Human Factors Engineering Task Analysis Technical Report

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Nonproprietary

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This technical report has been developed and is being submitted to support the NuScale Pre-Application program. It is intended to serve as a basis for discussion of the NuScale approach to performance of the Task Analysis process as described in NUREG-0711 Rev 3. The information contained in this report is preliminary. The formal Task Analysis implementation plan will be submitted with the NuScale Design Certification Application (DCA) in support of Chapter 18 of the NuScale DCA.

CONTENTS

TABLES

FIGURES

1.0 Introduction

1.1 Purpose

The purpose of this technical report is to describe the methodology for conducting the NuScale Power, LLC (NuScale) task analysis section of the Human Factors Engineering Program scope of work. Task analysis identifies the specific tasks personnel perform to accomplish their functions, and the alarms, information, controls, and task support required to complete those actions. Task analysis encompasses a range of plant operating conditions, including startup, normal operations, abnormal operations, transient conditions, low power, shutdown, and refueling conditions.

1.2 Scope

The NuScale task analysis effort applies to tasks conducted within operations, maintenance, testing, inspection, surveillance, or accident management functions involving the main control room, remote shutdown station, emergency operations facility, technical support center, or local control stations.

The results of the task analysis effort are used as inputs for evaluation of other human factors engineering (HFE) process elements to include the following:

- Staffing and qualifications
- Treatment of important human actions
- Human-system interface design
- Plant operating procedures development
- Training program design
- Human Factors Verification & Validation

In addition, the task analysis effort 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. When the task analysis effort is complete, NuScale shall provide a results summary report to the NRC that will contain the following information:

- The human actions to be addressed by task analysis
- A description of the task analysis methodology
- A description of
  - personnel tasks including a narrative of the activities to be performed
  - the applicable aspects of the tasks as identified in NUREG-0711, table 5-1 (see Reference 2.1.1)
  - the relationship between tasks
- An estimate of the time needed to perform the tasks
- Estimated workload
- A list of the alarms, information, controls, and task support identified by the task analysis
- An identification of the number of personnel needed to complete each task
- A designation of the knowledge and abilities needed to perform each task

This technical report satisfies the review criteria of U.S Nuclear Regulatory Commission, “Human Factors Engineering Program Review Model,” NUREG-0711, Revision 3 (Reference 2.1.1) and Section 3.7 of the “NuScale HFE Project Management Plan,” (Reference 2.1.2).

1.3 Abbreviations and Definitions

Table 1-1. Abbreviations

Term	Definition
FRA&FA	functional requirements analysis & function allocation
HFE	human factors engineering
HFEITS	Human Factors Engineering Issue Tracking System
HSI	human-system interface
K&A	knowledge and abilities
OER	operating experience review
PRA	probabilistic risk assessment

Table 1-2. Definitions

Term	Definition
task	A group of activities with a common objective.
subtask	A discrete human action executed to support a task. Multiple subtasks are often required to complete a task. A subtask may be cognitive or physical.
element	Is the smallest logically and reasonably definable unit of behavior required in completing a task or subtask.

2.0 References

2.1 Referenced Documents

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

2.1.2 NuScale Power, LLC, “Human Factors Engineering Project Management Plan,” NP-RP-0813-4248-P.

2.1.3 NuScale Power, LLC, “Functional Requirements Analysis and Function Allocation Implementation Plan,” NP-PL-302-3520-NP.

2.1.4 NuScale Power, LLC, “Human Factors Engineering Operating Experience Implementation Plan,” NP-PL-0302-3219-NP.

2.1.5 BrookHaven National Laboratory, “Trends in HFE Methods and Tools and Their Applicability to Safety Reviews,” BNL Tech Report No. BNL-90424-2009 & NRC Document -Human Factors of Advanced Reactors (NRC JCN Y-6529), October 2009.

2.1.6 U.S Nuclear Regulatory Commission, “Knowledge and Abilities Catalog for Nuclear Power Plant Operators, Pressurized Water Reactors,” NUREG-1122, Revision 2, Supp. 1, June 5, 1998.

3.0 Task Analysis Methodology

The task analysis process is a well organized methodology used by human factors professionals to develop a logical description of human-machine interactions that occur while operators are working to achieve a goal or objective in a specific environment. The analysis will reveal the timing and sequence of operator tasks and operator behavior, which for {{ }}[3(a)]

The task analysis effort is an iterative process that will increase in detail as the design of the NuScale nuclear power plant progresses through engineering design phases. The issues identified by the task analysis process will be captured in the Human Factors Engineering Issue Tracking System (HFEITS) database and actions that are needed will be tracked to ensure effective HFE influence on the NuScale plant design.

The task analysis process includes a top-down approach that starts with the functional requirements analysis and function allocation (FRA&FA) work elements, which break down the plant's high-level mission and goals into functions. The functions are then allocated to human or system resources, and the initial level of automation is determined. The objective of the task analysis is to identify the task requirements for accomplishing the functions allocated to plant personnel.

Two general considerations to guide the analysis are: (1) assessing what will be needed to do the job, and (2) determining how this will be provided. The task analysis will

- provide one of the bases for making decisions about design.
- verify that human-performance requirements do not exceed human capabilities.
- be used as basic input for developing procedures.
- be used as basic information for developing the staffing, qualifications, training, and communication requirements of the plant.
- form the basis for specifying the design requirements for the human-system interface (HSI).

To begin the analysis, each function is broken down into individual tasks that are to be performed by personnel who will operate and maintain the system. The tasks are then analyzed to identify required support functions such as alarms, displays, procedures, or controls that will be required in order for an operator to perform each specific task.

3.1 Task Analysis Process

During performance of the task analysis process, tasks will be selected from representative categories that encompass a full-range of modes of operations, representative conditions during operations, and additional scenarios that the team determines have a safety impact on system operations. In addition, the process will take into account the administrative tasks associated with the human actions. The administrative tasks can contribute to a high workload for operators and can challenge their ability to monitor the plant.

In the following sections, the task analysis process is broken down by activities performed by HFE team members in order to complete this iterative task analysis process. Figure 3-1 contains a process flowchart that outlines the major activities required to perform NuScale task analysis.

{{

}}3(a)-(c)

Figure 3-1. NuScale Task Analysis Process

3.2 Task Analysis Inputs

Sources for the task analysis inputs (see Figure 3-1) come from a variety of external and internal resources. The sources are generated from representative modes of operations (power, startup and shutdown, transient, emergency, and refueling). The following sections describe probable sources of task input information.

3.2.1 Functional Requirements Analysis and Function Allocation

The primary input to the task analysis process is the functional requirements analysis and functional allocation (FRA&FA). The FRA&FA is conducted to identify the allocated human actions and designated automation levels described in the NuScale document “Functional Requirements Analysis and Function Allocation Implementation Plan” (Reference 2.1.3).

An artifact of the FRA&FA will be a set of functions and their allocations to human actions and levels of automation for each function. {{

}}3(a) and (c) The task analysis process will be directly linked to the FRA&FA process and will share data between the two processes.

3.2.2 Important Human Actions

Important human actions identified through probabilistic and deterministic means are inputs to the task analysis process. The HRA input will allow identification of risk-important human actions in the task summaries and ensure that those human actions are fully analyzed. This includes ensuring that the task hierarchy has an adequate level of detail to support the analysis. The task analysis will also use the identified important human actions to highlight human tasks in order to prioritize and develop the analysis in appropriate detail.

3.2.3 Operating Experience Review

The operating experience review (OER) provides direct input into the task analysis process by identifying both past-performance issues and best practices. This experience may be applied to the analysis of each task. The OER provides a list of potential errors related to the important human actions and errors that will be included in the task analysis as well as guidance on the level-of-detail analysis that will be performed in order to satisfactorily address the OER-identified issues. The task analysis team will review the OER item list as part of their input.

The following are examples of operating experience information used for inputting to task analysis:

- Alerts – performance issues related to alarm priorities and avalanching alarms
- Information – performance issues related to ambiguous control room indications
- Teamwork – identification of adequate staffing size and assignments for a task
- Communication – best practices for communication
- Task support – both negative performance issues and best practices for computer-based procedures

The process used to provide operating experience for use in task analysis is described in the NuScale document “Human Factors Engineering Operating Experience Implementation Plan” (Reference 2.1.4).

3.2.4 Technical Specification Surveillances and Periodic Maintenance Procedures Important to Safety

Task analysis will be performed on operational tasks that are important to safety such as those identified by the technical specifications, probabilistic risk assessment (PRA), the D3 coping study, and accident analyses and that are undertaken by operators during maintenance, test, inspection, and surveillance. NuScale’s technical specification surveillances and periodic maintenance procedures for safety and regulatory treatment of nonsafety systems will become inputs to the task analysis process.

3.3 NuScale Task Analysis

3.3.1 Task Selection Criteria (Screening Methodology)

A screening methodology is applied to select tasks for analysis. Each selected task will be analyzed to a level of detail commensurate with its impact on safety. {{

}}3(a) and (c)

Tasks are selected from the full range of plant working conditions; any task that meets the criteria listed below will receive a detailed task analysis.

- All important human actions as determined from safety analysis, PRA, and defense-in-depth and diversity (D3) coping analysis for the instrumentation and control systems
- Tasks that, if performed incorrectly, could impact nuclear safety or power generation
- Tasks that are new or performed in a manner significantly different from similar tasks in the existing industry
- Tasks related to monitoring automated systems that are important to safety
- Tasks related to recognizing the failure or degradation of automated equipment and performance of associated tasks that implement backup responses
- Administrative tasks and support aids such as reference materials, hard copy graphs, and calculators that place a large burden on the control room personnel
- Maintenance or testing tasks that are important to safety
- Tasks with potential effects on personnel safety (such as maintenance tasks performed in the containment)

3.3.2 Develop Task Narrative

After categorization a task narrative is written. The purpose of the narrative is to (1) describe the objectives of a specific system's operator tasks and (2) provide an overview of the activities personnel are expected to accomplish to complete the task. Narrative descriptions of operator activities contain requisite detail for a reviewer to correlate the described task objectives to the results of the completed task analysis. The narrative will be brief for simple tasks but will increase in detail as the complexity of the task increases. The narratives will be reviewed by representatives from the operations group with experience in operating nuclear power plants.

3.3.3 Conduct Detailed Task Analysis

After a task is selected for further analysis, several additional activities are performed to gather more detailed information on each of the tasks. {{

}}3(b) and (c)

3.3.3.1 Decompose into Task Elements

The functional allocation and task narrative provide the objective and operating parameters for the operator work. The next step in the task analysis process is to decompose the task by identifying the parent task, subtasks, and task elements. A task is a well-defined unit of work that has an identifiable beginning and end. It may include multiple subtasks. A subtask is a discrete human action executed to support a task. Multiple subtasks are often required to complete a task. A subtask may be cognitive or physical. An element is the smallest logically and reasonably definable unit of behavior required in completing a task or subtask. A task or subtask may include multiple elements. {{

}}3(a) and (c)

The purpose of decomposing the tasks into elements is to ensure that each stimulus is tied to a response (and that response is directly tied to a stimulus). The general hierarchy of work-related human activity follows a top-down pattern: Job operation, duty, task, subtask, and element. The description for job operation and duty are described in the NuScale Concept of Operations document. A task constitutes a composite of related subtasks (informational, decision, and control activities) performed by an individual in accomplishing a prescribed amount of work in a specified environment. A subtask (perceptions, decisions, and responses) fulfills a portion of the immediate purpose within the task, e.g., remove lug nuts. This may involve operating, checking, adjusting, troubleshooting, or conducting some similar activity. The level of detail defined for the element is connected to the maturity of the design and the level of understanding of the task. {{

}}3(a)-(c)

Figure 3-2. Example of visual, high-level task-to-element decomposition

{{

}}3(a) and (c)

There are several HFE techniques that are commonly used in representative safety industries to accomplish task decomposition activities. {{

}}3(a) and (c) An artifact of the detailed task analysis will be a short descriptive statement of each of the lower-level elements.

3.3.3.2 Operational Sequence Diagram

In parallel to the effort to decompose tasks into their elements, an operational sequence diagram is created. {{

}}3(a) and (c)

{{

}}3(b) and (c)

The sequencing of the tasks provides input for the plant operating procedures and defines the activities that plant personnel should be trained to execute.

3.3.3.3 Determine Task Attributes and Complete Data Table

Once the tasks have been decomposed into elements and those elements have been sequenced to how the operator will potentially perform them, the next step is to assign the identified attributes to each element line item. Table 3-1, reproduced below from reference 2.1.1, provides 11 task consideration areas that need to be addressed. The table presents several examples of pertinent task details/attributes that fall into each of the task consideration areas.

Table 3-1. Task considerations (task attributes)

Topic	Example
Alerts	• alarms and warnings
Information	• parameters (units, precision, and accuracy) • feedback needed to indicate adequacy of actions taken
Decision-making	• decision type (relative, absolute, probabilistic) • evaluations to be performed
Response	• actions to be taken • task frequency and required accuracy • time available and temporal constraints (task ordering)

Topic	Example
	• physical position (stand, sit, squat, etc.) • biomechanics • movements (lift, push, turn, pull, crank, etc.) • forces needed
Teamwork and Communication	• coordination needed between the team performing the work • personnel communication for monitoring information or taking control actions
Workload	• cognitive • physical • overlap of task requirements (serial versus parallel task elements)
Task Support	• special and protective clothing • job aids, procedures, or reference materials needed • tools and equipment needed
Workplace Factors	• ingress and egress paths to the worksite • workspace needed to perform the task • typical environmental conditions (such as lighting, temperature, and noise)
Situational and Performance Shaping Factors	• stress • time pressure • extreme environmental conditions • reduced staffing
Hazard Identification	• identification of hazards involved, e.g., potential personal injury
Other	• the relationship between tasks • estimate of time to perform a task • identification of the number of people to perform a task

There are twenty-one mainstream HFE task analysis techniques, identified in reference 2.1.5, that facilitate collection of the data listed in Table 3-1. {{

}}[3(a) and (c)] Plant operations SMEs, paired with Human Factors Engineering, will provide realistic data metrics.

The goal of each detailed task analysis is to examine the specific human actions required for a task. This is done to determine whether the facility design features (such as software interfaces, procedures, hardware, or training) would meet the operator's requirements and, as a result,

enable the operator to perform the task effectively. On completion of steps listed in Section 3.3.3, recommendations will be identified for the basic features that are necessary to ensure that the task can be accomplished. These recommendations come in the form of the task attribute information and will be listed in the task analysis database, discussed in Section 4.1 below.

3.3.4 Identify Knowledge and Abilities

In addition to the attributes listed in Table 3-1, tasks are analyzed to determine the knowledge and abilities needed to successfully perform each task. The knowledge and abilities will be used to complete other important HFE elements such as the training program content, qualifications, and input to the development of the vendor-specific section of the NuScale Pressurized Water Reactor Knowledge and Abilities (K&A) Catalog. The NRC Knowledge and Abilities Catalog, published by the NRC's Operator Licensing and Human Performance Branch, provide the basis for development of the NuScale vendor-specific section (Reference 2.1.6). The task analysis effort will provide information to tailor and modify the PWR section of the NRC K&A catalog to represent the new plant design.

3.3.5 Assign Tasks to Roles

Additionally, the initial number of operations control room crew members and required crew skills will be addressed. The crew allocation of monitoring and control tasks will be performed in a manner that ensures a meaningful job that is within the physical and cognitive workload limits of the crew member will be created. {{

}}3(a) and (c) Tasks are then assigned to job positions in support of the staffing determination and future job analysis.

3.3.6 Analysis of the Feasibility and Reliability for Important Human Actions

At NuScale, important human actions are derived from the NuScale safety analysis, PRA, tech specs, and defense-in-depth and diversity (D3) coping analysis for the instrumentation and control systems. Any important human action identified by probabilistic and deterministic means will be addressed by a detailed task analysis, as discussed in Section 3.3.3. The NuScale definition, methodology and further analysis for addressing the treatment of important human actions will be discussed in the Important Human Actions Technical Report.

3.3.7 Task Analysis Outputs

Task analysis supports the development of the HSIs, procedures, training, and staffing and qualifications. All four elements are subject to a common evaluation process that verifies the four elements work together to maximize operator performance and ensure complete integration and consistency. {{

}}3(a) and (c)

A Task Analysis Results Summary Report will be submitted when the task analysis process is complete. The report will identify the specific tasks that personnel are to perform to accomplish their job functions. For each of these tasks the alarms, information, controls and task supports needed to perform those tasks will be stated. This will include a summary of review criteria for NUREG-0711 (Reference 2.1.1).

The following sections describe the Human Factors program areas where task analysis information is used as input to further design and analysis.

3.3.7.1 Human-System Interface Design Requirements

The results of the task analysis provide input to the HSI design requirements (Reference 2.1.2) by identifying the displays and controls that the operator will need to successfully complete the task, including the characterization of the interface items. This will include considerations for locating the interface items on individual displays, the required display navigation, or, if needed, the location of conventional analog interface items on panels such as hard buttons.

3.3.7.2 Procedures

Procedures are developed directly from the results of the task analysis. The operational sequence diagrams and decomposition of the tasks into elements produce the outlines from which procedures are written. All ranges of procedures are developed from the task analysis, which include normal, abnormal, alarm response, emergency and severe accident guidelines.

3.3.7.3 Training

Training is based on the systematic analysis of job and task requirements. The tasks, task elements, task attributes, and the task knowledge and abilities are used to develop the learning objectives from which training is designed, developed, and implemented. The training element is closely integrated with the staffing plan and personnel qualifications.

3.3.7.4 Staffing and Qualifications

Many tasks require teamwork and communication between control room staff, auxiliary operators, and other plant personnel. Staffing analysis determines the number and qualifications of operations personnel for the full range of plant conditions and tasks, including operational tasks (under normal, abnormal, and emergency conditions), plant maintenance, plant surveillance, and testing. The decomposition of tasks yields the information needed to determine what staffing is needed and the qualifications the staff must possess. Examples of this information include the following:

- Time needed to perform a task and the workload involved
- Personnel communication and coordination, including interactions between individuals for diagnosing, planning, and controlling the plant and interactions between personnel for administrative, communications, and reporting activities
- The job requirements resulting from the sum of all tasks allocated to each individual inside and outside the control room
- Potential decreases in the ability of personnel to coordinate their work due to changes to the plant
- Availability of personnel considering other work that may be ongoing, and for which operators may be responsible outside the control room (e.g., fire brigade)
- Actions and procedures to implement an initial accident response in key functional areas, as denoted in the emergency plan

During task analysis, an initial assignment is made of the task to a role (or job). Personnel tasks are assigned to staffing positions to ensure that jobs are defined considering

- the task characteristics, such as the knowledge and abilities required, relationships among tasks, time required to perform the task, and estimated workload.
- the person’s ability to maintain situation awareness within the area of assigned responsibility.

- teamwork and team processes, such as peer checking.

The staffing analysis is iterative; that is, the initial staffing goals may be modified as information from the HFE analyses from other elements becomes available.

3.3.7.5 Human Factors Engineering Verification and Validation

The human tasks identified in the task analysis process will be used to develop conditional sampling for verification and validation and to build scenarios for validation testing.

4.0 Task Analysis Tools

4.1 Task Analysis Database

A database will be used to capture data from the task analysis process. This database will contain the results from the task analysis and will serve to facilitate searches and reviews of past analyses. When complete, the task analysis database will contain the following:

- A list of tasks reviewed
- The task attributes as listed in Figure 3-1
- The knowledge and abilities identified for each task

5.0 Task Analysis Support

5.1 Human Factors Engineering Design Team Organization and Qualification

The NuScale Human Factors task analysis team is responsible for conducting task analysis. The qualifications of the HFE design team members supporting this HFE program are stipulated in "NuScale Human Factors Engineering Program Management Plan" (Reference 2.1.2).

5.2 Human Factors Engineering Issue Tracking

Human factors engineering issues, including those associated with task analysis, are captured and tracked throughout the life cycle of the HFE program for the NuScale design project using the Human Factors Engineering Issue Tracking System (HFEITS) database. The HFEITS database is described in "NuScale Human Factors Engineering Program Management Plan" (Reference 2.1.2).

6.0 Additional Consideration for Plant Modifications

The task analysis will be revised and updated to reflect plant modifications as the plant design matures. The scope of the changes considered to affect the task analysis effort encompasses both physical building modifications and individual system modifications. The building modifications can change an operator's physical working environment, which is taken into account under task consideration/task attributes documentation. The modification to an individual system can change the task sequencing and function allocation documented under the task consideration/task attributes documentation.

Modification to the plant in the future will require re-examination of the task analysis process reports and diagrams, including updated task summaries. This is done to ensure any new design modifications have not created downstream modifications to the human actions identified as risk-important. This will also require updating the FRA&FA results, database, and analysis diagrams after each modification has been identified. 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 task analysis database current up to the point at which it is turned over to the operating licensee. If the modification requires additional operator tasks specific to the owner, then an evaluation shall be made of the ability of the operator to carry out those actions.