities)
05 Human Reliability Analysis	NA
06 Human-System Interface Design	CWA1 - ADS with Functional Structure CWA2 - Control Task Analysis (Decision Ladders and Control Task Analysis Summaries) CWA3 - Strategies Analysis
07 Procedure Development	CWA2 - Control Task Analysis CWA4 - Social Organization and Cooperation Analysis CWA5 - Worker Competencies Analysis
08 Training Program Development	CWA1 -ADS CWA2 - Control Task Analysis CWA5 - Worker competencies Analysis CWA5 - Worker Competencies Analysis
09 Human Factors Verificaiton and Validation	NA
10 Design Implentation	NA
11 Human performance monitoring	NA

NuScale CWA Process	NuScale implentation plans for NUREG-0711 Rev 2.
CWA1 - ADS with Functional Structure	02 Functional Requirements Analysis 02 Function Allocation (iterative with mapping of responsiblities)
CWA2 - Control Task Analysis (Decision Ladders and Control Task Analysis Summaries)	02 Functional Requirements Analysis 03 Task Anlaysis 06 Human-System Interface Design 07 Procedure Development 08 Training Program Development
CWA3 - Strategies Analysis	02 Functional Requirements Analysis 06 Human-System Interface (iterative)
CWA4 - Social Organization and cooperation Analysis	02 Function Allocation 03 Task Analysis 04 Staffing
CWA5 - Worker Competencies Analysis	04 Qualifications 08 Training Program Development

A.2 CWA

CWA is an ecological formative process that allows for the study of the work space and captures the information that can be used to support design of effective HSIs (Reference 13, Reference 14, and Reference 32).

There are five phases in the CWA process; work domain analysis, control task analysis, strategies analysis, social organization and cooperation analysis, and worker competencies analysis. The work domain analysis (WDA) produces a representation of the work domain independent of any personnel, automation, goals, tasks, events, or HSI. This helps define the constraints and possibilities of the system. The second phase is control task analysis and is used to capture the goals of the system. This is done in a way that is independent of strategy or function allocation (level of automation allocation of tasks between human and machine). The third phase is strategies analysis and allows for defining the process of meeting the goals set forth in the control task analysis. This is the “how” the goal gets done and is independent of function allocation. The fourth phase of social organization and cooperation analysis facilitates the “who” part of the process (facilitates function allocation) and will define any team structure needed in the operation of the plant. Finally, worker competencies analysis addresses the constraints of the plant personnel.

A.3 CWA Scope

The CWA process will support the analysis phase, covered in this Human Factors Engineering Analysis Phase Implementation Plan, of the HFE program. There will also be support for the Human-System Interface Implementation Plan, Procedure Development Implementation Plan, and Training Program Development Implementation Plan that will be covered in future submittals. The data from the CWA process will be used in the EID process that will be outlined in the HSI IP.

The CWA covers several HFE program technical element implementation plans. The individual implementation plans will call out the documentation to support the NRC review criteria for each.

A.4 CWA Team

The CWA team will include a representative from HFE (who will be the OER team lead and report to the HFE lead), engineering, safety analysis group, operations and a customer representative if one is available. The inclusion of a customer representative is important to ensure that customer input is considered and incorporated into the process. A member of the HFE team will be assigned as the coordinator for the CWA process and tools. The CWA coordinator will be responsible for the quality and timeliness of the CWA to support the HFE program plan and schedule.

The CWA team will represent and support the corresponding implementation plans of the HFE program.

A.4.1 CWA Process and Tools

The work domain analysis will use the abstraction-decomposition space (ADS) modeling process for representing the work domain. It is anticipated that there will be 8-10 divisions of the ADS needed to represent the WDA space. The ADS has one axis for abstraction and another for decomposition. An example is shown in Figure A-1.

Decomposition

Abstraction		Total System	Subsystem	Unit	Subassembly	Component
	Purpose					
	Abstract					
	Generalized					
	Physical					
	Physical Form					

Figure A-1. Typical ADS template

Representative structures will be created to support the ADS development as necessary. This may be in the form of a system component structure diagram or hierarchy.

The ADS methodology normally uses the term function in a way that is different than in NUREG-0711 and that may cause confusion. The ADS function is defined as an affordance that is relevant to the purposes of which the work domain is designed. To avoid any potential confusion the interpretation of function within the HFE program undertaken by the NuScale the term “purpose relevant affordance” is used to represent what the ADS methodology would normally label function.

A database of affordances, as defined by the CWA process, will be created as part of the FRA&FA process called out in the implementation plan for that element. The FRA&FA database will contain information from the ADS and the control task analysis process. The goals used for the control task analysis process will also be added into the FRA&FA database. The affordances and goals will be used to create a list of functions that are representative of the NURGE-0711 Rev. 2 (Reference 1) definition of function.

Decision ladders and task summaries will be used to support FRA&FA, TA, S&Q and to set the framework for adding further data as the CWA process continues through the strategies analysis, social organization and cooperation analysis, and worker competencies analysis phases of the CWA process. There will be a multitude of decision ladders needed to support the control task analysis based on the anticipated number of divisions and instances of the ADS in support of the various operating conditions.

The decision ladder is a tool that will be used to capture the goals of the system along with a representation of the required information-processing activities to complete the goal. An example of a decision ladder template is shown in Figure A-2. The rectangles represent possible information-processing activities, while the circles on this figure represent states of knowledge associated with the information-processing activities. The complete decision ladder represents all the steps a novice agent

(human or machine) would need to go through in order to complete a task. In most cases, there will usually be a path through a subset of the information-processing activities and states of knowledge based on the agent that will ultimately perform the goal of the decision ladder. This subset represents a more typical and expected path of a trained and experienced (human) or designed and programmed (machine) agent.

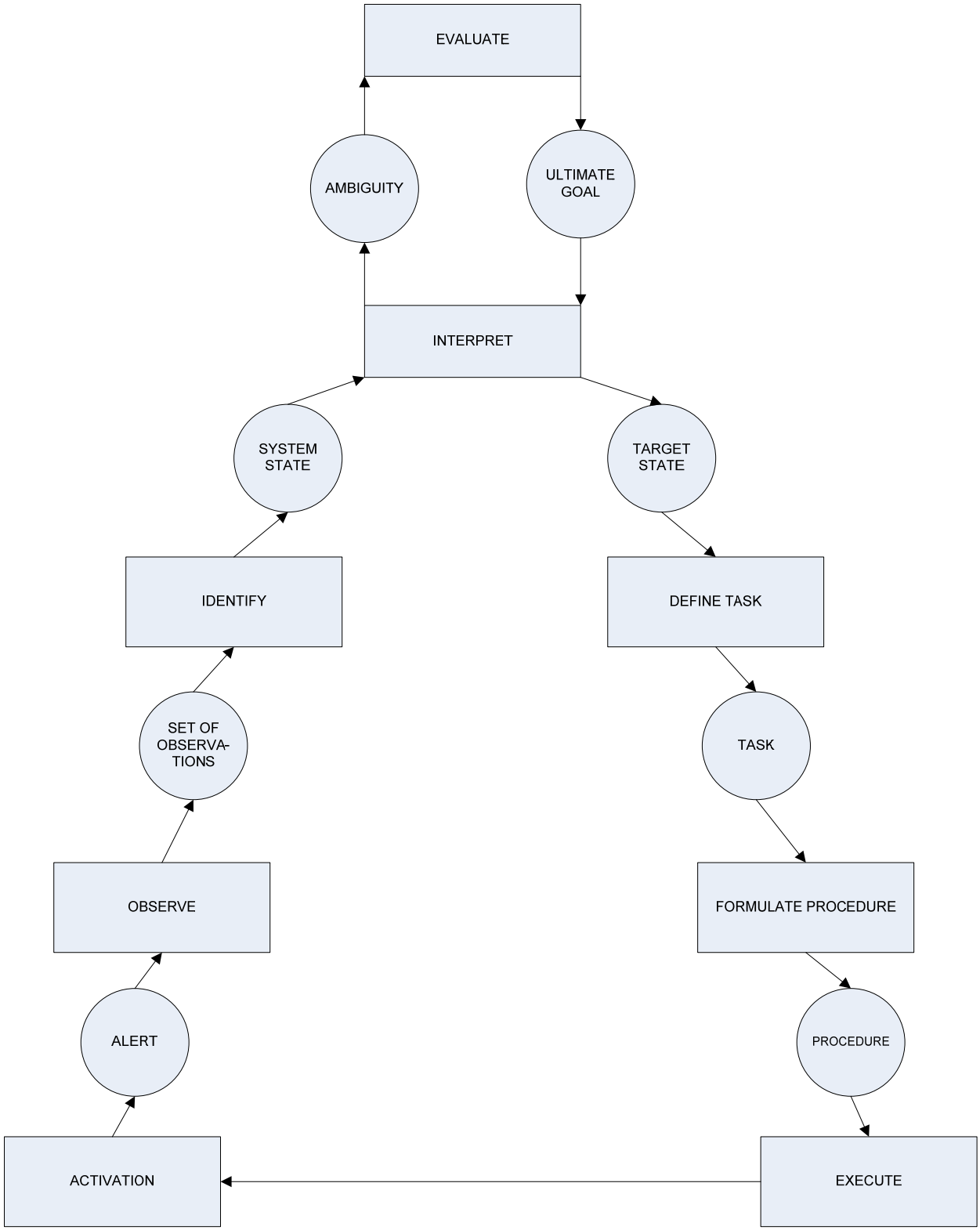

Figure A-2. Typical decision ladder template

A summary of the control task analysis process (using decision ladders) will be documented in a task summary. An example of a typical task summary is shown in Figure A-3 through Figure A-8.The task summary will be revised as necessary to document the results from the HFE program technical elements and the supporting CWA process.

Additional fields will be added to the task summary to collect data required in the FRA&FA and TA processes. This will support those processes along with supporting output from the FRA&FA and TA to other HFE program technical elements in the NuScale HFE program. The individual implementation plans will call out the format of data to be entered into the task summaries and when the data is to be entered.

Task Summary

Revision A

Summary of ADS and Decision Ladder							Strategies analysis	
Step	**Description**	**Associated Goal**	**Link**	**Ladder Code**	**Abstraction Level**	**Decomposition Level**	**Strategy ID**	**Strategy Description**
xxx.xx.xx.xx …as needed	text to describe task	goal used in creation of decision ladder	link between steps if applicable	Information-processing activity or state of knowledge	ADS abstraction level	ADS decomposition level	.Sxx (Step #. Strategy ID)	added identification to clarify HOW task is accomplished
0001.00.00.0								
0002.00.00.0								
0002.01.00.0								

Figure A-3. Typical task summary template with columns for data entry during strategies

Social Organization information (function allocation)

Allocation	**LOA**	**Basis & Analysis Method**	**Criteria**	**Staffing Resource Conflict**
Human or automation	1-8 level of automation	text explaining basis and analysis method	text explaining any deviation from FA method	Y/N along with description

Figure A-4. Typical task summary details added during function allocation

TA Process											
Input Review		Minimum Inventory			Information Requirements						
OER	**HRA**	**Minimum Inventory**	**Crew Requirements**	**Crew Skills**	**Alarms and Alerts**	**Parameters**	**Display**	**Data Processing**	**Controls**	**Parameters**	**Feedback Needed**
text describing if identified as OER item/NA	text describing if identified as HRA item that is risk-important human action/NA	MCR/RSS/NA (details in comments if just part of information needed)	type and number of crew (RO/SRO)	list any skills identified in TA process	list along with reference on requirement	(units, precision, accuracy)	information needed by operator to perceive, understand, or project (SA)	any data conversion or processing requirements for information	control action required	(units, precision, accuracy)	(indicates adequacy of actions)

Figure A-5. Typical task summary details added during TA process (input review, information requirements)

Decision Making Requirements Response Requirements											
Decision type	**Evaluations**	**Action type**	**Task Frequency**	**Task Tolerance**	**Task Accuracy**	**Timing issue**	**Time**	**Time method**	**Time Available**	**Temporal Constraint**	**Physical constraints**
(relative, absolute, probilistic)	(does task require formation of information before decision or action)		#/ time unit	tolerance limits of task if any	accuracy requirements for task	Y/N	hh:mm:ss.ss	method for determining time (actual, SME estimate, HRA/PRA input, other – provide reference)	time or	(ordering)	location, movements, forces

Figure A-6. Typical task summary details added during TA process (decision, response requirements)

Communication Workload				Task Support Requirements			Workplace Factors				Shaping Factors	Hazard ID
Personnel Communications	Cognitive Workload	Physical Workload	Task Overlap	Protective Clothing	Job Aids	Tools or Equipment	Ingress & Egress	Workplace Envelope	Typical Environment	Extreme Environment	Situational & Performance Shaping Factors	Personal Hazards
for monitoring information and control (details such as type and method)	Y/N (provide details, use NASA TLX categories for guidance)	Y/N (provide details)	(serial vs. parallel)	hands, suit, breathing	(reference materials needed)	list of equipment needed	identify issues	(space needed to perform action)	office/operating	(lighting, temperature, noise)	(stress reduced manning)	hazard to human

Figure A-7. Typical task summary details added during TA process (communications, work load, factors, hazards)

Situation Awareness Requirements				Social Organization information (function allocation)					Worker Competencies				General	
Level 1 SA Requirements	**Level 2 SA Requirements**	**Level 3 SA Requirements**		**Allocation**	**LOA**	**Basis & Analysis Method**	**Criteria**		**Skill-based Behavior**	**Rule-based Behavior**	**Knowledge-based Behavior**		**Comments**	**Recommendations**
perception of elements in the environment within a volume of time and space	comprehension of meaning	projection status in the near future		Human or automation (crew member if known)	1-8 level of automation	text explaining basis and analysis method	text explaining any deviation from FA method		description	description	description		text for clarifying comments	text listing any recommendations to design, procedures, training, or other

Figure A-8. Typical details of task summaries (situation awareness, worker competencies)

Strategies analysis will be conducted and documented by using instances of the control task analysis decision trees, information flow maps, and task summaries. The decision tree will be replicated and used to explore classes and individual strategies being considered in determining ways to accomplish the goal. Information flow diagrams may be used as part of the strategies analysis phase. The outcome of the strategies analysis will be documented in order to support the last two phases of the CWA process.

Social organization and cooperation analysis studies the ADS diagrams, FRA&FA database, and task summaries. This fourth phase of CWA will support the S&Q process, allocate functions and tasks to different system actors (human, machine or shared), and formulate staffing and organization structures. This information, along with the baseline for function allocation, will be documented in appended task summaries.

The last phase of CWA is worker competencies analysis and will be used to capture any new and unique requirements of the operators that are different from current LWRs. This will be performed using the skills,

rules, and knowledge framework for the process. During the S&Q process, the results will be converted to match the more standard form for the nuclear industry.

Appendix B. NuScale Function Allocation Process

The NuScale function allocation process is shown Figure B-1 and is comprised of the following steps.

- Select function

  This is a generic statement and applies to a function that was analyzed in the control task analysis step and documented by a decision ladder and task summary from the functional requirements analysis process.

- Check to see if human activation is mandatory for any of the functions, systems, or components assigned to machine in chosen level of automation scheme.

  This is adapted from (Reference 33). This process addresses criteria called out in NUREG/CR-3331 (Reference 10). Mandatory human activation will be directed by one of the following:

  - regulatory requirements
  - organizational policy
  - technical infeasibility
  - human performance limitations
  - environmental conditions

- Check to see if automation is mandatory or essential. This will be dictated by regulation or design.

- Map information-processing activities to one of the four observe-act steps

  This provides guidance to the assignment of level of automation for the four observer – act steps (observe, orient, decide, act) of the function being allocated (Reference 34). These will map to the predefined grouping of information-processing activities from the decision ladder as follows (states of knowledge will be used during the TA process to indicate situation awareness information and levels).

  - Observe (Acquisition) – activate, observe
  - Orient (Analysis) – identify, interpret
  - Decide (Decision) – evaluate, define task, formulate procedure
  - Act (Action) – execute

- Select specific level of automation (using NASA FLOAAT level descriptors for guidance) (Reference 35) for each of the applicable information-processing activities and states of knowledge supporting the function. This is recorded in the task summary.

- Check if function is technically feasible to automate, and if not, choose different level of automation scheme or refine function.

- Check if human can perform function and, if not, choose different level of automation scheme or refine function. When checking to if a human can perform function consider the following:
  - performance requirements
  - cognitive support requirements
  - job satisfaction
  - control requirements
  - information requirements
  - work load
  - reliability
  - organizational requirements
- Document function allocation and provide to automation system design or detailed task analysis

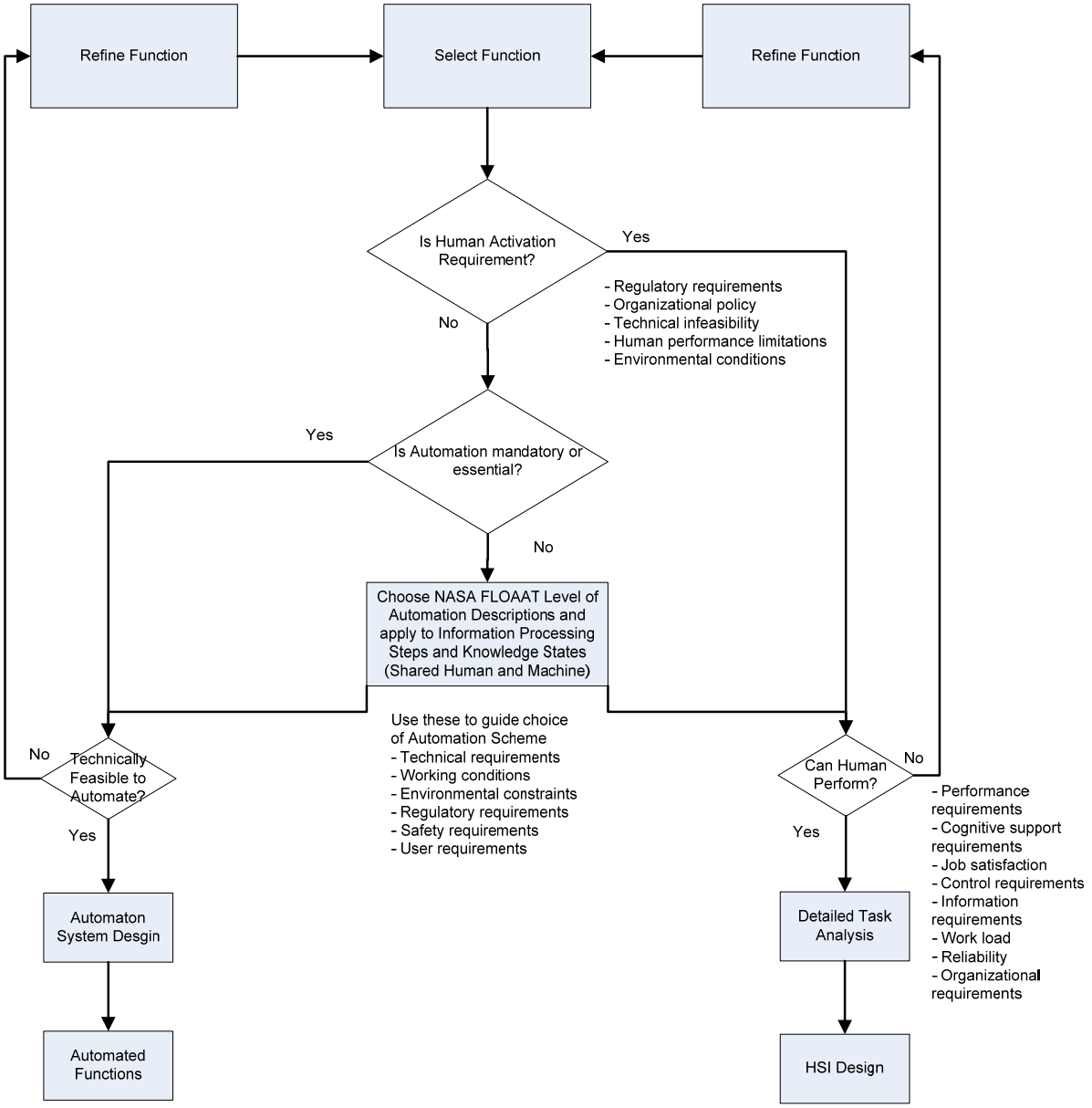

Figure B-1. NuScale function allocation process diagram