Staffing Plan Validation Methodology

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Oklo Inc., ~~Proprietary~~

Staffing Plan Validation Methodology executive summary

This topical report describes Oklo's methodology for developing and validating staffing plans to support a fleet-based concept of operations. This report is intended to support future exemption requests from the licensed operator staffing requirements in Title 10 of the *Code of Federal Regulations,* Section 50.54, "Conditions of licenses," paragraph m, which were developed for large light water reactors and do not reflect the safety features and operational simplicity of advanced reactor designs like Oklo's Aurora powerhouse which incorporate passive and inherent safety features and high-levels of automation which reduce or eliminate the need for operator action under most conditions.

Oklo's staffing plan validation methodology is performance based and grounded in human factors engineering (HFE) principles, combining structured analyses, simulation-based evaluations, and task performance assessments to determine operator roles, qualifications, and deployment strategies.

The methodology builds off existing U.S. Nuclear Regulatory Commission guidance in NUREG-0711, "Human Factors Engineering Review Model," Revision 3, November 2012, and incorporates fleet-based operational concepts introduced in Oklo's "Product-Based Operator Licensing Framework" topical report. As a follow-on, this report outlines the methodologies for operating experience review, functional requirements analysis, function allocation, and task analysis, and describes Oklo's overall HFE management plan. The HFE program applies an augmented approach that enhances the scope and rigor of analysis for functions and interfaces of high operational importance, ensuring effective integration of human performance considerations throughout the design and validation process. Together, these elements provide a defensible basis for future staffing plans that align with the Aurora powerhouse's design and Oklo's fleet-based operational model while continuing to meet safety objectives.

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1 Introduction

1.1 Purpose

The purpose of this topical report is to outline Oklo's staffing plan validation methodology and to request the U.S. Nuclear Regulatory Commission (NRC) staff to review and approve the methods described in this report.

This topical report, and the methodology described within, supports future license application submissions and the development of technical justification for exemptions to the following NRC regulations within Title 10 of the *Code of Federal Regulations* (10 CFR) 50.54, "Conditions of licenses":

- { }{ii}{vi}{viii}
- { }{ii}{vi}{viii}
- 10 CFR 50.54(m)

Additional related requirements and guidance documents are listed in Section 3. Proposed language for future exemptions to the regulations addressed in this report is outlined in Section 5.

1.2 Scope

This topical report presents the regulatory and technical basis for Oklo's staffing methodology to support the validation of operator staffing plans for the Aurora powerhouse fleet. The report outlines the human factors engineering (HFE) program management plan and supporting HFE analyses and methodologies that inform the development and validation of staffing plans. These methodologies include the following:

- Operating experience review (OER)
- Functional requirements analysis (FRA) and function allocation (FA)
- Task analysis

The report describes how these HFE analyses support the development of a staffing plan and its validation through HFE staffing studies. It provides context for the performance demonstration used to assess the adequacy of staffing levels, focusing on human-system integration and the operational characteristics of the Aurora powerhouse design and fleet-based operating model.

In addition, the report includes the following:

- A discussion of the limitations of existing NRC operator staffing requirements
- The proposed language for future exemptions from the existing NRC operator staffing requirements

- Key design and operational considerations relating to the Aurora powerhouse design and concept of operations

This report is intended to support the determination of staffing numbers for senior licensed Startup Operators (onsite and remote) and on-call engineering support staff (remote). It does not establish specific staffing numbers but rather provides the methodology by which such numbers may be justified and validated.

1.3 Relationship to Oklo's "Product-Based Operator Licensing Framework" topical report

This topical report builds on Oklo's "Product-Based Operator Licensing Framework" topical report, which was submitted to the NRC for review in March 2025. The "Product-Based Operator Licensing Framework" topical report provides information on the overall design of the Aurora powerhouse, the fleet-based concept of operations, and the product-based operator licensing framework. The "Product-Based Operator Licensing Framework" topical report includes the following:

- A description of the Aurora powerhouse and its key design characteristics
- A description of the overall Aurora powerhouse lifecycle and each lifecycle phase, except decommissioning
- A description of Oklo's fleet-based operations and centralized support functions, in part
- Discussion and application of the term "controls"
- A description of the Aurora powerhouse operating staff roles, responsibilities, qualifications, and training, as needed, in part
- A description of the expected roles and responsibilities of licensed operators deployed to supervise or conduct operations
- A description of the product-based operator licensing framework and regulatory compliance
- The basis for determining comparability of products as it relates to licensing operators to a specific technology, or "product"
- A description of the licensed operator training programs (initial, requalification, cold license)

As described in the previous report, licensed operators perform roles both onsite and offsite. The operating mode determines when a senior licensed Startup Operator is required to be onsite. In their offsite role in the powerhouse support center, senior licensed Startup Operators provide on-call operational and technical assistance, as needed, to the operating shift crew for each Aurora powerhouse and site. Certain functions performed as part of the on-call role include { }{ix}, which support confirming that the Aurora powerhouse remains within its safe operating envelope. Failures associated with these on-call tasks will not directly impact or jeopardize reactor safety; however, consideration to maintaining appropriate workload and situational awareness for Startup Operators, when in the on-call role, should still be made to reduce the potential for human errors that may impact reliable fleet operations. This consideration is especially significant as more Aurora powerhouses are deployed and as the on-call Startup Operators are expected to support multiple Aurora powerhouses across multiple sites (i.e., multi-unit, multi-site operations).

The safe and reliable operation of Oklo's Aurora powerhouse fleet requires a systematic, technically justified approach to determining operator and engineering support staffing levels. This "Staffing Plan Validation Methodology" topical report provides the foundational methodology for developing and validating those staffing plans, in alignment with HFE principles and regulatory expectations. Recognizing the unique operational and design attributes of the Aurora powerhouses and the centralized powerhouse support center, the methodology integrates industry operating experience, functional analysis and function allocation, and task-level evaluation to inform staffing decisions. This report and its appendices establish the structured process and analytical basis to be used to demonstrate that Oklo's final proposed staffing plans support safe plant operation and meet performance criteria through validation activities. The information herein is intended to inform regulatory review and support the development of empirical data for technical justifications for future exemptions where existing NRC staffing operator requirements,10 CFR 50.54(m), are not directly applicable to Oklo's Aurora powerhouse design and fleet-based concept of operations.

1.4 Suitability for a topical report and specific requests

Oklo is providing the information in this topical report to the NRC staff for review and approval of its approach to operator staffing and fleet-based operations approach. The methods described in this report were selected to be reviewed independently of a specific license application to increase the efficiency of future license reviews that reference this topical report.

Oklo requests that the NRC staff review and approve the following topic areas:

1. Staffing plan development and staffing plan validation methodology

2. Oklo's HFE program plan

3. Oklo's OER implementation plan (IP)

4. Oklo's FRA and FA IP

5. Oklo's task analysis IP

These topic areas collectively support the validity and comprehensiveness of Oklo's staffing plan validation methodology.

1.5 Limitations and conditions

This topical report is intended for use by commercial facilities. While the NRC may impose limitations or conditions as part of its safety evaluation, Oklo has not identified any such constraints that would affect the implementation or applicability of the proposed staffing plan validation methodology.

2 Definitions

Act: The Atomic Energy Act of 1954, including any amendments to the Act.

design artifacts: Documented outputs and materials generated during the engineering design process. These outputs include diagrams, drawings, specifications, models, system descriptions, interface layouts, procedural drafts, and analytical results that collectively define the system architecture, components, and operational concepts. Design artifacts are used to communicate design intent; support analysis and review; and provide a foundation for further development, verification, and regulatory evaluation.

facility (or facilities): As defined in 10 CFR 55.4, "Definitions."

facility licensee: As defined in 10 CFR 55.4.

HFE aspects: The elements of a system that fall within the scope of human factors engineering. These elements include tasks performed by personnel, characteristics of the work environment, human-system interfaces, equipment design, staffing, training, organizational structure, and support systems. HFE aspects are considered in the design and evaluation of systems to ensure safe, reliable, and effective human performance.

HFE program: A structured set of activities used to ensure that plant systems, procedures, training, and staffing are developed in a way that supports safe, reliable, and effective human performance. The HFE program includes analyses, design inputs, verification and validation activities, and documentation consistent with applicable regulatory guidance. It integrates human capabilities and limitations into the plant design to ensure that operators can successfully perform their roles under all expected plant conditions.

HFE simulator: A high-fidelity simulation environment designed to replicate plant control and operational conditions for evaluating human-system interfaces, operator tasks, and overall system usability. It is a key tool in the HFE program, supporting the validation of control room designs, operating procedures, and training programs. Importantly, the HFE simulator is also used to validate staffing plans by enabling realistic assessments of operator workload, task distribution, time-critical actions, and crew coordination under simulated normal, abnormal, and emergency conditions.

human factors engineering (HFE): The interdisciplinary application of knowledge about human capabilities, limitations, and behavior to the design of systems, tools, environments, and processes. In nuclear facility design, HFE ensures that systems and interfaces support safe, efficient, and reliable human performance, particularly in areas such as control room layout, procedure development, staffing, training, and human-system interaction.

human-system interface (HSI): Encompasses all tools, displays, controls, software elements, and environmental factors that enable interaction between humans (e.g., operators) and the technical systems they monitor or control. HSI design focuses on clarity, accessibility, and functionality to facilitate safe and effective human performance across normal, abnormal, and emergency conditions.

implementation plan (IP): In the context of HFE or systems engineering, defines the methods, resources, responsibilities, and schedules for carrying out a specific set of activities. As described in NUREG-0711, "Human Factors Engineering Review Model," Revision 3, November 2012, IPs provide the basis for ensuring that HFE activities are systematically executed, traceable to design requirements, and integrated with overall plant development and licensing processes.

important human actions (IHA): Operator tasks or decisions that are necessary to maintain plant safety, prevent or mitigate accidents, or ensure compliance with safety-related functions. These actions are identified through systematic analyses and are often subject to regulatory review, validation, and support through interface design, procedures, and training to ensure they can be performed reliably under expected conditions.

on-call engineering support staff: A technically qualified individual stationed at the powerhouse support center who provides continuous engineering expertise and technical consultation to support operations. This individual advises the senior licensed Startup Operator and onsite operating shift crew on equipment behavior, diagnostics, and system evaluations but does not hold operational authority.

Onsite Monitor: The individual primarily responsible for the on-shift monitoring of overall plant operation during normal operations. Onsite Monitors do not perform any credited operator actions. The Onsite Monitor is a non-licensed operator position and is subject to the fitness-for-duty program.

operating experience (OE): Collectively describes design, construction, and operating experience.

Plant Manager: The individual responsible for the overall operation of an Aurora powerhouse. The Plant Manager is part of the plant organization.

powerhouse: As used within this report, the overall Aurora powerhouse (reactor module and balance of plant). Interchangeable with the term “facility.”

powerhouse support center: Location remotely situated and staffed 24 hours a day, 7 days a week (or “24/7”), with on-call technical support staff (i.e., senior licensed Startup Operators and qualified on-call engineering support). The powerhouse support center receives near-real-time data from each facility, facility operating and administrative procedures, and communication links that enable the on-call technical support staff to communicate with onsite plant staff. The powerhouse support center is not provided the capability to perform any remote functions (e.g., reactor trip) or operations for any Aurora powerhouse.

primary tasks: The core activities that personnel must perform to directly fulfill their assigned operational functions and responsibilities. In a nuclear plant setting, these tasks typically involve monitoring, controlling, and responding to plant systems and conditions.

results summary report (RSR): A document that provides a consolidated summary of the methods, findings, and conclusions from the implementation of a specific HFE program element. As described in NUREG-0711, the RSR serves as part of the documentation package submitted to support regulatory review of the HFE program.

secondary tasks: Supporting activities that personnel perform in addition to their primary tasks. These activities may include routine communications, log-keeping, reference checks, procedural navigation, or system surveillance not directly tied to real-time control. While not always critical, secondary tasks can contribute to overall workload and may impact an operator's ability to perform primary tasks if not properly managed.

senior operator: As defined in 10 CFR 55.4.

significant human interface: Any human interface, such as controls, displays, alarms, or workstations, that plays a key role in enabling personnel to perform tasks determined to be operationally important. These interfaces are significant (but not safety-related) to ensuring positive human-system interaction that supports reliable fleet operations and are subject to HFE design, analysis, and validation to ensure usability, reliability, and error tolerance.

simulation facility: As defined in 10 CFR 55.4.

situational awareness: The operator's ability to perceive critical elements in the plant environment, understand their significance, and project future states to support effective decision making. Situational awareness encompasses three levels: perception of relevant data, comprehension of system status, and anticipation of future conditions. Maintaining situational awareness is essential for safe and efficient plant operation, especially during dynamic or abnormal conditions.

Startup Operator: Senior operators, licensed by the NRC, who perform licensed activities supporting the deployment and operation of Oklo's Aurora powerhouse product line.

systems approach to training (SAT): As defined in 10 CFR 55.4.

task: A measurable, well-defined unit of work with an identifiable beginning and end.

test bed: A controlled environment, either physical, virtual, or simulated, used to develop, test, and evaluate system designs, operational concepts, HSIs, or procedures. Test beds support iterative experimentation and data collection under reproducible conditions, often serving as platforms for human-in-the-loop evaluations, usability testing, or system integration trials.

workload: The cognitive, physical, and temporal demands placed on an individual while performing tasks. In the context of staffing and HFE, workload is assessed to ensure that personnel can perform their assigned duties without being overburdened, especially during high-stress or time-constrained conditions. Effective workload assessment supports safe staffing levels, task allocation, and interface design.

3 Regulations, policy statements, and guidance

The following sections outline the NRC regulations, NRC policy statements, and guidance documents referenced or addressed within this topical report.

3.1 Regulations

The information provided in this topical report relates to the Atomic Energy Act (AEA) of 1954 [As Amended Through P.L. 118-47, Enacted March 23, 2024] and the following NRC regulations:

- { }{ii}{viii}
- { }{ii}{viii}
- 10 CFR 50.54(m)

3.2 Related regulations

The information provided in this topical report also relates to the following NRC requirements:

- 10 CFR 50.2, “Definitions”
- 10 CFR 50.54(i)
- 10 CFR 50.54(x)
- 10 CFR 50.54(y)
- 10 CFR 50.120, “Training and qualification of nuclear power plant personnel,” paragraph (b)(2)
- 10 CFR Part 55, “Operators’ licenses”

3.3 *Federal Register*

The following *Federal Register* (FR) notices are referenced within this topical report:

- 48 FR 31611, July 11, 1983
- 54 FR 33639, August 15, 1989
- 89 FR 86918, October 31, 2024

3.4 Guidance considered

In developing this topical report, Oklo has taken the following guidance into consideration. This list is not intended to be comprehensive.[1]

- ANSI/ANS 3.1, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants," 2014
- RG 1.8, "Qualifications and Training of Personnel for Nuclear Power Plants," Revision 3, May 2000
- IAEA-TECDOC-668, "The Role of Automation and Humans in Nuclear Power Plants," 1992
- IEEE 845-1999, "IEEE Guide for the Evaluation of Human-System Performance in Nuclear Power Generating Stations," December 1999
- IEEE Standard 1023-2020, "IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities," 2020
- IEEE 2411-2021, "IEEE Guide for Human Factors Engineering for the Validation of System Designs and Integrated Systems Operations at Nuclear Facilities," 2021
- NEI 09-09, "Use of Simulation Facilities for Training and Examination of Nuclear Power Plant Personnel," Revision 1, April 2011
- NUREG-0700, "Human-System Interface Design Review Guidelines," Revision 3, July 2020
- NUREG-0711, "Human Factors Engineering Program Review Model," Revision 3, November 2012
- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 13
- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 18
- NUREG-0933, "Resolution of Generic Safety Issues" (Main Report with Supplements 1-35), 2011
- NUREG-1275, "Operating Experience Feedback Reports," 2021

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[1] The following acronyms are used in this list: American National Standards Institute (ANSI), American Nuclear Society (ANS), Division of Advanced Reactors and Non-Power Production and Utilization Facilities (DANU), Division of Reactor Oversight (DRO), Idaho National Laboratory (INL), Institute of Electrical and Electronics Engineers (IEEE), Interim Staff Guidance (ISG), International Atomic Energy Agency (IAEA), Nuclear Energy Institute (NEI), and Regulatory Guide (RG).

- NUREG-1791, “Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m),” July 2005

- NUREG/CR-3331, “Methodology for Allocating Nuclear Power Plant Control Functions to Human or Automatic Control,” August 1983

- NUREG/CR-6400, “Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience,” January 1997

- NUREG/CR-6393, “Integrated System Validation: Methodology and Review Criteria,” January 1997

- NUREG/CR-6749, “Integrating Digital and Conventional Human-System Interfaces: Lessons Learned from a Control Room Modernization Program,” September 2002

- NUREG/CR-6838, “Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m),” February 2004

- NUREG/CR-6947, “Human Factors Considerations with Respect to Emerging Technology in Nuclear Power Plants,” October 2008

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

- DANU-ISG-2022-05, “Advanced Reactor Content of Applications Project, Chapter 11, ‘Organization and Human-System Considerations,’” October 2023, Interim Staff Guidance

- DRO-ISG-2023-02, “Draft Interim Staff Guidance Augmenting NUREG-1791, ‘Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)’ for Licensing Commercial Nuclear Plants under 10 CFR Part 53,” September 2022, Draft Interim Staff Guidance

- DRO-ISG-2023-03, “Development of Scalable Human Factors Engineering Review Plans,” October 2024, Draft Interim Staff Guidance

- INL/EXT-13-30117, “Development of a Technical Basis and Guidance for Advanced SMR Function Allocation,” U.S. Department of Energy, Office of Nuclear Energy, September 2013

- Information Notice 95-48, “Results of Shift Staffing Study,” U.S. Nuclear Regulatory Commission, October 1995

- Information Notice 97-78, “Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times,” U.S. Nuclear Regulatory Commission, October 1997

4 Regulatory background

The operator staffing requirements in 10 CFR 50.54(m) were developed for large light water reactors (LLWRs) and do not reflect the design characteristics or operational needs of advanced reactors, such as Oklo's Aurora powerhouse. While NUREG-1791 offers a structured framework for assessing exemptions to these requirements, it does not fully address the distinctive attributes of the Aurora powerhouse design and Oklo's fleet-based operational model. These attributes include advanced digital control systems, high levels of automation, and passive safety features that reduce the need for active operator engagement to maintain safe operation, particularly during power operations and shutdown modes. Additionally, the framework does not consider the implications of a fleet-based operational model, such as Oklo's powerhouse support center, where staff may fulfill scalable, multi-unit, multi-site, or transitionary roles. These roles can influence both workload and situational awareness, not only at individual sites but across the broader fleet and from a centralized fleet-based support center (i.e., powerhouse support center).

As such, there is a need for a flexible, design-informed approach to operator staffing that remains consistent with regulatory safety intent. Oklo's staffing methodology addresses this need by providing a framework for establishing empirically supported staffing plans, validated through HFE analyses, and capable of evolving as the fleet grows and operational data becomes available.

4.1 Limitations of 10 CFR 50.54(m)

The current minimum per-shift staffing requirements for nuclear power plant licensed operators are specified in 10 CFR 50.54(m). These requirements were established in 1983 following the accident at Three Mile Island (TMI) Nuclear Generating Station (48 FR 31611; July 11, 1983). Before the TMI accident, NRC regulations only required (1) the presence of a licensed senior operator at the facility or readily available on call during operation, and (2) an operator or senior operator present at the controls at all times during operation.

When developing the current requirements of 10 CFR 50.54(m), the NRC, the industry, and other industry groups conducted studies on operating LLWRs. As a result, the current requirements are largely based on the operating characteristics of LLWRs, which, in contrast to Oklo's Aurora powerhouse, rely heavily on human recognition, decision making, and operator actions to ensure safety during certain postulated and beyond-design basis accidents. Several of the key operating assumptions and limitations of LLWRs are implicitly incorporated into the current requirements. The effects of these characteristics are as follows:

- Establish a maximum number of units and control rooms (i.e., three units and three control rooms)
- Require that there is always at least one operator at the controls for each unit [10 CFR 50.54(m)(2)(iii)]
- Require that there is always at least one senior operator onsite for each unit during operations
- Require that there is at least one senior operator onsite at all times [10 CFR 50.54(m)(2)(ii)]

- Require that there is one senior operator in the control room for each unit in operation [10 CFR 50.54(m)(2)(iii)]
- Require that there is one more senior operator than the number of units operating when multiple units are in operation in more than one control room, except when three units are in operation in two control rooms

Additionally, the operator and senior operator roles are the only two job functions addressed by the *Code of Federal Regulations*, and their roles, responsibilities, and qualifications are as defined in 10 CFR Part 55.

Finally, 10 CFR 50.54(m)(2)(iv) prescribes the following:

> Each licensee shall have present, during alteration of the core of a nuclear power unit (including fuel loading or transfer), a person holding a senior operator license or a senior operator license limited to fuel handling to directly supervise the activity and, during this time, the licensee shall not assign other duties to this person.

The existing staffing requirements reflect a conservative margin of safety philosophy intended to ensure that a sufficient number of licensed operators and senior operators are available to perform all required safety functions under both normal and off-normal conditions. This requirement also includes an implicit expectation for an additional operator to account for unforeseen unavailability, often referred to as a “plus one” margin incorporated into the minimum per-shift operator staffing requirements. These assumptions were developed for LLWRs, but the design characteristics of the Aurora powerhouse reduce reliance on continuous operator action and support a new fleet-based concept of operations that requires fewer onsite personnel. Consequently, the safety margin traditionally achieved through additional staffing is effectively embedded within the Aurora design itself, enabling a reduced yet validated staffing model that maintains compliance with safety objectives.

Although the requirements codified in 10 CFR 50.54(m) were developed for LLWRs, the foundational objective of these requirements is to ensure that licensed operators are available to perform necessary safety functions and provide for licensed senior operator authority, oversight, and accountability across all modes of operation. Oklo’s approach is consistent with this intent, even though the staffing model differs in structure and scale. Oklo’s concept of operations includes senior licensed Startup Operators with authority and oversight responsibilities, supported by engineering staff at the powerhouse support center. This approach ensures that licensed control and oversight are maintained during all operating modes across the fleet, including transient conditions.

As shown in Table 4-1, Oklo’s proposed concept of operations aligns with the underlying intent of and principles based on the 1983 rulemaking. Many of the changes introduced through that rulemaking increased regulatory oversight and imposed additional requirements based on the standard operating practices of LLWRs at the time (48 FR 31611; July 11, 1983). While the intent of these requirements was to ensure safe operation through adequate licensed staffing and oversight, the rule also incorporated prescriptive language and assumptions that reflect the operational characteristics of LLWRs, including a strong reliance on continuous human action. These prescriptive elements are not directly applicable to advanced reactor designs, such as the Aurora powerhouse, that incorporate passive safety features and higher levels of automated control. These design attributes reduce the need for operator intervention to ensure the health and safety of the public across all modes of operation.

Table 4-1: Comparison of Oklo's proposed operator staffing approach to existing requirements and their bases

Existing	Bases	Oklo approach
A shift supervisor with a senior operator's license shall be onsite at all times that any unit is loaded with fuel.	Ensures that a technically qualified individual is present to supervise plant operations and respond to abnormal conditions. The senior operator has detailed knowledge of plant limits, conditions, and specifications beyond that of a reactor operator or unlicensed individual. This requirement reflects the need for immediate availability to respond to changing plant conditions, particularly in LLWRs that rely on operator action for safe operations.	{i}{ii}{viii}{ix}
A senior operator shall be present at all times in the control room from which a unit is being operated.	Ensure that an experienced, licensed operator is always available in the control room to provide oversight, manage emergent conditions, and support decision making. The requirement also ensures the ability to act immediately in the event of abnormal conditions or emergencies in designs that depend on human action for safe control.	{i}{ii}{viii}{ix} However, during operational modes where no licensed operator is physically onsite, there are no credited human actions necessary to maintain safety. Additionally, a senior licensed Startup Operator remains available 24/7 on call from the powerhouse support center to provide }{ix}. The Aurora design relies on inherent safety and automation, minimizing the need for immediate operator intervention. Oklo's approach ensures the intent of the regulation is maintained through continuous availability of licensed expertise, scaled appropriately based on the Aurora powerhouse design and operational model.

Existing	Bases	Oklo approach
Core alterations shall be supervised by an individual who holds a senior operator license or a senior operator license limited to fuel handling for that unit.	Ensures that core alterations, including fuel movement, are overseen by personnel with advanced training and a senior license. This requirement provides assurance that technical specifications and safety procedures are followed and that risks associated with refueling or core alterations are properly managed.	Oklo's approach is consistent with the traditional requirement. A senior licensed Startup Operator is physically onsite during refueling and core alterations and provides direct supervision of all related activities. When in this role, the operator performs no other duties. This approach meets the intent of the requirement by ensuring licensed oversight, procedural compliance, and adherence to safety limits during core operations.
Each unit shall have one licensed operator at the controls at all times in addition to a senior operator in the control room, and operating units shall have an additional licensed operator assigned to the unit.	Ensures that plant instrumentation is continuously monitored, controls are properly manipulated, and sufficient licensed staff are available for relief or emergent needs. This model assumes continuous human involvement in maintaining safe plant operations.	Oklo's approach differs from the traditional model. }{ix} the Aurora powerhouse does not rely on human intervention to maintain safety. Safety functions are passive and automated. A senior licensed Startup Operator is available 24/7 on call from the powerhouse support center, and all facility control actions are restricted to licensed personnel. { } {i}{ii}{viii}{ix}

While the traditional staffing requirements embed a margin of safety by requiring sufficient operators plus an additional reserve to cover unforeseen absences, Oklo's design integrates this margin through reduced operational demands and increased safety performance. The result is a staffing model that meets the regulatory objectives for safe operation, operational control, and licensed oversight, while leveraging the safety and performance characteristics unique to advanced reactor designs.

4.2 SECY-11-0098

In July 2011, the NRC staff issued a policy issue memorandum, SECY-11-0098, "Operator Staffing for Small or Multi-Module Nuclear Power Plant Facilities," to inform the Commission of ongoing efforts concerning the application of the NRC's onsite licensed operator staffing requirements to small or multi-module nuclear power plants. Within the memorandum, the NRC staff recommended a two-step approach to address operator staffing requirements for advanced reactor designs with concepts of operations that propose onsite operator and senior operator staffing levels different than those prescribed in 10 CFR 50.54(m). In the near term, the NRC staff proposed that applicants can request exemptions to the current operator staffing requirements in 10 CFR 50.54(m) and the staff will review the request using existing or modified guidance.

As noted in SECY-11-0098, the NRC staff recognized the need for a long-term regulatory solution to address operator staffing requirements for advanced reactor designs that rely less on operator action to ensure public health and safety. The staff acknowledged that, once sufficient experience is gained with these new designs and operational models, the longer-term solution would be to revise the regulations accordingly. To that end, the NRC is actively pursuing rulemaking under 10 CFR Part 53, "Risk informed, technology-inclusive regulatory framework for advanced reactors," to develop a risk-informed, performance-based framework that includes appropriate staffing requirements for advanced non-light water reactors. Still, no revised staffing requirements for advanced reactors have yet been finalized. In the interim, and until applicable rulemaking is complete, Oklo is pursuing the use of exemptions as a near-term regulatory path to support its staffing approach.

The NRC staff has acknowledged that applicants seeking exemptions from the requirements of 10 CFR 50.54(m) should support their proposals with analyses grounded in HFE principles. These analyses should provide a performance-based justification for determining the number and qualifications of licensed operators and senior operators needed to ensure the health and safety of the public. The existing review guidance in NUREG-1791 offers a framework for evaluating such exemption requests. It provides NRC staff with a methodology that accounts for differences in plant design, particularly as they relate to task demands and the role of plant personnel. This guidance, and its relevance to Oklo's approach, is further discussed in the following section.

4.3 NUREG-1791

NUREG/CR-6838, developed by Sandia National Laboratories, provides the technical foundation for evaluating proposed exemptions to operator staffing requirements. It introduces methods, criteria, and supporting rationale to determine whether alternative staffing approaches can satisfy the safety intent of existing regulations. This foundational work informed the development of NUREG-1791, which provides structured guidance for NRC staff to review and assess requests for exemption from the licensed operator staffing requirements in 10 CFR 50.54(m).

The purpose of the NRC's review is to ensure that any proposed exemption maintains the protection of public health and safety. This focus is achieved by evaluating whether the applicant's staffing plan and supporting assessments, based on HFE principles, adequately justify the exemption. NUREG-1791 specifies the type of information that should be submitted, including the following:

- A description of the exemption request, concept of operations, and operational conditions considered
- Supporting analyses based on OER, FRA and FA, task analysis, job definition, and the proposed staffing plan

- Results from performance-based validation exercises demonstrating that the proposed staffing levels support safe plant operation

The review process consists of 11 structured steps (illustrated in Figure 4-1) and begins with defining the scope of the exemption request. This step includes identifying any new concepts or terminology and evaluating whether additional exemptions are needed. The next step is to review the applicant's concept of operations, which establishes the operational context for evaluating the exemption.

Then, NRC staff assess the operational conditions considered by the applicant, particularly those that pose the greatest challenge to licensed personnel under the proposed staffing model. The NRC then evaluates whether the staffing methodology includes representative and challenging conditions (e.g., multi-unit and multi-site operations) as part of its validation approach.

Finally, the NRC reviews the staffing plan validation, which must be performance based and demonstrate that the staffing model supports safe and reliable plant operation. The review concludes with an overall assessment to determine whether the exemption request is acceptable.

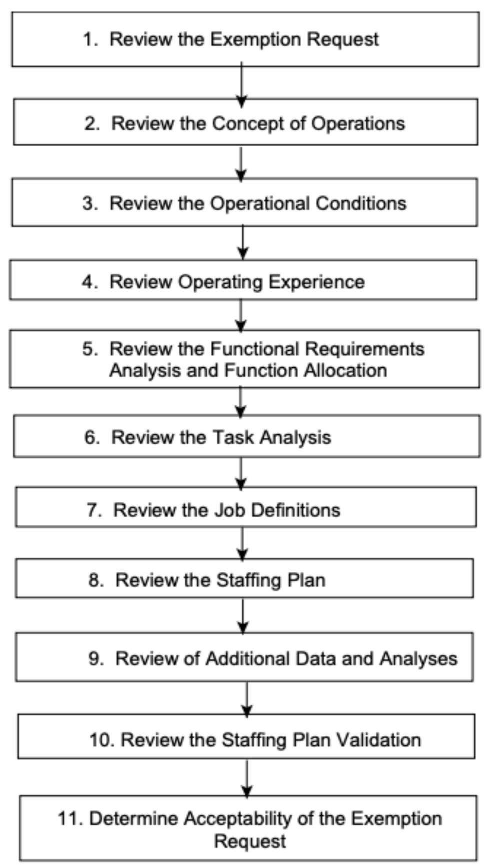

Figure 4-1: The exemption request review process, reproduced from NUREG-1791

While NUREG-1791 provides a clear framework for evaluating exemption requests, it is recognized that applying this framework to advanced reactor designs presents unique challenges, including the following:

- Different operator tasks (e.g., responsible for the operation of multiple units, located at multiple sites, in different modes of operations)
- Different skill sets required for operators and non-licensed operators, along with a potentially different distribution of qualifications
- Fleet-based concept of operations or concepts that involve operators who oversee multiple units at multiple locations or sites, managing the operation of additional units as they are placed online. As the number of units increases, the demands on the operators, and potentially the number of operators required to support safe and reliable fleet operation, will change (i.e., multiple staffing plans may be necessary).

Oklo's staffing methodology, including its approach to validation, was developed with these complexities in mind. It reflects the Aurora powerhouse's unique design and the role of senior licensed Startup Operators in a fleet-based support model. While NUREG-1791 outlines the information to be reviewed in a staffing exemption request, it relies on NUREG-0711 to define how the HFE program elements and analyses should be conducted. The following section discusses how Oklo's methodology applies the principles and processes from NUREG-0711 to support the development and validation of its staffing plan.

4.4 NUREG-0711

NUREG-0711 provides the NRC's framework for reviewing the adequacy of HFE programs submitted in support of nuclear plant licensing. The review model is technology neutral and performance based, allowing it to be applied to a wide range of reactor designs, including advanced reactors that feature digital control systems, automation, and fleet-based operational models.

The structure of NUREG-0711 reflects a systems engineering approach, organized around key phases such as analysis, design, verification and validation, and implementation. This approach ensures that HFE considerations are systematically integrated throughout the plant's lifecycle and are aligned with the broader engineering design process. The foundation of the review model is the HFE Program Management element. This element ensures that the applicant has established a clear plan for organizing, managing, and executing HFE activities. It includes identification of scope, roles and responsibilities, coordination among disciplines, and a schedule for completing each HFE element.

While this section provides the regulatory background and context for the use of NUREG-0711, detailed descriptions of the applicable HFE program elements and their role in supporting Oklo's staffing plan validation are provided in subsequent sections of this topical report.

4.5 Insights on operator staffing from a risk-informed, technology-inclusive regulatory framework for advanced reactors

As described in Section 4.1, many licensing requirements in 10 CFR Part 50, "Domestic licensing of production and utilization facilities," and 10 CFR Part 52, "Licenses, certifications, and approvals for nuclear power plants," were originally developed for LLWRs and reflect assumptions specific to their operational characteristics. To modernize the regulatory framework and accommodate advanced reactor technologies, Congress enacted the Nuclear Energy Innovation and Modernization Act (NEIMA), signed into law on January 14, 2019. NEIMA directs the NRC to establish a technology-inclusive regulatory framework for optional use by advanced reactor applicants. In response, the NRC issued a proposed rule for 10 CFR Part 53 to support diverse reactor technologies through flexible, practicable evaluation methods (89 FR 86918; October 31, 2024).

In its proposed 10 CFR Part 53, the NRC establishes an alternative regulatory framework for licensing future commercial nuclear plants. The new alternative requirements and implementing guidance adopt technology-inclusive approaches that consider the variety of technologies and designs being deployed for new reactors and use risk-informed and performance-based techniques to ensure, at a minimum, an equivalent level of safety to that of operating commercial nuclear plants. Oklo's Aurora powerhouse design builds on the legacy of the Experimental Breeder Reactor II (EBR-II) and the Integral Fast Reactor (IFR) program, which had decades of operational experience in the United States. The Aurora powerhouse retains many of the inherent mechanisms for safety and passive design features from EBR-II. Additionally, the Aurora powerhouse incorporates key design characteristics, as described in Oklo's "Product-Based Operator Licensing Framework" topical report, that enhance the design's safety profile and reduce the need for human involvement throughout operations. During certain modes of operation, no licensed operators are required to be onsite.

As stated in 89 FR 86918, October 31, 2024,

> New technologies may involve concepts of operations that are more conducive to customizable licensed operator staffing requirements than the prescriptive requirements of 10 CFR 50.54(m). Analyses and assessments that are based on HFE principles provide a performance-based means of determining licensed operator and senior operator staffing needed to support safe operations. The NRC recognizes that technology-inclusive facility staffing will need to account for a potentially wide range of concepts of operations; for this reason, flexible and performance-based approaches for establishing required facility staffing are appropriate. However, once the appropriate facility staffing has been determined and approved by the NRC, such staffing must be maintained to ensure that the appropriately qualified individuals will be available when needed to support the safe operation of the facility.

Consistent with this approach, the NRC proposes a requirement for applicants for an operating license (OL) or combined license (COL) to submit a staffing plan that details operations staffing, how engineering expertise will be provided, and what staffing will be available to provide other needed support functions. Following NRC approval of the OL or COL, the staffing plan becomes a condition of the facility license. The NRC intends that, at a minimum, the approved licensed operator and senior operator staffing, positions, and personnel locations will be incorporated into corresponding requirements within the facility technical specifications and that a license amendment is thus required for any subsequent changes.

In addition to the operator staffing insights that can be gleaned from the proposed rule, the NRC also proposes to require that engineering expertise be accounted for within the applicant's submitted staffing plan. This proposed requirement is in lieu of the traditional position of the shift technical advisor (STA) that was established following the TMI accident. The NRC further proposes to impose clarifying requirements that stipulate that individuals providing "engineering expertise" on shift would need, among other things, to possess either a qualifying 4-year degree or licensure as a Professional Engineer. Oklo is proposing the use of on-call engineering support staff to provide on-call engineering expertise to the operating staff of the Aurora powerhouse. Minimum education and experience requirements for the on-call engineering support staff are outlined in Oklo's "Product-Based Operator Licensing Framework" topical report and meet the proposed education requirements for engineering expertise in the proposed Part 53 rulemaking by the NRC.

Through its proposed rulemaking, the NRC staff has developed interim staff guidance, DRO-ISG-2023-02, for assessing exemptions using NUREG-1791. This ISG provides guidance to NRC staff for the review of customized facility operator staffing plans that are submitted to the NRC for review consistent with the proposed Part 53 rulemaking. The ISG is structured to be a companion document to NUREG-1791 and adapts the existing HFE-based methodologies of that document for use in the evaluation of staffing plans that would be submitted under the Part 53 rule. The ISG provides further guidance to address other staffing-related considerations, such as provisions for engineering expertise. This review guidance was used to inform Oklo's fleet-based staffing plan approach, specifically in defining what the plan must address, including how the plant is monitored outside the control room or offsite, how engineering expertise is made available, and how operating modes influence the minimum shift complement.

4.6 Summary

The existing operator staffing requirements in 10 CFR 50.54(m) were developed for LLWR designs and reflect assumptions about continuous operator presence, high operator workload, and reliance on human action for plant safety. While these requirements are prescriptive in nature, their underlying intent is to ensure that licensed operators are available to maintain safe and effective control of the plant under all operating conditions. Oklo's concept of operations, centered on the design of the Aurora powerhouse, supported by senior licensed Startup Operators and a centralized powerhouse support center, differs in implementation but aligns with the regulatory intent by maintaining licensed oversight, accountability, technical authority, and operational safety during all modes of operation.

SECY-11-0098 outlines a regulatory path for addressing staffing requirements in the context of advanced reactors, identifying both a long-term rulemaking strategy and a short-term approach through the use of exemptions. As no final rule has been established, Oklo is pursuing the exemption path under the current 10 CFR Part 50 framework. The exemption justification will leverage the structured review guidance in NUREG-1791, informed by NUREG/CR-6838, while incorporating additional considerations necessary for advanced reactor applications, including changes in operator roles, multi-unit and multi-site operations, and fleet-based operational models. NUREG-0711 provides a flexible, technology-neutral framework grounded in systems engineering principles. This framework supports the development, analysis, and validation of HFE elements and will be used to guide the performance-based assessments that underpin Oklo's staffing plan validation methodology.

5 Future exemptions

The operator staffing approach described in Oklo's "Product-Based Operator Licensing Framework" topical report requires exemptions from certain provisions in the NRC's regulations under 10 CFR 50.54, specifically the following:

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- { }{ii}{vi}{viii}
- 10 CFR 50.54(m)

The purpose of this section is to present proposed exemption language and to outline the regulatory basis for seeking such exemptions. Under 10 CFR 50.12, "Specific exemptions," the Commission may grant exemptions from the requirements of 10 CFR Part 50, either upon application by an interested person or on its own initiative. An exemption may be granted if it is authorized by law, does not pose an undue risk to public health and safety, and is consistent with the common defense and security. In addition, the exemption request must demonstrate that one or more "special circumstances," as defined in 10 CFR 50.12(a)(2) paragraph i through vi, apply to the request.

It is important to note that any licensee seeking regulatory exemptions from the above requirements must submit a supporting technical basis as part of its application. This justification must include supporting analyses and data demonstrating that the proposed staffing approach maintains compliance with the underlying safety intent of the regulation and meets the exemption criteria established in 10 CFR 50.12.

5.1 10 CFR 50.54(m)

As discussed in Section 4.1, the existing regulations for the minimum licensed operator per-shift staffing in 10 CFR 50.54(m) are prescriptive and based on the operating characteristics and experience from LLWRs. Under Oklo's fleet-based concept of operations, licensed operators are not required to be continuously stationed onsite but are deployed during specific modes of operation. As a result, Oklo is seeking an exemption to the staffing requirements of 10 CFR 50.54(m). A staffing plan will be developed and validated using the methodologies outlined in this topical report, which are based on HFE analyses and principles. The validated staffing plan will serve as the technical basis for an exemption to 10 CFR 50.54(m) and will be incorporated into the facility's technical specifications.

Proposed exemption language to the requirement of 10 CFR 50.54(m) is outlined in Table 5-1.

Table 5-1: Proposed exemption language for 10 CFR 50.54(m)

Regulation	Language
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	{ii}{vi}{viii}

5.2 { }{ii}{vi}{viii}

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Table 5-2: { }{ii}{vi}{viii}

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Table 5-3: { }{ii}{vi}{viii}

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6 Site-specific staffing plan development

This section outlines Oklo's approach to developing a staffing plan. Multiple staffing plans will be developed: one for onsite Aurora powerhouse operations (i.e., the site-specific staffing plan) and one for the operating staff providing certain functions from the powerhouse support center (i.e., fleet-support center staffing plan). Developing multiple staffing plans supports scalable, fleet-based operations by providing a mechanism to (1) define the onsite staffing requirements necessary to ensure the health and safety of the public and (2) ensure certain administrative and decision tasks are performed offsite to support operation of Oklo's Aurora powerhouse fleet within its safety envelope.

6.1 Relationship between site-specific and fleet-support staffing plans

Traditional staffing plans are typically developed for a single reactor unit or for multiple co-located units operating under the conventional assumptions of LLWRs. While these plans account for the operational demands of multiple units at a given site, they are not designed to support a distributed fleet of facilities at multiple geographical locations, particularly in cases where key operational functions such as supervision, engineering, or technical support are provided from an offsite location. Oklo's staffing model addresses this limitation by establishing two distinct but integrated staffing plans: a site-specific staffing plan and a fleet-support staffing plan. The site-specific staffing plan defines the roles and personnel required to support the operation of a specific site, including considerations for one or more units. The fleet-support staffing plan specifies the staffing and capabilities required at the fleet-based support center (i.e., powerhouse support center) to provide centralized operational, engineering, and supervisory support to facilities across the fleet.

As conceptually depicted in Figure 6-1, the fleet-support staffing plan supports the site-specific staffing plan while simultaneously establishing staffing requirements for the powerhouse support center.

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Figure 6-1: }{ii}{viii}

This two-tiered staffing approach is consistent with the principles outlined in NUREG-1791, which recognizes the potential for alternative staffing arrangements based on advanced technologies and new operational concepts. NUREG-1791 supports the use of fleet-oriented models and centralized support functions, where justified by analysis and demonstrated through validation.

The development and validation of Oklo’s staffing plans also aligns with NUREG-0711, which provides guidance for the systematic application of HFE. Specifically, the staffing and qualifications (S&Q) and verification and validation (V&V) elements of NUREG-0711 inform the methods used to establish, verify, and validate the adequacy of proposed staffing levels and role assignments under expected operating conditions. Oklo’s site-specific and fleet-support staffing plans are developed and validated together through staffing analyses and performance-based evaluations that reflect the integrated operation of each site and the broader fleet support infrastructure.

Following initial validation, the fleet-support staffing plan provides a scalable foundation for extending centralized support to additional sites and units across the fleet. As new facilities are brought online, the validated support center framework can be expanded while maintaining operational effectiveness, clarity of roles, and compliance with applicable licensing requirements.

The following sections describe the methodology used to develop the site-specific staffing plan for onsite staffing. Section 7 outlines the development of the fleet-support staffing plan and explains how the fleet-support staffing plan is maintained, validated, and implemented in support of scalable fleet-based operations.

6.2 Insights from Oklo's fleet-based concept of operations

As specified in NUREG-1791, applicants requesting an exemption to 10 CFR 50.54(m) must provide information relating to the proposed fleet-based concept of operations. A concept of operations describes how the design, systems, and operational characteristics of the plant relate to the proposed organizational structure, staffing model, and management approach. Section 2.2 of NUREG-1791 outlines key elements that support the NRC staff's review of exemption requests, including staffing goals, personnel interactions with automation and one another, control room responsibilities, and training and qualification requirements.

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Figure 6-2:

Figure 6-3:

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Insights from the concept of operations directly inform the structure and content of Oklo's staffing plans. Both the site-specific and fleet-support staffing plans are initially developed and validated together to reflect this integrated operating model. Following initial validation, the fleet-support staffing plan provides a scalable foundation for supporting additional sites and units across the fleet.

6.3 HFE program

Licensed operator staffing goals both inform and are influenced by several elements of the HFE program. These goals are confirmed through the staffing validation methodology described in Section 8 and are subject to revision based on the outcomes of HFE analyses. These analyses include OER, FRA and FA, task analysis, and S&Q evaluations. The methodologies used to perform these analyses are documented in corresponding IPs or RSRs, as applicable. Collectively, these HFE elements provide the technical basis for defining and refining the staffing requirements outlined in the staffing plan, including any updates made as the design matures or as the fleet expands.

Oklo's HFE program was developed based on the guidance provided in NUREG-0711, Chapter 2. The primary goal of Oklo's HFE program is to provide a systematic methodology for integrating state-of-the art HFE into the overall design of the Aurora powerhouse to achieve safe, efficient, and reliable plant operations. The HFE program is in effect early in the design process and continues through the completion of the initial plant startup test program. Human performance monitoring continues throughout plant operations.

The HFE design process is an iterative process that integrates a human-centered approach and perspective into the design of the Aurora powerhouse. The HFE program ensures that the overall plant safety goal to ensure health and safety is met in the following manner:

- Users are provided high-quality interfaces with systems that are easy to use and understand.
- Situational awareness is supported by the design of HSIs, operating procedures, training, staffing levels, and personnel qualifications.
- Vigilance is maintained over all plant operating modes and states as supported by the HSI design, procedures, training, staffing levels, and personnel qualifications.
- Human errors are minimized, and error detection and recovery capabilities are supported.
- Personnel tasks are accomplished when required and to the required performance criteria supported by the HSI design, procedures, training, staffing levels, and personnel qualifications.
- Task demands and workloads for personnel are reasonable throughout all plant operating modes and states.
- Plant modifications are evaluated for potential impacts to human performance. HFE considerations should be provided to ensure that
    - disruptions to existing work activities are minimized during the planning, installation, and implementation of plant modifications;
    - changes to plant procedures and training are properly coordinated to ensure personnel are provided the tools necessary to successfully complete their tasks; and

- training is conducted prior to implementation of plant modifications to ensure personnel have the necessary knowledge and skills to complete tasks impacted by the plant modifications.

These goals are achieved by integrating HFE elements and activities with relevant engineering activities early in the design process to ensure the consistent application and integration of HFE principles into the design and verification of applicable facilities and HSIs. It is anticipated that as the HFE program develops, these goals will be further refined and defined to support HFE tests and evaluation. Provisions are made in all processes for necessary iteration, review, and verification.

A full description of Oklo's HFE program is provided in Appendix A. It includes information on the following topics:

- HFE program goal and scope
- HFE team and organization
- HFE processes and procedures
- Tracking HFE issues
- Technical program, and program elements

The staffing validation methodology is described in Section 8 and is based on the guidance of NUREG-0711, Chapter 11. The following sections describe each of the HFE program elements listed above and how they inform staffing plan development and validation.

6.4 Operating experience review

Foundational to the HFE program is the systematic use of relevant operating experience and lessons learned to inform design, staffing, training, and procedural decisions. Oklo's OER methodology is structured in accordance with the guidance in NUREG-0711, which identifies OER as a key input to human performance-focused design and validation activities.

Oklo's OER process considers sources from both nuclear and non-nuclear domains, with an emphasis on experience that relates to multi-unit, multi-site operations; task coordination between onsite and offsite personnel; and supervision in highly automated environments. These considerations are central to Oklo's approach to developing both site-specific staffing plans and fleet-support staffing plans.

In particular, the OER evaluates traditional roles and responsibilities of licensed operators and how these roles are impacted by the Aurora powerhouse's use of inherent safety features, digital controls, and high levels of automation. The review also considers how offsite supervision during certain operating modes may affect workload, communication requirements, and human reliability. These findings directly inform role definitions, location-based staffing requirements, and minimum per-shift staffing levels.

The methodology is supported by insights from previous NRC research and operating reactor experience. These sources include but are not limited to the following:

- NUREG/IA-0137, "A Study of Control Room Staffing Levels for Advanced Reactors," November 2000, which found that staffing models tailored to specific plant design features improved operator performance and reduced workload compared to prescriptive staffing requirements

- Possible impact on staffing because of work hour limits, required break times, and required days off, as specified in 10 CFR 26.205, "Work hours," as part of the fitness-for-duty rule

- Regulatory Issue Summary 2009-10, "Communications between the NRC and Reactor Licensees during Emergencies and Significant Events," which underscores the importance of reliable communication between licensees and the NRC during emergencies and significant events. This report informs the design of communication protocols between onsite and offsite staff in Oklo's staffing model.

- NRC Information Notice 97-78, which highlights the regulatory expectations and limitations associated with crediting automatic actions in safety analyses. These expectations inform how Oklo justifies reduced reliance on human actions and supports its staffing model assumptions.

- NRC Information Notice 95-48, which highlights the safety implications of operator workload, reinforcing the need to identify and eliminate unnecessary human tasks in the design and staffing strategy for the Aurora powerhouse

Operating experience drawn from these sources has been used to inform assumptions and decision making throughout the HFE program. Key insights from the OER feed directly into FRA and FA, task analysis, staffing and qualifications, training program development, procedure development, and HSI design. Most importantly, these insights are incorporated into Oklo's staffing validation methodology to ensure that both site-specific and fleet-support staffing plans are realistic, effective, and aligned with demonstrated industry practices and human performance principles.

Oklo's OER methodology is outlined in Appendix B. The results of the OER inform subsequent HFE analyses by identifying relevant human performance issues, design considerations, and operational insights that contribute to the development of function allocation, task analysis, and other HFE program elements.

6.5 Functional requirements analysis and function allocation

The purpose of FRA and FA is to identify the high-level plant functions necessary to achieve the safety and performance goals of the Aurora powerhouse and to determine how those functions are best assigned to personnel, automation, or inherent design features. This process directly supports the development and validation of both site-specific staffing plans and fleet-support staffing plans by defining what functions must be performed, under what conditions, and by whom or what.

Oklo's FRA and FA methodology is based on the guidance in NUREG-0711 and is further informed by INL/EXT-13-30117, which provides HFE design review guidance specifically for small modular reactors and advanced reactor designs. As recommended in INL/EXT-13-30117, Oklo implements FRA and FA early in the design process to identify and evaluate human roles within the context of advanced safety strategies and automation. This approach enables a staffing model that is not adapted from legacy designs but rather purpose-built to reflect the Aurora powerhouse's operational concept, design characteristics, and safety envelope.

The FRA step identifies the plant's high-level functional objectives, performance requirements, and constraints, laying the foundation for understanding how plant systems and personnel contribute to safety and operational goals. The subsequent FA step assigns those functions to either personnel, automation, or both, based on systematic application of HFE principles and performance-based design philosophy. These allocations are structured and documented to produce clear, consistent, and justifiable role assignments.

Oklo's concept of operations and the OER serve as key inputs to the FRA and FA process. The concept of operations establishes the safety and performance goals for the plant, including the use of passive safety systems, high automation, and remote supervision. Operating experience, drawn from both nuclear and non-nuclear industries, informs role assumptions, workload considerations, and coordination between onsite and offsite personnel, especially for multi-unit and multi-site contexts. Together, these inputs help shape the scope and intent of the FRA and FA methodology and support allocations that move beyond traditional operator-centered models.

Safety analysis, including transient and accident scenarios, is integrated into the FRA and FA to identify and confirm which safety functions must be achieved under off-normal conditions. These analyses help define the functional requirements and serve as a technical foundation for allocating those functions to passive features, automated systems, or humans, where necessary and aligned with Oklo's staffing goals. This process is inherently iterative and matures alongside the Aurora powerhouse design.

Consistent with lessons from INL/EXT-13-30117, Oklo's FA approach emphasizes early and deliberate decisions to eliminate unnecessary human tasks, simplify remaining tasks, and rely on passive and automated systems for safety-critical functions. For example, during power operations and shutdown conditions, no credited human actions are required to maintain plant safety, and supervisory functions are managed by on-call licensed personnel at the fleet-based support center. Onsite personnel conduct monitoring and support functions that are non-credited, and their roles are defined accordingly through the FA process.

At completion of the FRA and FA, the following is developed:

- A list of the high-level plant functions that must be accomplished to meet the overall performance goal to ensure health and safety of the public
- A database containing information gathered during the analysis of functions (e.g., requirements related to the high-level plant functions)
- A hierarchical depiction of functions, processes, systems, and components that show relationships between high-level functions and the plant's systems responsible for performing the functions (to include inherent and passive design features)
- A comparison of the plant's functional hierarchy with predecessor or related plants and systems (e.g., EBR-II, Fast Flux Test Facility)
- Documentation of allocation of functions to the operator, machine (e.g., design features, hardware, or software), or both at varying levels of allocation

The FRA and FA process is iterative and matures with the design of the Aurora powerhouse. Upon completion of the FRA and FA, an RSR is generated. Results from the FRA and FA serve as a resource for other elements of the HFE program plan, to include the following:

- Task analysis
- Staffing and qualification
- HSI design development
- Procedure development program
- Training program development

Oklo's FRA and FA methodology is outlined in Appendix C. FRA and FA form the basis of the task analysis, which further defines the specific actions, information needs, and role responsibilities necessary to support the allocated functions under the Aurora powerhouse's concept of operations.

6.6 Task analysis

Task analysis is a core element of the HFE program, performed in accordance with the guidance provided in NUREG-0711. As described in Chapter 6 of NUREG-0711, the purpose of task analysis is to identify the tasks that plant personnel must perform and to define the requirements necessary to support successful task execution. These requirements include the information, controls, interfaces, and job support tools needed to perform tasks safely and effectively. Task analysis provides a foundational input to the development and validation of both the site-specific staffing plans and fleet-support staffing plans.

Oklo's task analysis methodology builds on the results of the FRA and FA. FRA and FA define which plant functions are allocated to personnel and which are assigned to automation or passive design features. Task analysis then identifies the specific actions that personnel must take to accomplish the allocated functions. Relevant input includes the operational context, information needs, role responsibilities, and coordination required across staff located both onsite and offsite, in alignment with the Aurora powerhouse concept of operations.

The task analysis process begins with system-level evaluations that group individual tasks by function and system. As the analysis matures, it integrates tasks across multiple systems to reflect broader operator responsibilities and interdependencies. This iterative approach allows the task analysis to evolve with the plant design and support a comprehensive understanding of crew roles and task interactions.

Incorporating insights from Research Information Letter (RIL) 2020-07, "Human Factors Engineering Aspects of Emerging Technologies," published by the NRC in August 2020, Oklo's task analysis methodology considers how advanced technologies, including automation and digital control systems, shape staffing needs and operator roles. In line with the guidance in RIL 2020-07, the analysis emphasizes a systematic understanding of how work is distributed among operators, how automation is leveraged to reduce manual tasks, and how staffing strategies are aligned with actual operational needs rather than historical norms.

Personnel tasks identified during the task analysis process are assigned to staffing positions based on the following considerations:

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The outputs of task analysis are critical to several downstream elements of the HFE program. These elements include the development and refinement of HSIs; the definition of roles and responsibilities; the creation of draft operating procedures; the identification of knowledge, skills, and abilities required to perform tasks; and the determination of training needs for both licensed and non-licensed personnel. Task analysis also directly supports staffing analysis by providing essential input on operator workload, task sequencing, and crew coordination. These insights help determine appropriate staffing levels and crew composition and ensure that operators have the capacity to maintain situational awareness and effectively manage their responsibilities. The results of task analysis also inform the development of training and qualification programs, particularly for non-licensed roles, to ensure personnel are adequately prepared to fulfill their assigned functions.

Oklo's task analysis methodology is outlined in Appendix D. Task analysis builds on the results of the FRA and FA to define the specific human actions, information requirements, and role-based responsibilities necessary to support the allocated functions within the Aurora powerhouse's concept of operations. The outcomes of the task analysis inform the identification of staffing needs and the qualifications required to perform assigned operational roles.

6.7 Development of the initial site-specific staffing plan

The initial staffing plan is developed using a structured and iterative process that draws from key HFE activities, including the operating experience review, FRA and FA, task analysis, and formal job definitions for each operational role. This plan forms the foundation for defining overall staffing needs and the composition of the operating shift crew, ensuring that staffing supports the protection of public health and safety across all plant operating conditions.

This phase of staffing analysis is aligned with the guidance in Chapter 10 of NUREG-0711, which addresses staffing and qualification. The analysis ensures that the number and capabilities of personnel are sufficient to perform the human functions allocated during prior phases of the HFE program. The initial staffing plan serves as a baseline for both the site-specific staffing plan and the fleet-support staffing plan, each of which is validated and updated through the staffing validation process described in subsequent sections.

The initial staffing plan accounts for both traditional and non-traditional control locations. For example, when certain operational tasks are performed from the fleet-support center rather than the control room, the plan explicitly defines the physical location and function of each operating shift crew member. This definition ensures that operational control and support responsibilities are clearly assigned and covered, regardless of personnel distribution across sites.

The staffing plan accounts for detailed information such as the following:

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This level of detail ensures that the staffing plan not only reflects the current operational model but also supports future scalability and alignment with Oklo's fleet-based approach. As outlined in Section 6.1, separate staffing plans are developed for each site (site-specific) and for the powerhouse support center (fleet-support). Appendix E presents the site-specific staffing plan template, structured to ensure that the operating crew can safely manage plant conditions across all modes. Appendix F provides the template for the fleet-support staffing plan, which includes staffing to support centralized monitoring and supervision functions across multiple sites. The initial staffing plan is subject to refinement as additional HFE program elements mature. HSI development, procedure design, and validation activities provide opportunities to revise assumptions and verify that staffing is sufficient to support expected operator roles, workload, and interactions across both onsite and offsite locations.

7 Fleet-support staffing plan development

This section describes Oklo's approach to developing the powerhouse fleet-support staffing plan. The plan addresses the staffing needed to support a single Aurora powerhouse while also considering the requirements of a scalable model that enables centralized oversight of multiple units across different sites. The development of this plan draws from inputs described in the previous section, including key characteristics of Aurora powerhouse operations, the broader fleet-based concept of operations, and the results of foundational HFE analyses.

Unlike the site-specific staffing plan, which defines the operating shift crew required at an individual facility, the fleet-support staffing plan focuses on the centralized personnel structure at the powerhouse support center. This structure includes remote supervisory roles, real-time engineering support, and coordination across multiple facilities. The plan enables safe and effective plant operation by ensuring that sufficient offsite support is available under all operating conditions, while maintaining flexibility to scale with the growing fleet.

7.1 Inputs to the fleet-support staffing plan

Similar to the development of the site-specific staffing plan, the fleet-support staffing plan is informed by key HFE analyses, including the operating experience review, FRA and FA, and task analysis. These inputs help establish initial staffing estimates, role definitions, and qualification requirements for personnel located at the fleet-based support center (i.e., powerhouse support center).

The concept of operations also plays a central role in guiding the development of the fleet-support staffing plan. It defines the operational philosophy under which supervisory, technical, and coordination functions may be performed remotely. This philosophy informs the scope, location, and communication responsibilities of fleet-support personnel. Additionally, the role definitions and staffing assumptions defined in the site-specific staffing plans provide important context for identifying the functions that must be supported by powerhouse support center personnel across the fleet.

Specific considerations used to inform the fleet-support staffing plan include the following:

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These inputs ensure that the fleet-based support center is staffed appropriately to provide centralized support for one or more units across one or multiple sites and is adaptable to evolving fleet demands

7.2 Development of the initial fleet-support staffing plan

The initial fleet-support staffing plan is developed using inputs from FRA, FA, task analysis, and job definitions for each role required under expected operational conditions. These inputs form the foundation for estimating minimum staffing levels, assigning functional responsibilities, and defining shift composition and scheduling at the fleet-based support center.

The initial plan identifies the required personnel to support operations for one or more units across one or more sites. It defines both licensed and non-licensed staffing necessary to perform remote supervisory, technical, and coordination functions during various operating modes. It also considers operator workload, the number of supported units, and the infrastructure needed to maintain situational awareness from the fleet-based support center.

The initial fleet-support staffing plan includes, but is not limited to, the following elements:

- The composition of the minimum shift complement, including licensed and non-licensed personnel (e.g., on-call engineering support staff), required to perform functions from the fleet-based support center
- The number of sites and units for which a licensed operator provides supervisory coverage remotely
- A description of plant monitoring protocols and HSIs that enable oversight from the fleet-based support center
- Operating mode definitions, as applicable, and how the operating mode and number of units affect minimum staffing
- A description of how engineering expertise is made available to on-shift site personnel (if provided from the fleet-based support center)

A key consideration in the development of the initial plan is the definition of unit-to-support-center relationships. While initial deployment may involve a one-to-one configuration, the plan allows for flexible scaling to support multiple units across multiple sites from a single or even multiple fleet-based support center(s). This configuration must be clearly defined, as it serves as a foundational input to the staffing validation process. Figure 7-1 provides an illustrative example of an initial fleet-support staffing plan and a corresponding initial site-specific staffing plan developed to support an initial deployment.

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Figure 7-1:

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7.3 Updating the fleet-support staffing plan

The fleet-support staffing plan is developed to support a defined number of units across one or more sites based on the expected roles, workload, and functional responsibilities of staff at the fleet-based support center. Inherently, the approved staffing plan establishes the maximum number of units and sites that can be effectively supported under the assumptions, roles, and workload analyses used in its development.

As the fleet expands, any increase in the number of units or sites supported beyond what is stipulated in the approved staffing plan requires an update to the plan. This update ensures that the staffing structure continues to provide adequate support across the operating fleet, while maintaining alignment with the principles of safe and effective plant operation. Updates to the fleet-support staffing plan are supported by applicable operating experience, workload assessments, and HFE analyses. These updates may involve adjustments to staffing levels, supervisory structure, engineering support capabilities, or coordination protocols. Figure 7-2 illustrates a representative scenario in which the fleet-support staffing plan is revised to support the integration of an additional site into the operating fleet.

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Figure 7-2:

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The process ensures that staffing continues to reflect the realities of a growing and evolving fleet and that the centralized support model remains robust and scalable. This approach enables Oklo to maintain a flexible, fleet-based operational strategy while ensuring that staffing plans remain technically justified, performance-based, and responsive to future expansion.

8 Staffing plan validation methodology

This section describes Oklo's staffing plan validation methodology. Considering Oklo's approach to operations, multiple staffing plans are developed, one for each site (i.e., site-specific staffing plan) and another for the powerhouse support center (i.e., fleet-support staffing plan). The staffing plan validation methodology described in this section provides a performance-based means to validate the staffing plans through HFE staffing studies. The phrase "HFE staffing studies" is used throughout the following subsections and is interchangeable with the phrase "staffing plan validation."

8.1 Staffing plan validation methodology overview

The staffing plan validation methodology aligns with the review guidance provided in NUREG-0711, Chapter 11, and consists of the following steps:

- Identify challenging operational conditions
- Develop test plan
- Conduct test and collect data
- Review and synthesize results (if necessary, revise staffing plan)

This process is depicted in Figure 8-1.

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As discussed in Section 6.7, the overall staffing analysis is an iterative process. The results of the HFE staffing studies are evaluated to determine whether performance measures are met. Based on this evaluation, the staffing plan may be revised and revalidated through additional iterations until the performance measures are successfully achieved. Each element of the staffing plan validation methodology is further described in the following sections.

8.2 Identification of challenging operational conditions

The primary objective of the first stage is to evaluate and select operational conditions for test scenarios that meet the following criteria:

(1) Representative of the range of events that could be encountered during operation

(2) Reflect the characteristics expected to contribute to variations in overall system performance

(3) Consider the safety significance of HSI design

NUREG-0711, Section 11.4.1, “Sampling of Operational Conditions,” provides a robust set of guidelines for identifying challenging operational conditions to be tested during the HFE V&V. The product of this stage is a collection of integrated test scenarios that challenge overall system and personnel performance based on a systematic review of operating conditions across a wide range of sampling dimensions (plant conditions, personnel tasks, and situational factors known to challenge personnel performance). {

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The process for identifying operational conditions for testing, described in the following subsections, comprises three activities: (1) sampling dimensions, (2) identification and selection of scenarios, and (3) documentation of scenario abstracts.

8.2.1 Sample dimensions

A multidimensional set of criteria is used to define the set of scenarios included in the HFE staffing studies. The sampling dimensions for HFE staffing studies are initially based on those identified in NUREG-0711, Section 11.4.1.1, “Sampling Dimensions.”

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- Plant conditions (based on NUREG-0711, Rev 3., Section 11.4.1.1)
    - Normal, off-normal, and emergency conditions
    - All operating modes (e.g., power operations, shutdown, startup, and refueling), including both those that require a licensed operator onsite and at the controls and those that do not require a licensed operator onsite and at the controls
    - Normal operations, including plant startup, shutdown, refueling, and significant changes in operating power during power operations when the licensed operator is positioned offsite in the powerhouse support center
    - Transients and accidents specific to the Aurora powerhouse
        - Transients (e.g., failure of primary pumps, balance-of-plant failures, turbine failure/trip, loss of power)
        - Accidents (e.g., steam line break or rupture, positive reactivity addition, control assembly insertion at power, anticipated transient without scram, various sizes of reactor vessel leaks)

        - Off-normal events (e.g., fires) that require evacuation of the monitoring room or require the reactor to be shut down from outside the monitoring room

    - Communication system, instrumentation and control system, and HSI failures or degraded capabilities or conditions, including but not limited to the following:

        - Loss or partial loss of remote displays and indications; network connection failure

        - Instrumentation and control system type failures, including sensor, monitoring, automation and control, and communication failures

        - Instrumentation and control system failures during postulated accidents

        - HSI failures, including loss of processing or display capabilities for alarms, displays, controls, and computer-based procedures

- Personnel tasks (based on NUREG-0711, Rev 3., Section 11.4.1.1)

    - Manual initiation of protective actions, including situations that may require a non-licensed operator to initiate a manual reactor trip from the monitoring room

    - Automatic system monitoring (local at the Aurora powerhouse and remote)

    - OER-identified problematic tasks

    - Range of procedure-guided tasks, to include the following:

        - General operating procedures

        - Procedures for startup, operation, and shutdown

        - Procedures for abnormal, off-normal, and alarm conditions

        - Procedures for combating emergencies and other significant events

        - Procedures for control of radioactivity

        - Procedures for controlling measurement and test equipment and for surveillance tests, procedures, and calibration

        - Procedures for performing maintenance

        - Procedures for chemistry and radiochemical control

    - Range of knowledge-based tasks that are not well defined by detailed procedures

    - Range of human cognitive activities, including the following:

        - Detecting and monitoring a situation

        - Assessing a situation
        - Planning an event response
        - Implementing an event response
        - Obtaining feedback
    - Range of human interactions, including the range of interactions between onsite and offsite personnel

- Situational factors or error-forcing contexts known to challenge human performance and assess the overall system's error tolerance, and the ability of personnel to recover from any errors, should they occur. These factors and contexts include the following (based on NUREG-0711, Rev 3., Section 11.4.1.1):
    - High-workload situations
    - Varying-workload situations
    - Fatigue situations
    - Environmental factors

8.2.2 Scenario identification and selection

A preliminary list of the types of scenarios that are considered includes those outlined in Table 8-1.

Table 8-1: Examples of various types of scenarios for testing

Type	Description
Major operational transitions	Major plant transitions, such as significant heatup or cooldown, cover multiple mode changes and operational state transitions for several systems and equipment, which is typically a high-workload operation. Multiple mode changes also involve transition of the supervisory function between the onsite Startup Operator and the on-call Startup Operator located in the powerhouse support center, which challenges operator workload and teamwork (communication/coordination). Furthermore, simultaneously occurring major plant transitions typically challenge operator workload both onsite and in the powerhouse support center.
Reactor startups	Reactor startups present potentially complex situations for operators and non-licensed plant staff.

Type	Description
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Operations during modes that do not require a licensed operator onsite	{ {i}{ii}{vi}{ix}
Accidents and emergency events	Accidents and emergencies are an important part of the HFE staffing studies. Since abnormal and emergency procedures (rule-based decision making) cannot fully cover the full range of unexpected problems and unplanned situations, operators will often need to rely on knowledge-based tasks to address problems. Knowledge-based tasks and decision making are more likely to occur in complex failure events wherein the symptoms do not resemble the typical case and thus are not amenable to pre-established rules. Accidents and emergency events are expected to be tested across all operating modes.
Maintenance at full-power operations (lockout/tagouts)	Lockout/tagouts are an important element of operation. These situations can become increasingly difficult considering that the on-call Startup Operator is providing the supervisory function from the powerhouse support center. Validation needs to show that testing and maintenance are well supported and that there are adequate ties to the technical specifications and overall plant safety.

The actual set of integrated scenarios included in the HFE staffing studies is selected and defined by an interdisciplinary team that includes design engineers, system engineers (including instrumentation and control), plant operations personnel (procedures, training), HFE design personnel, and safety analysis personnel (inputs from transient and accident analysis). As part of the scenario selection process, the interdisciplinary team is responsible for ensuring that the scenarios selected for testing do not overly represent the following:

- Scenarios for which only positive outcomes are expected
- Scenarios that, for the purpose of the HFE staffing studies, are relatively easy to conduct (i.e., scenarios should not be avoided simply because they are demanding to set up and run on a simulator or test bed)
- Scenarios that, for the purpose of HFE staffing studies, are familiar and well structured (e.g., address familiar systems and failure modes that are highly compatible with plant procedures, such as “textbook” design-basis accidents)

8.2.3 Scenario abstracts

After identifying scenarios for testing, scenario abstracts are developed, documented, and approved. Scenario abstracts are subsequently utilized to develop integrated test procedures, which are conducted by test personnel during the HFE staffing studies. The level of detail for scenario abstracts should be comparable to what would be included in a test plan, including the following:

- A description of the scenario and any pertinent prior history necessary for personnel to understand the state of the plant at the beginning of the scenario
- Specific initial conditions (a precise definition of the plant's functions, processes, systems, component conditions, and performance parameters, similar to the information provided at shift turnover)
- Events (e.g., failures) that will occur during the scenario and their initiating conditions (e.g., based on time, or a value of a specific parameter)
- Precise definition of workplace factors (e.g., environmental conditions, such as low levels of illumination)
- Needs for task support (e.g., procedures and technical specifications)
- Staffing level
- Details of communication content between monitoring room personnel and remote personnel (e.g., on-call Startup Operator via telephone)
- Scripted responses for test personnel who will act as plant personnel in the test scenarios
- The precise specification of what data is to be collected, as well as when and how that data will be collected and stored (including videotaping, questionnaires, and rating-scale administrations)
- Precise specifications on simulator setup
- Specific criteria for terminating the scenario

Scenarios are developed to have sufficient task fidelity so that realistic task performance can be observed in the HFE staffing studies and so that the test results can be generalized to actual operation of the real plant. {

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8.3 Testing plan development

The development of a comprehensive testing plan is a critical component of the staffing validation methodology. This section describes the approach used to design and implement testing activities that assess whether the staffing plan supports acceptable human performance during operational scenarios. The testing plan is structured to evaluate performance measures such as operator workload and situational awareness, consistent with the expectations outlined in NUREG-0711, Chapter 11. Key elements include developing test procedures; defining testing roles; configuring and validating the test bed; and identifying, selecting, and training test participants. The process begins with the translation of scenario abstracts into detailed test procedures and includes pilot testing activities to verify the adequacy of the test design before full implementation.

8.3.1 Performance measures

The primary objective of the HFE staffing studies is to identify potential safety issues related to the proposed staffing plan through performance-based evaluation. These evaluations are supported by the overall design of the unit, the concept of operations (including fleet-based operations), and insights gained from other HFE analyses. Consistent with the guidance in NUREG-0711, Chapter 11, "Verification and Validation," performance-based evaluations are used to verify that the staffing plan supports safe, reliable, and effective operation under representative conditions.

To support this objective, performance measures must be defined to assess staffing effectiveness, plant performance, and crew performance during simulated scenarios. Measures of personnel performance must be sensitive to the impacts of staffing levels and operating environments and must yield meaningful information about the ability of operators to manage unit-level and fleet-level operations. In accordance with NUREG-0711, performance measures should address both objective criteria—such as plant performance, operator task execution, and error rates—and subjective criteria—such as workload, situational awareness, and ergonomic fit. Together, these measures support a comprehensive evaluation of whether the staffing plan enables safe and effective human performance across a range of conditions.

8.3.1.1 Plant and personnel performance measures

Objective performance measures include the following:

- Plant performance measures relating to ensuring the health and safety of the public. These measures comprise high-level plant safety functions, systems, components, and HSIs necessary to ensure that the overall safe operations performance goal is met.

- Personnel task performance (to include tasks performed from the powerhouse support center, such as those relating to the supervisory function and providing engineering expertise)

Personnel task (primary and secondary) performance measures are defined based on the inputs obtained from task analysis. Personnel tasks are categorized as either primary or secondary tasks. Primary tasks are those involved in performing a functional role (e.g., monitoring, decision making, control), and secondary tasks are those the operator must perform when interfacing with the plant HSIs but that are not directed to the primary task (e.g., time spent configuring a workstation or navigating the HSI to complete a primary task). Both primary tasks and secondary tasks are used to measure overall personnel performance during the staffing studies. However, primary tasks are assessed based on the level of detail appropriate to the tasks' demands. For example, simple scenarios may only need time measurements, while more complicated tasks (especially those described as knowledge-based) may require more specific measures relating to decision making, actions, and feedback.

For each scenario, the tasks that are required to be performed to achieve scenario goals (e.g., ensure health and safety of the public) are identified. The measures selected for each task represent the specific task aspects that are necessary to achieve successful task performance. These measures may include time (e.g., "*complete action in 15 seconds*") and accuracy.

Tasks performed by test participants during the studies are compared to the required tasks to determine if successful personnel task performance was achieved. Tasks required to be performed that were not performed by test participants are considered errors of omission. Any additional actions taken by personnel that deviate from the tasks required to be performed are documented and analyzed as errors of commission. Errors are analyzed to identify human engineering discrepancies, which are managed through HFE program process. Changes are incorporated into HSIs, procedures, training, and staffing to address human engineering discrepancies.

8.3.1.2 Situational awareness

Situational awareness is a key performance measure evaluated during staffing validation activities, particularly for roles involved in on-call operations and monitoring within a fleet-based operational model. As defined in NUREG-0711, situational awareness is the degree to which personnel's perception of plant parameters and understanding of the plant's condition corresponds to the actual condition at any given time. This capability is essential for maintaining safe and effective control of plant operations, especially in complex, high-consequence environments such as nuclear facilities.

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8.3.1.3 Workload

Workload is a key performance measure considered during staffing validation, as outlined in NUREG-0711, that defines workload as the physical, cognitive, and other demands that tasks place on plant personnel. Understanding workload is essential to ensuring that assigned tasks are within operator capacity under a range of operating conditions, including normal, abnormal, and emergency scenarios.

In the context of Oklo's fleet-based operational model and on-call support approach, workload must be evaluated with respect to how tasks are distributed, monitored, and executed across multiple units (and sites). Operators supporting units on an on-call basis may experience workload fluctuations depending on the number and complexity of concurrent demands, the urgency of the situation, and the quality of information provided through the HSI. Task design, interface design, alarm strategy, and system automation all influence the cognitive and physical demands placed on operators in these settings.

Modern human factors theory recognizes that workload is not simply a function of task count or duration but emerges from the interaction between task demands, environmental conditions, and individual characteristics such as experience, training, and cognitive strategies. Excessive workload can increase the likelihood of human error, while underload may reduce engagement and performance. As a result, the validation process evaluates whether the staffing plan ensures task demands remain within acceptable workload levels across expected operating conditions.

To assess workload in staffing validation studies, multiple evaluation methods are employed, such as subjective assessments like interviews, observations, and operator self-ratings, as well as objective measures such as task performance data. While subjective methods are more flexible and easier to integrate, they may be influenced by bias. Objective approaches offer higher fidelity but can be intrusive or resource intensive. A multi-method strategy is therefore used to balance these tradeoffs and provide a comprehensive view of operator workload. By combining observed behavior with reported perceptions and performance outcomes, the validation approach ensures that workload remains within safe and manageable levels for on-call operators supporting multiple units.

8.3.1.4 Anthropometric and physiological factors

Anthropometric and physiological factors are important considerations in validating the HSIs, as they influence an operator's ability to interact effectively with plant systems under real-world conditions. In the context of Oklo's fleet-based operations and on-call monitoring model, these factors are evaluated not only at individual control workstations but also in shared monitoring environments where large, wall-mounted video display units or projection systems may be used to present fleet-level operational data.

While early-stage design reviews and mockups help address basic factors such as reach, visibility, and control accessibility, a more complete evaluation occurs during HFE Integrated System Validation. Integrated System Validation allows the full HSI to be tested under realistic, scenario-based conditions using actual or representative hardware. This testing ensures that operators, including those supporting multiple units from centralized locations, can clearly view displays, interpret data, and access necessary controls without physical strain or restriction.

These evaluations are particularly useful in identifying subtle mismatches between interface layout and human capabilities that may not be apparent during component-level testing. Through Integrated System Validation, staffing evaluators confirm that the system supports physically comfortable, sustained interaction and does not introduce barriers to task performance due to poor visual design, control placement, or spatial configuration. This assessment ensures that operators in an on-call, fleet-support role can maintain awareness and execute responsibilities without unnecessary physical or ergonomic limitations.

8.3.2 Testing roles

The personnel involved in in the HFE staffing studies consist of two main groups: test participants and test personnel. The following section describes the approach used to select, train, and, as necessary, qualify individuals involved in the performance of the HFE staffing studies.

8.3.2.1 Test participants

Individuals selected to perform test participant roles for the HFE staffing studies are representative of the roles who will interact with the HSI (e.g., licensed operators or applicable non-licensed plant staff, rather than training personnel or engineers). For the performance of the HFE staffing studies, test participants are selected and assigned to one of the following test participant role categories:

- Startup Operator test participant
- Monitor test participant
- On-call engineering support staff test participant

To best represent the expected operating shift crew, test participant candidates are initially screened by comparing the candidates' education and experience to the minimum education and experience of the test participant roles. In additional to meeting the education and experience requirements, Startup Operator test participants are interviewed by test personnel for leadership competencies expected of the Startup Operator role.

To properly account for human variability, participant samples reflect the characteristics of the population from which they are drawn. Those characteristics expected to contribute to variations in system performance should be specifically identified; the sampling process should reasonably assure that the validation encompasses variation along that dimension. Determining representativeness should include considering the participants' license type and qualifications, skill/experience, age, and general demographics. In selecting personnel to participate in the tests, the applicant should consider the minimum, nominal, and maximum shift staffing levels, including shift supervisors, reactor operators, and shift technical advisors.

Test participants may not include individuals who

- are members of the design organization;
- participated in prior evaluations; or
- were selected for some specific characteristic, such as individuals identified as good performers or as more experienced.

Prior to participating in the HFE staffing studies, test participants undergo training that is representative of what is expected for actual plant personnel. This training is designed to ensure that participants are prepared to perform assigned tasks in a realistic and meaningful manner during the validation exercises. Training includes both classroom instruction and hands-on activities. Classroom sessions provide foundational knowledge on the plant's design, normal and off-normal operating conditions, the use of HSIs, alarm response strategies, and relevant procedures. Hands-on training is conducted using a task simulator or limited scope simulator that replicates critical interface elements and operational sequences expected in the plant environment.

Test participants are evaluated through both written and performance-based assessments to verify knowledge retention and task proficiency. These assessments are intended to establish a baseline level of competency comparable to that of qualified operators. By subjecting participants to this level of preparation, the HFE staffing studies can more accurately assess human performance and workload under conditions that reflect actual operational expectations.

8.3.2.2 Test personnel

The HFE staffing study test personnel consist of a multidisciplinary team of design engineers, system engineers, human factors engineers, and plant operations personnel (including individuals with experience in procedure development and training instruction). These personnel are considered part of the overall HFE design team and meet the design qualification requirements of the HFE program plan. Test personnel are responsible for the performance of the tests and for documenting test results.

Prior to testing, test personnel receive training that covers the following:

- Test procedures use and importance
- Experimenter bias and the types of errors that may be introduced into test data through the failure of test conductors to accurately follow test procedures or interact properly with test participants
- Importance of accurately documenting problems that arise during testing, even if due to test conduct oversight or error

Test personnel act as surrogates for onsite personnel who perform tasks outside the monitoring room. There are limits to the ability to preplan communications because test participants may ask unanticipated questions or make unforeseen requests. However, efforts should be made to detail what information that onsite personnel who perform tasks outside the monitoring room can provide and to script the responses to likely questions.

8.3.3 Test design

The purpose of this section is to describe overall test design requirements for conducting HFE staffing studies. These requirements include selecting scenarios for each testing crew, test procedures, test participants, test personnel, and pilot studies.

8.3.3.1 Scenario selection and balancing

Prior to the conduct of HFE staffing studies, formal test procedures are developed, reviewed, and approved to provide structured guidance on the selection, assignment, and sequencing of test scenarios. These procedures ensure that each test crew is evaluated under operationally relevant, technically representative, and methodologically balanced conditions. Scenario selection is a foundational element of the test design process, as it directly influences the validity, comparability, and fairness of the resulting staffing data.

The scenario selection process is designed to ensure that each test crew is presented with a similar range of operating conditions, including normal operations, abnormal transients, and potentially off-normal or degraded states, consistent with the operational profile of the Aurora powerhouse. Scenarios are developed to reflect the full range of operator responsibilities—both onsite and offsite—and are constructed to exercise key functional areas such as alarm response, system diagnostics, control actions, communications, and coordination with on-call support personnel.

While test crews may encounter different individual scenarios, the scenario set assigned to each crew is designed to be equivalent in terms of difficulty, task type, cognitive demand, time sensitivity, and system complexity. This equivalency ensures that the evaluation of staffing levels is not skewed by scenario-specific factors. Scenario characteristics are documented and categorized (e.g., by operating mode, initiating event type, and required operator action) to facilitate controlled selection and support traceable justification of test balance.

To minimize potential learning effects and crew-to-crew variability, the sequence in which scenarios are presented varies across crews. Test procedures specify a balanced rotation of scenario order, such that no single sequence is repeated and no crew benefits from a fixed progression from simpler to more complex tasks. This approach reduces familiarity bias and helps ensure that performance outcomes are a function of true operator capabilities, not practice or predictability. Additionally, rest intervals and briefing periods are structured between scenarios to avoid carryover effects and cognitive fatigue, supporting more consistent crew performance throughout testing.

Care is also taken to ensure that no scenario content is disclosed to test participants prior to testing. Scenario descriptions, initiating conditions, and potential outcomes are withheld until the formal pre-scenario briefing, at which point only the information necessary to initiate the test is shared. This arrangement maintains the realism of operator responses and prevents premature strategy development that could distort workload, situational awareness, or team dynamics.

In summary, scenario selection and test balance are key components of the HFE staffing study design process. They ensure that each test crew is exposed to a fair and representative set of operating conditions and that the data generated is suitable for comparative analysis across crews and scenarios. By applying rigorous controls to scenario construction, assignment, and sequencing, Oklo ensures that the staffing validation results are robust, defensible, and reflective of actual operational demands across the Aurora powerhouse fleet.

8.3.3.2 Test procedures

Prior to the execution of any HFE staffing studies, detailed test procedures are developed, reviewed, and formally approved to ensure a consistent, traceable, and methodologically sound testing process. These procedures are essential to ensure that the evaluation of staffing levels, operator roles, and performance under simulated operational conditions is conducted in a manner that is systematic, reproducible, and aligned with both regulatory expectations and Oklo's internal quality standards.

The test procedures define the overall structure of the testing effort, including the coordination and scheduling of test crews, the content and sequencing of test scenarios, and the standardized methods for briefing, conducting, and evaluating tests. Each crew is assigned specific scenarios based on a pre-established test matrix, and the procedures specify the order in which those scenarios are to be presented. This structure ensures consistency across test runs, helps balance potential learning effects, and supports statistical or comparative analysis of performance across crews and operating conditions.

Standardized instructions are provided for briefing test participants to ensure that each crew receives consistent baseline information prior to simulation execution. These instructions include guidance on the scope of the test, the scenario context, the rules of engagement, and the expectations for operator conduct. The goal is to simulate realistic conditions while minimizing artificial variation that could skew results.

Clear direction is also given to test personnel, described in Section 8.3.2.2, for the proper conduct of test scenarios. Instructions include procedures for establishing the correct initial conditions in the simulator, verifying that system states align with scenario assumptions, and preparing any preconditions (e.g., simulated faults or plant status cues). Test personnel are instructed on how to interact with test participants during the scenario execution so as to avoid any influence that could alter test participant performance or situational awareness.

The test procedures provide structured methods for when and how to collect, document, and store test data. These methods include the capture of objective performance metrics (e.g., time to respond, number of errors, task completion) and subjective data such as workload ratings, post-scenario debrief interviews, and observer assessments. Specific guidance is included on the use of data collection tools, timing of data capture, and chain-of-custody protocols for preserving test records.

A dedicated set of instructions is included for test documentation, specifying what information must be logged during the conduct of each test scenario. This information includes the date and time of execution, the identity of the crew, the exact version of the scenario used, and any deviations from the written procedure, including changes in test flow, technical issues, or environmental anomalies. Documentation also captures any unusual occurrences or operator behaviors that may be important for interpreting test results, particularly those that reflect unanticipated human-system interactions or systemic design insights. The procedures clarify when such information should be recorded (e.g., during real-time observation or post-scenario debriefing), ensuring a consistent and complete historical record.

By clearly defining the responsibilities of all test personnel, the flow of each scenario, and the methods for data collection and documentation, the test procedures establish a robust framework for conducting HFE staffing studies. This framework not only supports the integrity and credibility of the test results but also facilitates regulatory review by providing a transparent, well-documented process for evaluating how staffing levels and HSI designs support safe, effective, and reliable operation of the Aurora powerhouse fleet.

8.3.4 HFE staffing study test bed

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8.3.4.1 *Test bed criteria*

To ensure the validity of staffing studies and other HFE evaluations, a simulation facility modeled after the Aurora powerhouse monitoring room and fleet-based support center interfaces must satisfy specific fidelity and completeness criteria. The simulator test bed used in support of HFE staffing studies is designed to conform to the guidance provided in NUREG-0711, Chapter 11. The test bed must maintain representative system elements, interface functionality, and environmental factors necessary to support performance-based evaluations of human-system interaction. While the test bed does not need to replicate full-scale plant fidelity, it provides sufficient realism to enable valid assessment of task execution, workload, and situational awareness within the intended operational context.

The test bed criteria outlined in NUREG-0711, Chapter 11, are based on the principle that the simulation environment must provide sufficient fidelity to support valid and reliable assessment of human performance under conditions that are representative of actual operational tasks and environments. The following criteria are used to assess the suitability of the test bed for integrated system validation, including staffing analysis:

- Interface completeness
- Interface physical fidelity

- Interface functional fidelity
- Environmental fidelity
- Data completeness fidelity
- Data content fidelity
- Data dynamics fidelity

Collectively, these criteria ensure that the test bed used for HFE validation, including staffing studies, supports credible, repeatable, and high-integrity evaluation of operator behavior and performance. By achieving a high degree of physical, functional, and environmental fidelity, the simulator enables Oklo to accurately assess how well the staffing plan supports safe and effective operation of the Aurora powerhouse, both at the site and from the fleet-based support center. The following sections describe the specific criteria that define an acceptable test bed for use in staffing validation activities.

8.3.4.1.1 Interface completeness

The test bed should fully represent the integrated HSI, extending beyond only the elements required in specific test scenarios. Controls, displays, and procedures should be incorporated that, while not directly exercised during a given test, may influence operator behavior or task performance due to their proximity, contextual relevance, or interaction with other systems. Adjacent HSIs can affect decision making, error recovery, and information scanning behavior.

8.3.4.1.2 Interface physical fidelity

The test bed should present HSIs and procedures with high physical fidelity to the reference design of the Aurora powerhouse. High physical fidelity is defined as the accurate representation of alarms, display configurations, control devices, physical job aids, communications equipment, interface management tools (e.g., navigation tabs, menus), and the spatial layout and ergonomics of the monitoring room. As a result, operator actions and interactions can reflect those expected in the actual operating environment.

8.3.4.1.3 Interface functional fidelity

The simulator should include complete functional representations of all HSI features, matching the behavior, logic, and operability of the reference system. The HSI should respond to mode changes, user selections, and plant state transitions. For example, alarm prioritization, screen navigation, and interface logic must behave identically to the real system, ensuring that operator workload and situational awareness can be assessed accurately.

8.3.4.1.4 Environmental fidelity

The physical environment of the simulator should replicate expected ambient conditions such as lighting levels, background noise, temperature, and humidity. Noise contributions from equipment such as HVAC systems, computing infrastructure, and communication tools must also be simulated. Environmental fidelity is important for evaluating factors such as operator comfort, distraction, fatigue, and overall realism of the task environment.

8.3.4.1.5 Data completeness fidelity

All information available to personnel in the simulator should mirror what is available in the actual plant, including the full set of parameters, status indications, and system-level data necessary for plant monitoring and control. The completeness of this information is essential to support valid assessment of operator performance under realistic cognitive loads.

8.3.4.1.6 Data content fidelity

The accuracy of the data presented should match the Aurora powerhouse reference design. This fidelity is supported by an underlying simulation model that correctly reflects the behavior of plant systems, ensuring that data values, control logic, and system feedback match actual plant responses. Controls and displays must not only look correct; they must be fed by models that behave like the real systems they represent.

8.3.4.1.7 Data dynamics fidelity

The timing and responsiveness of data—how quickly system parameters update, how alarms trigger, and how operator inputs are reflected—must align with the behavior of the operational plant. The process simulation should incorporate realistic signal propagation delays and system lags, ensuring that the tempo of operator-system interaction is authentic. This realism is critical for evaluating workload, timing-critical actions, and coordination among operators.

8.3.4.2 Test bed validation methodology

Prior to conducting HFE staffing studies, the validation test beds for both the Aurora powerhouse monitoring room and the powerhouse support center must be formally validated to ensure they meet the required fidelity and completeness characteristics. This validation step is essential to establish that the simulation environment accurately represents the reference design and operational conditions under which operators and support personnel will perform their tasks. Without this assurance, any data generated during staffing evaluations could lack the validity needed to inform licensing or operational decisions.

Validation confirms that the test beds are functionally and physically representative of the intended operational environment. The HSIs, plant control logic, visual and auditory cues, alarm behavior, and environmental conditions such as lighting and background noise must accurately reflect those in the reference design of the Aurora powerhouse and support center. The process involves a detailed review of simulator features, including alignment with reference plant data, control behaviors, layout, and interface responsiveness. Controls and displays must function as expected, and all systems must support natural and intuitive operator interaction.

To achieve this natural interaction, the simulator configuration is reviewed and tested. Functional elements such as displays, alarms, procedures, job aids, and communication tools are exercised to confirm that they behave as they would in the actual plant. Environmental aspects like communications noise and equipment hum may also be replicated to preserve the physical realism of operator experience. The underlying plant models are also reviewed to ensure that simulator responses are dynamic, accurate, and consistent with expected system behavior.

According to the guidance provided in NUREG-0711, Chapter 11, the simulation environment must provide sufficient fidelity to support valid and reliable assessment of human performance. Oklo's approach to test bed validation incorporates this guidance by ensuring that the test bed realistically represents the operating environment in which staffing evaluations will be conducted. As an enhancement to direct system checks, Oklo may also incorporate scenario-based testing into the validation process. In this approach, representative operational scenarios are executed in the simulator to demonstrate that it supports integrated operator task performance under realistic conditions. These scenarios are not used to evaluate staffing adequacy but serve to confirm the readiness and credibility of the test bed itself.

This scenario-based validation approach is informed by industry best practices, including those described in NEI 09-09, which emphasize scenario realism, consistency, and integrated task performance. During these scenario runs, members of the HFE team observe how personnel interact with displays, controls, procedures, and communication systems. They evaluate the timing and behavior of alarms, confirm system response fidelity, and assess whether operator workflows unfold in a realistic as-designed manner. While not the primary method for validation, feedback from test participants may be collected and used to inform validation of the simulator test bed. This input helps confirm that the simulation environment is perceived as realistic and supports credible human response and interaction. By gathering multiple sources of feedback, including technical review and participant experience, Oklo strengthens the overall validity and credibility of the test bed for use in staffing evaluations.

The validation process, whether performed through detailed system review, scenario-based observation, or both, is completed and documented before any HFE staffing studies are executed. If any modifications are made to the simulator following the initial validation, such as updates to interface elements, control logic, or physical layout, a re-validation is required to ensure continued alignment with fidelity and completeness expectations. By incorporating scenario-based methods as part of this process, Oklo strengthens confidence in the simulation environment, particularly in support of novel operating concepts and distributed support roles.

Through this methodical and layered approach to test bed validation, Oklo ensures that staffing validation activities are conducted in a simulated environment that faithfully reflects the operational conditions of the Aurora powerhouse and fleet-based operational model.

8.3.5 Pilot testing

Prior to the formal execution of HFE staffing studies, pilot testing is conducted to evaluate the adequacy of the overall integrated test design. Scenario content, performance measures, data collection tools, and procedural guidance are reviewed. The primary objective of pilot testing is to identify and resolve any issues that could compromise the validity, consistency, or efficiency of the full-scale study. Pilot testing serves as a critical quality control step that ensures the study is ready for execution under operationally realistic conditions and that all test elements function as intended.

During pilot testing, representative scenarios are executed in the same simulation environment that will be used for the full staffing study. The pilot tests are conducted using personnel who are trained to perform the necessary tasks and simulate the roles of operators and support staff but are not part of the actual study participant pool. This separation helps prevent bias and preserves the validity of future test runs by ensuring that actual participants remain unaware of the test scenarios. The pilot test participants are fully briefed, and their interactions are observed in the same structured manner as the formal study will employ.

Pilot testing evaluates many important elements, including the clarity and effectiveness of test procedures, the ability of facilitators to establish scenario conditions consistently, and the adequacy of participant briefing materials. It also confirms that performance measures, such as task response times, workload assessments, and situational awareness indicators, can be captured accurately and meaningfully. If subjective measures such as workload or usability ratings are part of the test design, pilot testing allows for refinement of rating scales, data collection, and interviewer protocols to ensure participant comprehension and consistent administration. In addition, pilot testing helps verify the integration and operability of the test bed, confirming that simulator behavior, data logging systems, HSI fidelity, and environmental conditions all function correctly and reflect the intended reference design. Observations from the pilot test may lead to adjustments in scenario timing, task sequencing, communications flow, or interface configurations to better support the study objectives and enhance realism.

Importantly, pilot test participants may later be used as test personnel, including in roles such as facilitators, observers, or data collectors for the formal staffing studies, provided they meet all training and qualification requirements applicable to those roles. This reuse is appropriate because, although they may have been exposed to scenario content, they are no longer eligible to participate as test participants. In fact, their familiarity with the test procedures may enhance the consistency and quality of test administration.

All outcomes of the pilot testing effort, including identified issues, procedural updates, and configuration changes, are documented in a Pilot Test Summary Report. This report serves as a quality assurance record and provides traceability from pilot testing to formal study execution. It should also identify any corrective actions implemented as a result of pilot testing and include the rationale for any decisions not to alter the test design following observed issues. Through comprehensive pilot testing, Oklo ensures that the HFE staffing study methodology is practical, technically sound, and capable of generating valid, repeatable, and actionable data. This proactive step enhances confidence in the final study results and reinforces the credibility of staffing conclusions used to support safe and reliable operation of the Aurora powerhouse fleet.

8.4 Conduct of staffing studies

HFE staffing studies must be carried out in accordance with approved test procedures to ensure consistency, traceability, and the integrity of study outcomes. All testing activities, including test execution, data collection, and personnel coordination, are governed by these pre-established procedures, which define the test environment, testing flow, participant interactions, data handling protocols, and documentation requirements. Strict adherence to these procedures is necessary to ensure that the results of the staffing study are both credible and repeatable.

All test personnel, including observers, facilitators, and technical support staff, must be adequately trained in their roles and responsibilities prior to participating in any part of the study. Training includes instruction on the operation of the simulator or test bed, proper conduct during scenario execution, data capture techniques, and the handling of unexpected test events. Similarly, test participants, such as operators and support staff performing in simulated roles, must be formally briefed prior to testing using standardized briefings defined in the test procedures. These briefings ensure that participants are familiar with the simulation environment, their role expectations, and the test rules, without disclosing any details related to the specific scenarios they will encounter.

To protect the security and integrity of the test scenarios, participants must not be given access to scenario content or structure ahead of time. Scenarios are designed to elicit realistic human-system interaction under representative operational conditions and are intended to simulate the types of tasks, decisions, and workload that operators would encounter during actual plant operations. While different crews may receive different scenarios, each scenario must be designed to evaluate the same set of functional requirements, operator actions, and performance criteria. Scenario variation must not introduce differences in complexity, difficulty, or timing that could confound the evaluation of staffing adequacy.

Throughout the execution of each scenario, data collection is conducted according to predefined methods outlined in the test procedures. Collected information includes objective performance data (e.g., task completion time, alarm response time, error frequency), subjective ratings (e.g., workload assessments), and qualitative observations. Data must be collected consistently across crews and scenarios to allow for comparative analysis and reliable interpretation of results.

Following test execution, data must be reviewed to verify validity and completeness. Verification includes confirming that test scenarios were conducted as planned, initial conditions were properly established, no procedural deviations occurred, and data was captured correctly. If a test run is determined to be invalid, for example, due to equipment malfunction, a significant procedural deviation, or the unintentional exposure of scenario content to participants, it must be formally documented and excluded from analysis.

By enforcing strict procedural discipline, ensuring adequate preparation of all involved personnel, protecting scenario integrity, and rigorously verifying test results, Oklo ensures that the conduct of HFE staffing studies supports credible, evidence-based conclusions regarding the adequacy of staffing levels and HSI performance in support of safe, reliable Aurora powerhouse operations.

8.5 Review and synthesize results

The collection and synthesis of test data is a critical phase in the execution of HFE staffing studies. Following the completion of each test scenario, data collected during the execution phase is organized, verified, and evaluated to ensure accuracy, completeness, and relevance to the study objectives. Data is gathered from multiple sources, including real-time observations, automated system logs, operator performance metrics, participant self-assessments, observer ratings, and post-scenario debriefs. This multi-method approach ensures a comprehensive understanding of operator performance, workload, situational awareness, and team coordination under simulated conditions.

Once collected, all raw data undergoes a verification process to confirm that it was captured in accordance with the approved test procedures. Verification includes ensuring time synchronization between data streams, cross-checking observer logs against simulator recordings, confirming that scenario execution matched the intended design, and identifying any anomalies that may affect data integrity. Any scenarios determined to be invalid due to procedural deviations or equipment malfunctions are excluded from analysis, and the reasons for exclusion are documented for traceability.

The next step involves the synthesis and analysis of verified data. This process includes aggregating performance metrics across scenarios, comparing operator responses and task completion times, evaluating workload trends, and identifying recurring human-system interaction patterns. Data synthesis should also account for scenario variability to ensure that observed outcomes are not artifacts of scenario differences. When applicable, statistical techniques may be employed to support comparative assessments and validate trends in workload or staffing performance across operating modes or crew configurations.

The results of the data analysis are then integrated into a comprehensive final Staffing Justification Report, which forms the basis for determining the adequacy of proposed staffing levels. This report documents the methodology, test environment, participant structure, results, findings, and conclusions, ensuring transparency and regulatory traceability. It serves both as an engineering justification for staffing decisions and as a record of compliance with applicable HFE guidance and regulatory expectations.

The final Staffing Justification Report should contain, at a minimum, the following elements:

- A description of the test objectives and overall methodology used to validate staffing levels
- Identification and justification of the scenarios used, including how they support staffing validation across operating modes
- A summary of test bed verification activities and confirmation that the simulator met fidelity and completeness criteria
- A listing of test participants (anonymized, if appropriate) and their roles, qualifications, and training status
- A description of how data was collected, including tools, methods, and timing
- A summary of performance results for each crew, including key task completions, response times, and observed human-system interactions
- Evaluation of workload and situational awareness, supported by subjective and objective measures
- Documentation of any test anomalies, deviations, or invalid runs, including justifications for exclusion
- A synthesis of results across all crews and scenarios, with identification of trends, limitations, and interpretation of findings
- Final conclusions on the adequacy of the proposed staffing plan, including specific recommendations for onsite staffing, offsite support, and conditions for operator deployment
- Appendices containing raw data, observer notes, participant debrief summaries, scenario descriptions, and applicable logs

Through careful collection, synthesis, and reporting of test data, Oklo ensures that the staffing validation process is robust, transparent, and defensible. The final staffing report serves not only as an engineering deliverable but also as a critical component of the licensing and safety assurance framework, demonstrating that operator staffing is sufficient to support safe, effective operation of the Aurora powerhouse fleet.

9 Conclusion

This topical report advances the foundational principles introduced in Oklo's "Product-Based Operator Licensing Framework" topical report by providing a detailed methodology for establishing, validating, and maintaining appropriate staffing levels across the Aurora powerhouse fleet. While the licensing framework outlined in the March 2025 submission defines the roles, responsibilities, and regulatory structure for licensed operators, this report addresses the practical application of those principles, specifically how Oklo determines the number, location, and support structure of senior licensed Startup Operators and on-call engineering support staff necessary to ensure safe and reliable operations.

The core challenge addressed in this report lies in adapting traditional staffing expectations, rooted in LLWR design characteristics and typical control room-centric operations, to a fleet-based operations and remote monitoring approach. Oklo's Aurora powerhouses, with their inherent design simplifications, passive safety features, and centralized support capabilities, require approaching staffing in a way that reflects both the safety case of the design and the augmented operational structure.

Oklo employs a rigorous, human-factors-informed methodology for staffing analysis and validation. The process ensures that onsite staffing during each mode of operation is appropriately aligned with safety-critical functional needs, while also recognizing the role of offsite licensed senior operators and on-call engineering support personnel. The report details how Oklo uses task analysis, HSI evaluations, and simulator testing to confirm that staffing plans are not only compliant but effective, maintaining situational awareness, minimizing workload-induced errors, and ensuring sufficient technical support across all operational conditions.

As Oklo continues to scale its fleet of Aurora powerhouses, the methodologies described in this report will support consistent and reliable operations at multiple sites. The integration of centralized support from the powerhouse support center, combined with a flexible, validated staffing strategy, positions Oklo to maintain a high standard of operational safety while enabling efficient use of both licensed personnel and engineering expertise. This report demonstrates Oklo's commitment to safe, innovative, and forward-looking staffing practices that are grounded in regulatory rigor and informed by the unique characteristics of its technology.

10 References

[1] J. L. Seymour, D. R. Desaulineirs, and B. D. Green, “Technology-Inclusive Human-System Considerations for Advanced Reactors - IAEA-CN-084 TIC2022.” U.S. Nuclear Regulatory Commission, May 2022. [Online]. Available: https://www.nrc.gov/docs/ML2213/ML22136A209.pdf

[2] U.S. Nuclear Regulatory Commission, “Human-System Interface Design Review Guidelines (NUREG-0700).” Jul. 2020. [Online]. Available: https://www.nrc.gov/docs/ML2016/ML20162A214.pdf

Appendix A HFE Program Plan

The human factors engineering (HFE) program plan is informed by the guidance provided in NUREG-0711, Rev. 3, "HFE Program Review Model," and applies to facilities, systems, structures, components, and programs for the Aurora powerhouse and, as needed to support safe operations, the powerhouse support center.

A.1 Purpose

The purpose of the HFE program is to incorporate "state-of the art" HFE design principles into the overall design process for the Aurora powerhouse and, as needed to ensure support safe operations, the powerhouse support center. The HFE program plan

- establishes the goals of the overall HFE program, supporting the design, development, and implementation of each product deployment;
- defines input assumptions and constraints associated with the HFE program;
- establishes the methodology for determining the extent of HFE application through an augmented approach informed by the operational significance of human involvement;
- defines the human-system interface (HSI), training, and procedures the HFE program plan applies to;
- identifies and describes each of the HFE program elements, as applicable;
- defines the processes and procedures that ensure integration of state-of-the art HFE principles and concepts into the applicable aspects of the overall product design;
- defines the HFE program team structure and composition, member responsibilities, placement, and authority within the HFE program design process;
- defines the HFE program team member qualifications;
- defines the processes to document, track, resolve, and close issues relating to HFE design and implementation; and
- ensures HFE principles are applied to the design, development, and evaluation of HSI, procedures and training.

The following sections summarize the design and structure of the HFE program.

A.2 Program goals

The primary goal of the HFE program is to provide a formal systematic process for integrating HFE into the analysis, design, verification and validation, and deployment of Oklo's designs (i.e., Aurora powerhouse). The implementation of the HFE program produces state-of-the art human factors engineering products (i.e., HSI design, procedures, training) that support the overall safe and reliable operations, maintenance, and testing of each powerhouse.

The HFE design process is an iterative process that integrates a human-centered approach and perspective into to the design of Oklo's products. Utilizing a human-centered approach, the HFE program is designed to ensure overall plant safety goals are met in the following manner:

1. Users are provided high-quality interfaces with systems that are easy to use and understand.

2. Situational awareness is supported by the design of HSIs, operating procedures, training, staffing levels, and personnel qualifications.

3. Vigilance is maintained over all plant operating modes and states as supported by the HSI design, procedures, training, staffing levels, and personnel qualifications.

4. Human errors are minimized, and error detection and recovery capabilities are supported.

5. Personnel tasks are accomplished, when required, to the required performance criteria supported by the HSI design, procedures, training, staffing levels, and personnel qualifications.

6. Task demands and workload for personnel are reasonable throughout all plant operating modes and states.

Plant modifications are evaluated for potential impacts to human performance. HFE considerations should be provided to ensure that

- disruptions to existing work activities are minimized during the planning, installation, and implementation of plant modifications;

- changes to plant procedures and training are properly coordinated to ensure personnel are provided the tools necessary to successfully complete their tasks; and

- training is conducted prior to implementation of plant modifications to ensure personnel have the necessary knowledge and skills to complete tasks impacted by the plant modifications.

These goals are achieved by integrating HFE elements (elements are described in Section A.6) and activities with relevant engineering activities early in the design process to ensure the consistent application and integration of HFE principles into the design and verification of applicable facilities and HSI. It is anticipated that as the HFE program develops, these goals will be further refined and defined to support HFE tests and evaluation. Provisions are made in all processes for necessary iteration, review, and verification.

A.3 Program design

The approach to the design of the HFE program takes the following into consideration:

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A.4 Scope

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A.5 Program duration

The HFE program is initiated early in the design process and continues through completion of the initial startup and test program. However, due to the iterative nature of Oklo's staffing plan development and its reliance on operational insights, elements of the HFE program will continue into powerhouse operations. Specifically, human performance monitoring, as described in Section A.10.11, is implemented during operations to assess the effectiveness of human-system interfaces and procedures, support continuous improvement in plant performance, and identify opportunities for design or procedural enhancements.

As additional Aurora powerhouses are deployed across new sites, the staffing validation process remains active. Initial staffing assumptions are validated through performance-based evaluations conducted at the first operating units. These evaluations, supported by task analysis, workload assessments, and human performance monitoring, generate empirical data on the effectiveness of staffing configurations and operational roles. The insights gained during the operation of early units are used to refine staffing models and inform planning for subsequent deployments. This iterative and data-informed approach enables Oklo to apply an adaptive staffing validation methodology across the Aurora fleet. It incorporates task execution data, workload metrics, and human performance monitoring results, as well as feedback from integrated system validation and post-startup assessments. Site-specific considerations such as facility layout, staffing constraints, and regulatory interface requirements are also incorporated into the refinement process.

HFE program elements that support staffing validation, including task analysis, staffing and qualifications, and human performance monitoring, remain active throughout operations and are reapplied during the design and licensing phases of future Aurora powerhouse sites. This approach ensures that staffing and operational models evolve in response to operational experience while remaining consistent with the guidance provided in NUREG-0711.

A.6 Program elements

The HFE program is informed by the guidance provided in NUREG-0711 and applies to facilities, systems, structures, components, and programs that are determined to be scoped under the HFE program for Oklo's products.

The HFE program is composed of the following elements:

- HFE program management plan (i.e., this appendix)
- Operating experience review (OER)
- Functional requirements analysis (FRA) and function allocation (FA)
- Task analysis (TA)
- TIHA
- Staffing and qualifications (S&Q)
- HSI design
- Procedure development program
- Training program development
- HFE V&V
- HFE design implementation
- Human performance monitoring (HPM)

A.7 Ownership, design team, roles, and qualification

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A.8 General processes and procedures

The following general processes are used by team members to perform their responsibilities in the implementation of the HFE program:

- HFE work and activities are assigned to team members by the program lead. For HFE activities assigned to extended team members, the program lead and technical project manager coordinate applicable team leads and the technical project manager.
- Internal coordination of HFE work and activities is managed by the technical project manager. The program lead provides oversight of all of team activities and is ultimately responsible for the implementation of the HFE program.
- The technical project manager is responsible for ensuring that team members assigned HFE work and activities by the program lead meet the qualification requirements to perform their assigned activities.
- HFE design recommendations and decisions are made through design reviews, design team meetings, or other existing engineering processes. The HFE design team has the authority and organizational placement to ensure that the HSI design is implemented in accordance with the HFE program plan or program document (i.e., IPs, style guide).
- When design changes are proposed, the HFE design team evaluates the proposed design change for potential impacts on the performance of personnel, schedule disruptions, training, and procedures. Any identified impacts are tracked using the human factors tracking process, as described in Section A.8.1.
- HFE products are peer reviewed by team members prior to approval by the program lead. HFE team members should consider extended team member peer reviews when information being reviewed covers subject matter that the HFE team member is unfamiliar with. The program lead is responsible for ensuring that necessary agreement from directors, managers, and team leads is obtained prior to approving HFE products.

A.8.1 Tracking HFE issues

Human factors issues are tracked within the HFITS, which facilitates evaluation and resolution of issues. Issues are those items that need to be addressed later and hence must be tracked to ensure that they are not overlooked. Human factors issues include

- known human issues or recognized human issues to the industry (defined in the OER element),
- human issues identified throughout the lifecycle of the HFE project, and
- human engineering discrepancies (HEDs).

HEDs are issues discovered during the V&V program element of the HFE program and may require engineering changes or design modifications and subsequent verification to resolve. However, some HEDs may be resolved without changes or modification. In such cases, the basis (e.g., published HFE literature, tradeoff studies, or engineering evaluations) for HED changes must be documented. HEDs are identified, documented, and resolved, if possible, during V&V activities.

A procedure is developed, established, and maintained by the HFE design team to define the following:

- Criteria for identifying human factors issues that are to be entered into the system
- Process for tracking issues within the tracking system until the potential for negative effects on human performance is reduced to an acceptable level
- Administrative responsibilities of the HFE core team members and extended team member for maintaining the tracking system and tracking logs
- Process for evaluating and documenting proposed resolutions to human factors issues and the residual effects of the implemented resolutions for the issue. When no action is required to resolve the issue, adequate justification shall be documented in the tracking system.
- Format of the HFITS reports that can be used by the both the HFE design core team and extended team

Resolution verification is the element of the process that verifies that human factors issues are evaluated and documented. Identified issues are justified, analyzed, and prioritized so that design solutions can be developed. In this way, modifications can be adequately addressed in the design. Use of a “desktop simulator” or “engineering/part-task simulator” may allow issues to be addressed and closed out before a full-scope simulator is available. Issues that cannot be resolved until the full-scope simulator is available are specifically identified and incorporated into the design verifications of the HFE V&V activities. Those issues that cannot be resolved until the plant facility is available will be addressed in design implementation activities. HEDs are issues discovered during the V&V program element of the HFE program and may require engineering changes and verification. HEDs are identified, documented, and resolved through V&V.

A.8.2 Subcontracting HFE activities

If a subcontractor is involved in HFE activities, the HFE team is responsible for ensuring that the subcontractor

- has the background and experience compatible with the work being assigned,
- is properly trained to comply with the HFE processes and procedures established in or via the HFE program plan, and
- is provided access to the tools needed to conduct HFE activities in accordance with the HFE processes and procedures established in or via the HFE program.

The scope of work established in the agreement with the subcontractor should clearly identify the final deliverable with the appropriate level of specification to ensure that the final deliverable meets HFE program expectations. Specifications include a clear description of the contents, format, and timeline for delivery of the final product.

The HFE team is responsible for ensuring that the work performed by the contractor is performed in accordance with the established standards and for ensuring that the final deliverable meets the minimum specifications specified in the agreed-upon scope of work.

A.9 Generic HFE program implementation milestones

Table A-1 outlines generic HFE program element milestones in relation to major licensing and operational events. The table identifies when each HFE element is initiated or completed, either prior to or at the time of combined license application (COLA) submittal, prior to fuel load, or after initial startup.

Each activity is aligned with associated implementation deliverables. “IP” refers to the implementation plan, which outlines the methodology and scope for each HFE element. “RSR” refers to the Results Summary Report, which documents the outcomes of the HFE element execution and supports verification and validation of the plant design.

Table A-1: Generic HFE program element milestones

HFE program element	COLA submission or prior	Prior to fuel load
OER	IP	RSR
FRA and FA	IP	RSR
Task analysis	IP	RSR
S&Q	—	RSR
TIHA	—	RSR
HSI design	IP	RSR
Procedure development	*(Included in Final Safety Analysis Report)*	
Training program development	*(Included in Final Safety Analysis Report)*	
Verification and validation	IP	RSR
Design implementation	IP	— [1]
Human performance monitoring	—	IP[2]

[1] No RSR is required for this element because conformance of the as-built design is confirmed by inspections, tests, analyses, and acceptance criteria (ITAAC).

[2] In effect at time of fuel load and continues through operations

A.10 Program element descriptions

This section provides a description of each element of the HFE program. Each element is briefly characterized in terms of its scope, purpose, and role within the overall HFE process. The descriptions reflect how each element contributes to the integration of human factors into plant design, operation, and verification. These elements are consistent with those identified in U.S. Nuclear Regulatory Commission (NRC) guidance for comprehensive HFE programs.

A.10.1 OER

The main purpose of conducting an operating experience review is to identify HFE issues related to plant or personnel safety. Issues and lessons learned from operating experience provides a basis for improving the plant design. Negative features should be avoided, and positive features should be retained. Operating experience is evaluated for applicability and relevance to the design of Oklo's powerhouses. Operating experience items of high relevance are tracked in the human factors issues-tracking database. The database ensures that relevant items are dispositioned for incorporation into the design and are adjudicated during HFE verification and validation. An IP is developed to establish the methodology for the operating experience review. An RSR will be generated upon closure of this element.

A.10.2 FRA and FA

The purpose of this element is to identify the high-level functions that must be carried out to satisfy the plant's safety goals and assign those functions to personnel, automation, or both in a way that takes advantage of human strengths and avoids human limitations. The personnel role is examined in two steps: FRA and FA. An FRA identifies those plant functions that must be performed to satisfy the plant's overall operating and safety goal: to ensure the health and safety of the public by preventing or mitigating the consequences of postulated accidents. This analysis determines the objectives, performance requirements, and constraints of the design and sets a framework for understanding the role of controllers (personnel or system) in regulating plant processes.

Function allocation is the assignment of functions to (1) personnel (e.g., manual control), (2) automatic systems, and (3) shared combinations of both. Function allocations should be founded on functional requirements and HFE principles in a structured, well-documented methodology that produces clear roles and responsibilities for personnel.

A successfully completed FRA and FA will produce the following:

- A documented list of the high-level functions that must be accomplished to meet the plant's performance goal to ensure health and safety of the public
- A database containing information gathered during the analysis of functions (e.g., requirements related to the high-level function)
- A hierarchical depiction of functions, processes, systems, and components that shows relationships between high-level functions and the plant's systems responsible for performing the functions (to include inherent design features)

- A documented comparison of the plant's functional hierarchy with predecessor or reference plants and systems
- Documentation of allocation of active functions to the human operator, machine (e.g., design features, hardware, or software), or a shared combination of both the human and machine at varying levels of allocation

The FRA and FA is an iterative process and matures with the design of each product. An IP is developed that establishes the FRA and FA methodology. An RSR will be generated upon closure of this element.

Results from the FRA and FA serve as a resource for other elements of the HFE program plan, to include the following:

- Task analysis
- Staffing and qualification
- HSI design
- Procedure development
- Training program development

A.10.3 Task analysis

The functions allocated to plant personnel define the roles and responsibilities that they then accomplish via human actions (HAs). HAs can be divided into tasks, a group of related activities with a common objective or goal. The objective of this review is to verify that the applicant undertook analyses identifying the specific tasks needed to accomplish personnel functions, as well as the alarms, information, control support, and task support required to complete those duties.

The results of the task analysis offer important inputs in many HFE activities, to include the following:

- Staffing and qualification
- HSI design procedures
- Procedure development
- Training program development
- Task support verification (see HFE V&V)

One of the important products of the task analysis is a knowledge and abilities (K/A) catalog. The catalog is an important input into training program design, development, implementation and evaluation. A K/A catalog is needed to develop written examinations and operating tests for Startup Operators (senior licensed operators).

An IP is planned to be developed to establish the task analysis methodology. An RSR will be generated upon closure of this element.

A.10.4 Treatment of IHA

The objective of this element of an HFE program is to identify those HAs most important to safety for a particular plant design; this identification is accomplished through a combination of probabilistic and deterministic analyses. The objectives of this element are to

- identify important HAs and
- consider human-error mechanisms for important HAs in designing the HFE aspects of the plant.

State-of the art HFE is applied to IHAs to minimize the likelihood of personnel error and help ensure that personnel can detect and recover from any errors that occur. An IP is planned to be developed to establish the methodology for identification and treatment of IHAs. An RSR will be generated upon closure of this element.

A.10.5 Staffing and qualifications

Plant staff and their qualifications are important considerations throughout the design process. Initial staffing levels may be established based on experience with previous plants, staffing goals (such as for staffing reductions), initial analyses, and government regulations. Final staffing levels result from the analyses described in this section, the applicant's policy and practices, and regulatory information.

Existing regulatory requirements for operator staffing were developed for the current fleet of light water reactors and are codified in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.54, "Conditions of licenses," paragraph m. These requirements assume conventional designs and traditional control room configurations. The NRC has acknowledged that advanced reactor designs, which employ increased automation, inherent safety features, and passive systems, may not align with these assumptions and may therefore warrant exemptions to existing staffing rules.

The Aurora powerhouse design incorporates several features that support a revised staffing model. These features include automatic control systems that minimize the need for continuous manual intervention, inherent and passive safety functions that reduce reliance on active operator actions, and a design philosophy that supports high reliability with simplified operational demands. In addition, Oklo's fleet-based operational model centralizes certain functions within a centralized support center, allowing for shared staffing resources across units.

In light of these design attributes, Oklo anticipates requesting an exemption to 10 CFR 50.54(m), supported by the methods described in this topical report, which are informed by the guidance in NUREG-1791, "Guidance for Assessing Exemption Requests from the Requirements of 10 CFR 50.54(m) for Onsite Staffing at Nuclear Power Plants," July 2005, and NUREG-0711. These documents provide a flexible and technology-neutral framework for evaluating staffing approaches that deviate from current norms and are particularly applicable for designs that do not fit the assumptions embedded in 10 CFR 50.54(m).

The S&Q analysis draws on several elements of the HFE program, including OER, FRA and FA, task analysis, treatment of IHA, procedure development, and training program development. Task analysis plays a central role in defining staffing needs by identifying tasks assigned to personnel and evaluating their characteristics, such as the required knowledge and skills, the relationships among tasks, the duration of each task, and the estimated workload. The analysis also considers whether individuals in staffing roles will be able to maintain situation awareness within their assigned area of responsibility.

Procedure development and training program development provide important supporting input. Procedures clarify how tasks are carried out under various operating conditions and help determine the timing, sequencing, and coordination demands placed on staff. Training development defines the qualification requirements for staff and supports an evaluation of whether personnel are prepared to perform their assigned roles effectively under the proposed staffing model.

An IP for staffing and qualifications will be developed to define the methodology used for the staffing analysis. This plan will support the development of an initial staffing plan, which will specify proposed staffing levels and qualification requirements. The plan will also describe the validation methods and testing activities that will be used to assess the adequacy of the initial staffing levels.

The staffing analysis will be conducted as an iterative process. Initial staffing levels will be refined based on results from other HFE elements and validation testing. Adjustments may be made as operational concepts and interface designs mature. Following validation, a staffing justification report will be prepared to document the final staffing and qualification levels. This report will serve as the formal technical justification supporting an exemption request to 10 CFR 50.54(m).

A.10.6 Human-system interface design

The objective of this element is to identify and translate the functional and task requirements to HSI design requirements and to the detailed design of alarms, displays, controls, and other aspects of HSIs.

One of the products of this element is a concept-of-use document that states the roles and responsibilities of operations personnel based upon anticipated staffing levels. The concept-of-use document should

- provide a high-level description of how personnel will work with HSI resources and
- address the coordination of personnel activities, such as interactions with auxiliary operators and the coordination of maintenance and operations.

An IP is planned to be developed to establish a structured methodology for designing HSIs, complete with an HSI style guide that is used by designers to identify and select candidate HSI approaches, define the detailed design, and perform HSI tests and evaluations. An RSR will be generated upon closure of this element.

A.10.7 Procedure development

Procedures are essential to plant safety because they support and guide personnel interactions with plant systems and personnel responses to plant-related events. The goal of the procedure development program is to incorporate HFE principles and criteria, along with all other design requirements, to develop procedures that are technically accurate, comprehensive, explicit, easy to utilize, validated, and in conformance with 10 CFR 50.34, “Contents of applications; technical information,” paragraph (f)(2)(ii). The products of the procedure development program are the generic technical guidelines, the procedure writers’ guides, and the full set of plant procedures. There are no IPs or RSRs associated with this element.

A.10.8 Training program development

Training plant personnel is important to ensuring the safe, reliable operation of nuclear power plants. Training programs aid in offering reasonable assurance that plant personnel have the knowledge, skills, and abilities needed to perform their roles and responsibilities. The goal of training program development is to ensure the necessary processes and procedures are in place to implement a systems approach to training. The product of training program development is a comprehensive training program for both licensed and non-licensed plant staff. There are no IPs or RSRs associated with this element.

A.10.9 Human factors verification and validation

V&V evaluations comprehensively determine that the final HFE design conforms to accepted design principles and enable personnel to successfully and safely perform their tasks to achieve operational goals. The product of the applicant’s V&V program is a completed design that is verified and validated.

This element involves the following activities, with the following objectives:

- HSI task support verification: Verification that the HSI provides the alarms, information, controls, and task support defined by tasks analysis needed for personnel to perform their tasks

- Staffing plan validation: Verification of the staffing plan to ensure staffing levels are commensurate with the level required to ensure the plant achieves its overall safety objectives. This verification may be done as part of the integrated system validation.

- HFE design verification: Verification that the design of the HSIs conform to HFE guidelines (such as the applicant’s style guide)

- Integrated system validation (ISV): Using performance-based tests, validation that the integrated system design (i.e., hardware, software, procedures and personnel elements) supports safe operation of the plant

During these evaluations, HEDs may be identified. HEDs are tracked using the human factors issues tracking system. HEDs are evaluated for correction or dispositioned after the correction has been made and verified.

An IP will be developed that describes the methodology for conducting V&V, including

- the inventory developed to characterize the HSIs;
- the criteria to be used for task support verification and HFE design verification;
- the complete set of detailed scenarios for ISV (and how they were identified through the sampling of operational conditions), performance measures, and acceptance criteria; and
- the methods by which HEDs will be evaluated.

An RSR will be generated upon closure of this element.

A.10.10 Design implementation

This element addresses implementation of the HFE aspects of the plant design for new plants and plant modifications. For a new plant, the implementation phase is well defined and carefully monitored through startup procedures and testing; implementing modifications is more complex. The product of the design implementation element is a final verified and validated as-built HFE design. An IP is planned for development. No RSR is required for this element because conformance of the as-built design to the verified and validated design is confirmed by ITAAC.

A.10.11 Human performance monitoring

The objective of reviewing an applicant's human performance monitoring program is to verify that the applicant prepared a program to

- adequately assure that the conclusions drawn from the integrated system validation remain valid with time and
- ensure that no significant safety degradation occurs because of any changes made in the plant.

The applicant may incorporate this monitoring program into their problem identification and resolution program and their training program. An IP is planned to be developed prior to fuel load.

A.11 HFE requirements, standards, and specifications

The HFE program is guided by a set of regulatory requirements, NRC guidance documents, and industry standards that establish expectations for the design and evaluation of HSIs, staffing models, and operational support systems. These sources provide the technical foundation for the HFE methods and activities described throughout this program plan.

The applicable regulations, guidance documents, and standards that form the basis of the HFE program are identified in Section 3 of Oklo's "Staffing Plan Validation Methodology" topical report. These references include NRC regulations, review models, interface design guidance, and relevant human factors and ergonomics standards. They inform the planning, execution, and review of HFE analyses and ensure that the program supports safe, effective, and licensable design outcomes.

The HFE design team is responsible for ensuring that all activities are performed in alignment with these sources and for identifying any additional standards or specifications that may be necessary to support specific analyses or design decisions as the project progresses.

A.12 HFE facilities, equipment, tools, and techniques

The HFE program employs a range of facilities, tools, and techniques to support the analysis, design, and evaluation of human-system interactions within the monitoring room, powerhouse support center, and other operating environments associated with the Aurora powerhouse.

The HFE team uses digital design and analysis tools to support activities such as FRA and FA, task analysis, and HSI development. These tools are used to create interactive mockups, assess operator workload, and evaluate workflows and staffing concepts during early design phases.

To support interface and role evaluation, the HFE program uses a staged approach to simulation and prototyping. Mock monitoring rooms and low- to medium-fidelity simulators are used in the early phases to review layouts, displays, and operational concepts. These mockups support structured walkthroughs, expert reviews, and preliminary usability assessments. As the design matures, limited-fidelity simulators are used to evaluate task sequences, information presentation, and coordination across roles. Full-scope simulators may be used to support integrated evaluations, scenario-based assessments, and testing of staffing and interface performance under representative operational conditions.

These facilities and tools enable the HFE design team to iteratively evaluate how personnel interact with automation, displays, alarms, and control interfaces in both normal and off-normal scenarios. The tools and techniques used for each HFE element are selected based on the phase of design, the maturity of the system, and the objectives of the activity. The use of these resources is documented in the relevant HFE program element IPs to ensure consistency and traceability throughout the program.

A.13 Documentation

The scope of documentation for the HFE program may include but is not limited to the following:

- IPs for each of the applicable HFE program elements
- RSRs for each applicable HFE program element
- Staffing plan and subsequent staffing justification report
- K/A catalog
- Scenario abstracts, test plans, and procedures
- Design descriptions
- HSI style guide
- Procedure writers' guidance and generic technical procedure guidelines
- Concept of use documentation

This documentation and any supporting documentation and materials are maintained throughout the life of the associated product deployment. Documentation listed above is further described, as necessary, in the next section under the applicable HFE element.

Appendix B Operational Experience Review Implementation Plan

This implementation plan (IP) describes Oklo's methodology for conducting the operating experience review (OER) as part of the overall human factors engineering (HFE) program. The methodology was developed based on the review criteria provided in Chapter 3 of NUREG-0711, "Human Factors Engineering (HFE) Program Review Model," Revision 3, November 2012, which outlines the purpose, scope, and approach for identifying and applying relevant operating experience to support human-system interface (HSI) design and the identification of important human actions (IHAs).

B.1 Purpose

The purpose of conducting an OER is to identify and document safety issues and lessons learned from applicable and relevant operating, design, and construction experience (referred to collectively as "operating experience"). Operating experience is sourced from multiple industries. Lessons learned are addressed in the design of Aurora powerhouse systems, operations, procedures, and training for operators to avoid past shortcomings while retaining positive features or aspects of previous designs and operations.

B.2 Scope

The scope of OER includes the following:

- Predecessor and related plants and systems
- Recognized industry HFE issues
- Related HSI technology
- Issues identified by plant personnel
- IHAs

The following section provides additional context related to the scope of OER.

B.2.1 Predecessor and related plants and systems

The Aurora powerhouse is a pool-type sodium-cooled fast reactor (SFR) design. The Aurora powerhouse incorporates inherent passive safety design features and higher levels of automatic control. There are no commercial nuclear reactors in operation in the U.S. today that can be considered its direct predecessor. However, the Aurora builds off the design of Experimental Breeder Reactor-II (EBR-II), which was built and operated by Argonne National Laboratory (Argonne) West in Idaho from 1964 to 1994.

Previously and currently operating SFR designs were evaluated and determined to have varying degrees of relevance to the Aurora powerhouse. The OER screening process enables Oklo to identify related operating experience from these similar SFR designs in a graded manner such that applicable and highly relevant operating experience is prioritized.

Table B-1: Related SFRs

Related plants	Country of operation
Experimental Breeder Reactor II (EBR-II)	United States
Fast Flux Test Facility (FFTF)	United States

}{ii}{viii}

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B.2.2 Review of recognized HFE issues

NUREG/CR-6400, “Human Factors Engineering (HFE) Insights for Advanced Reactors Based Upon Operating Experience,” January 1997, provides a detailed list of HFE-relevant operating experience pertinent to the HSI design process for advanced reactors. These issues are organized into the following categories:

- Unresolved safety issues and generic safety issues
- Three Mile Island incident issues
- U.S. Nuclear Regulatory Commission (NRC) generic letters and information notices
- Operating experience reports in NUREG-1275 series, Vol. 1 through 14
- Low power and shutdown operations
- Operating plant event reports

Much of the operating experience in NUREG/CR-6400 is based on commercial large light water reactors (LLWRs). Even so, the operating experience in those categories listed from NUREG/CR-6400, including what was published after NUREG/CR-6400, is screened for applicability. If the operating experience is determined to be applicable, the experience is identified as a potential operating experience item and screened for technical relevance.

B.2.3 Related HSI technology

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B.2.4 Issues identified by plant personnel

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B.2.5 IHA

The Aurora powerhouse design builds on the legacy of EBR-II. Related plants are identified in Table B-1. During OER of these plants and systems, IHAs are identified and evaluated to determine whether they remain important to the Aurora powerhouse design. Documented operating experience from predecessor designs and related plants and systems (e.g., from personnel interviews, published papers and reports, or lessons-learned reports) can provide insight into whether identified IHAs were actually needed and successfully completed, if any human errors occurred. Those aspects of the design that help to ensure success of the identified human actions are documented and tracked using the OER methodology described in Section B.3.

B.3 OER methodology

B.3.1 Responsibilities

The HFE team is accountable for the conduct and performance of the OER. The roles and qualifications of HFE team members supporting this activity are described in the HFE program plan. The HFE team is responsible for developing, establishing, and maintaining the HFE OER procedure, which provides instructions for evaluating, documenting, tracking, and resolving relevant operating experience issues.

B.3.2 OER process overview

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B.3.3 Operating experience screening

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B.3.4 Determining technical relevance and assigning grouping

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B.3.5 OE items requiring further evaluation

Any OE item that is identified to need a more detailed evaluation is documented in the OE database tracking log. The OE item is then evaluated by a multidisciplinary team to determine the root or apparent cause and identify solutions that could be implemented either into the design of the Aurora powerhouse or an HFE program element. Items are assigned priority levels based on whether the OE item affects overall plant safety goals directly or indirectly. The OE database tracking log documents the following for each OE item requiring further evaluation:

- Root cause or apparent cause
- Lessons learned
- Classification or grouping
- HFE or design concern
- OE priority

- Implementation actions
- Implementation completion date
- Implementation verification

B.3.6 Assigning OE resolution responsibility

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B.3.7 Resolution of OE items

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B.4 OE documentation

B.4.1 OE database

The OE database is used to document information relevant to the applicable OE items. The HFE design team lead is responsible for the overall management and upkeep of the database, which contains the following information:

- Description of the OE item
- Tracking number
- Source of the OE item
- Level of relevance
- Identification of the root or apparent causes
- Lessons learned
- Determination of a design or HFE OE item
- Group responsible
- Description of the resolution of the item with justification and supporting evidence
- Verification of the item closure (or disposition to HFE issues-tracking system)

At the completion of the OER effort, the OE database is reviewed. Any open OE items are transitioned to the HFE issues-tracking system and closed in the OE database. The OER RSR shall capture open OE items that are still being tracked in the HFITS.

B.4.2 Results summary report

An OER RSR is submitted to the NRC at the completion of the OER effort. The OER RSR contains, at a minimum, the following:

- Identification of predecessor and related plants and systems
- Methodology used to review the OE (may refer to this appendix)
- List of OE sources and documents reviewed
- Discussion of the conduct of the OER and of the results of reviewing relevant HSI technology
- Description of, and findings from, interviews with plant personnel or other users
- Listing of OER-identified issues incorporated into the design
- Enumeration of open issues still being tracked in the HFITS

Summaries may be used for any of the above items, provided that references are given for more detailed supporting documentation.

Appendix C Functional Requirements Analysis and Function Allocation Implementation Plan

This implementation plan (IP) describes Oklo's methodology for conducting functional requirements analysis (FRA) and function allocation (FA) as part of the overall human factors engineering (HFE) program. The methodology was developed based on the review criteria outlined in Chapter 4 of NUREG-0711, "Human Factors Engineering Program Review Model," Revision 3, November 2012, which provides guidance for identifying the functions that must be performed to achieve plant safety and operational goals and determining how those functions are allocated between humans and systems.

C.1 Purpose

The FRA and FA process is a significant element of the HFE program. The purpose of FRA and FA is to verify that the functions, and their allocations, that must be carried out to satisfy the Aurora powerhouse performance goals take advantage of human and machine strengths and avoid limitations. The product of the FRA is a complete set of requirements necessary to satisfy Aurora powerhouse high-level plant functions. The product of the FA is the identification of how personnel and automatic controls perform the functions.

C.2 Scope

The scope of the FRA and FA includes activities performed by licensed operators onsite or at the controls in the monitoring room of the Aurora powerhouse during normal, abnormal, and emergency operating conditions. It also includes activities performed by licensed operators when stationed in the powerhouse support center during normal, abnormal, and emergency events. Onsite refueling activities performed by a senior licensed operator directly supporting refueling are also included.

The FRA and FA also include activities performed by non-licensed personnel, including Onsite Monitors and on-call engineering support staff. Analysis of maintenance activities completed by craft or technicians, unless they are determined to impact licensed operator responsibilities, are outside the scope of the FRA and FA process. When licensed operator responsibilities are impacted, the area of concern is analyzed to a degree sufficient to quantify the impact to licensed operator function responsibilities.

Design changes to the Aurora powerhouse that require direct operator interaction, relative to the plant design, are evaluated for HFE impact. Each task is analyzed to ensure plant goals and desired performance are accomplished. Analysis includes determining that the system components, instrumentation, controls, automation, and alarms are sufficient.

C.3 FRA and FA methodology

FRA and FA are conducted early in the design process to ensure that the functions required to support Aurora powerhouse operation are clearly defined and analyzed. Allocations can therefore take advantage of the respective strengths of humans and automation while minimizing the potential for error or degraded performance.

The FRA and FA process is part of a broader set of HFE analyses that relies on design documentation, subject matter expert input, and safety analysis. Safety analysis serves as a key input by identifying credited human actions, important safety functions, and time-critical operator responses. This information helps ensure that functions allocated to personnel are achievable and that automation is appropriately integrated to support safety and performance requirements.

FRA and FA provide foundational input to task analysis, staffing and qualifications, and the development of human-system interfaces (HSIs), procedures, and training programs. They also receive feedback from other HFE elements. For example, the treatment of important human actions and the operating experience review may identify functions that require updates to the FA. This methodology remains consistent whether FRA and FA are conducted as an early step or revisited during design development. Because the design and HFE processes are both iterative, the sequencing of activities is flexible rather than fixed. As the design matures, updates to task definitions may require corresponding updates to FA tables. Likewise, changes in FA may necessitate revisions to the task analysis.

Changes resulting from this iterative relationship are managed as part of the design development and HFE program implementation process. For example, if a new task is introduced in the task analysis, the FA table may be updated to reflect the responsible role. Conversely, if a function previously allocated to automation is reassigned to an operator, that change is reflected in the task definition. When such updates can be resolved within the normal design process, they are incorporated directly into the revised documentation. When further coordination is required, the necessary updates are entered into the human factors issues-tracking system (HFITS) for evaluation and resolution. This tracking is conducted in accordance with the HFE program plan to ensure consistency, traceability, and integration with other program elements.

The FRA and FA process is maintained throughout the design lifecycle, including operations and decommissioning, and is updated as needed to support design changes and maintain alignment with plant functional and safety objectives.

C.3.1 FRA and FA process overview

The overall process for FRA and FA is to be performed iteratively throughout design, development, operation, and decommissioning.

1. Identify high-level functions needed to meet the goals and desired performance of the Aurora powerhouse

2. Specify functional hierarchy, including, as appropriate, goals, functions, processes, systems, and components

3. Specify functional requirements

4. Analyze functions

5. Allocate functions, if function is shared by both humans and machine; define the level of automation

6. Incorporate into the design

7. Verify the analysis and allocations (to be covered under the HFE validation and verification IP)

The FRA begins with a conceptual review of the plant's high-level safety and performance functions. This initial phase focuses on identifying the major objectives the Aurora powerhouse must achieve and how the plant's systems are expected to contribute to those objectives. The analysis is conducted by the HFE design team in collaboration with system designers and system owners, who provide design requirements and performance expectations. These design requirements form the basis for identifying and decomposing high-level plant functions into supporting functions across processes, systems, structures, and components. This conceptual FRA defines what the plant must do and how various systems are expected to contribute, establishing a foundational understanding of plant behavior and functional intent.

As system design progresses, the analysis becomes more detailed. In the preliminary FRA phase, system-level design requirements are more fully defined and reviewed to ensure they continue to align with the high-level plant functions. During this phase, system interactions and interfaces are evaluated, and additional detail is incorporated regarding the role of instrumentation, controls, automation, and alarms. The detailed FRA phase is conducted when system specifications are established. At this stage, the functional descriptions from the system design descriptions and functional specifications are used to ensure that design implementations fulfill the intended plant functions. Inputs from subject matter experts are used throughout to assess the operational context, identify required functions, and ensure alignment with plant goals.

The FRA process supports and informs FA by establishing a traceable foundation for understanding what must be accomplished, when, and by whom or what. Early FA is informed primarily by design goals and automation strategies, including the assumption that no operator action is required for safety-related functions. As the design matures and more information becomes available through system design documentation and safety analysis, the FA process is refined to consider the capabilities and limitations of both humans and machine-based systems. Allocation decisions consider operational context, human-system interaction complexity, time-criticality, reliability, and recoverability.

Function allocation determinations serve as the basis for establishing design requirements that implement the selected allocations. These determinations influence how systems are designed to support the roles of both personnel and automation, ensuring that assigned responsibilities are achievable and that interfaces and controls are appropriately matched to operator roles. As the design evolves and new functions are introduced or existing functions are refined, the FA process is revisited to maintain alignment between functional intent and system implementation.

The FRA and FA process is inherently iterative. Insights from downstream HFE elements such as task analysis, treatment of important human actions, and operating experience review may require updates to both the functional analysis and the allocation decisions. Likewise, the outcomes of the FRA and FA process feed back into design development, helping to refine requirements, inform specifications, and ensure that human-system roles are clearly defined and appropriate. The outputs of this process provide the technical basis for subsequent HFE activities and are maintained to ensure consistency throughout the plant lifecycle.

C.3.2 Identify high-level functions

The first step in the FRA and FA process is to identify the high-level functions necessary to achieve the performance goals of the Aurora powerhouse. These goals include operational performance, safety, and regulatory objectives. The overall performance goals and associated high-level plant functions are described in Oklo's "Product-Based Operator Licensing Framework" topical report.

High-level functions are defined in general terms and should not reference specific systems, components, or implementation details. At this stage of the analysis, the focus is on what the plant must accomplish rather than how those functions are implemented. Further analysis to identify the supporting design features, processes, systems, and components is performed during later stages of the functional decomposition. Some high-level functions correspond directly to safety objectives. Functions that support the plant's goal of ensuring the health and safety of the public are classified as safety functions. For example, the function to retain radionuclides supports the overall safety objective by preventing the release of radioactive material. This function represents a fundamental safety requirement that is independent of any specific system or physical boundary.

By the end of this step, a complete set of high-level plant functions are identified. Both safety and non-safety functions that together support the full range of performance goals for the Aurora powerhouse are included. These functions serve as the foundation for subsequent functional decomposition and allocation activities.

C.3.3 Function decomposition

Function decomposition expands upon the identification of high-level plant functions by examining how each function is fulfilled through a hierarchy of design features, processes, systems, and components. This hierarchy reflects the layered structure of the plant, in which high-level functions are supported by processes that depend on specific systems, which in turn are composed of physical components. In many cases, a single high-level function is achieved through a combination of multiple systems and supporting elements.

During this step in the analysis, each high-level safety function is examined and broken down to determine the specific elements needed to support its accomplishment. The decomposition process continues until critical end-item requirements are identified. These requirements serve as the basis for evaluating whether the plant's design is capable of achieving its safety and performance goals.

The decomposition addresses several layers of plant capability, including the high-level functions identified earlier in the analysis, any supporting processes that enable their achievement, the specific plant systems and components responsible for executing those functions, and human actions where applicable. As part of this analysis, relationships or linkages between functions and their supporting systems and components are identified to ensure functional integrity and traceability throughout the design.

Differences between the Aurora powerhouse design and predecessor or reference plants are identified during this process. Where design features, systems, or functions differ, a technical basis is established to support the deviation. The technical basis must consider how those differences affect the ability to achieve the intended function and whether additional design features or operator actions are necessary.

At the completion of this step, the full functional hierarchy is established and serves as a reference framework for subsequent HFE activities, including task analysis and FA. This hierarchy provides a clear and traceable structure linking design elements to plant performance objectives and safety functions.

C.3.4 Function allocation

The FA assigns task responsibilities to personnel and automation, taking advantage of human and machine strengths and avoiding limitations. Each system function is analyzed at the component level (e.g., pumps, control valves) and for specified plant conditions (e.g., system startup or shutdown). The tasks that need to be performed are identified. Then for each task, a determination is made for the technical basis, the allocation (automatic, manual, or shared), and the role of the operator.

The technical bases for determining the FA are as follows:

- Operating experience (major plant evolutions or subject matter expert determination that automation would aid the operator)
- Whether human error is likely (complex sequence or performing tasks within the available time)
- Whether human capabilities are exceeded
- Technical feasibility (i.e., implementable design, system integration capability, engineering viability, demonstrated operability)
- Cost (i.e., financial constraints on the overall project)
- Whether precise control is required, for example in
    - quick response;
    - routine or repetitive tasks;
    - continuous monitoring;
    - temperature, pressure, or level control; or
    - standby pump starts.

- Whether human knowledge and judgment is needed

Once the functional requirements are understood, functions are allocated to either humans or machines, which may include hardware, software, or passive systems, depending on how the function is intended to be performed. This allocation may involve personnel performing manual control without automation, automatic systems executing functions without operator input, passive self-controlling phenomena, or combinations of personnel and automation working together.

Functions allocated to personnel are those that will be performed by human actions (HAs). Functions are allocated to meet the functional requirements while considering technology readiness and cost. To ensure the safety and reliability of a design, one must also consider the relative capabilities, strengths, and weaknesses of humans and machines. For example, if a functional requirement is that an action must be performed within seconds of a pump trip, it is likely to be automated because operators are unlikely to recognize the pump trip and take the required action in the specified timeframe. In many cases, ensuring that a control function is achieved requires allocating overlapping and redundant responsibilities to personnel and automation (e.g., assigning personnel the responsibility of monitoring and maintaining supervisory control over automated systems). Functional allocation decisions are made to maximize total system performance and effectiveness. However, the allocation of some functions is mandatory and predetermined by constraints established during earlier stages of design (for example, specifications or regulatory requirements).

Function allocation determinations are initially proposed by the system owner or system designer based on the intended system functionality, operational goals, and automation strategy. These determinations identify whether a function is to be performed manually by plant personnel, automatically by system hardware or software, or through a combination of personnel and automation.

The HFE design team is responsible for reviewing the proposed function allocations to ensure they are appropriate given the capabilities and limitations of both human operators and system technology. This review confirms that allocations support safe and effective operation under expected conditions and align with the overall objectives of the HFE program.

Following review and concurrence by the HFE design team, the system owner or system designer is responsible for incorporating the approved function allocation determinations into the system design requirements. The design then reflects the intended human and machine roles, and the allocation decisions are carried forward through detailed design, implementation, and verification activities.

C.3.5 Automation philosophy

Oklo's "Product-Based Operator Licensing Framework" topical report provides additional information on the following topics:

- Approach to automation
- Allocating active safety function to automation
- Assigning levels of automatic control

- Role of automation

Determining the level of automation during design is an iterative process. Balancing the needs of the operator, the capabilities of the instrumentation and controls architecture, and the design of the system requires alignment and agreement between several work groups. Guiding principles are established by engineering management to assist designers and system engineers in the prioritization of needs:

- Automation is utilized to aid the operator and to avoid human error.
- For routine tasks, it is preferred that the automation identifies initiating conditions and prerequisites and prompts the operator to perform the task instead of requiring the operator to select the appropriate automation to perform. As an example, to perform the correct dilution amount on the correct unit, the automation monitors parameters and requests the operator to concur with the selected automation.
- Automation is designed to prevent the operator from performing an undesired action through use of interlocks, prompts, and intuitive displays.
- Information display for automation is as consistent as possible in terms of location, arrangement, and functionality to optimize operator-to-system interaction and reduce potential error.
- Automation controls are standard and intuitive to understand. This principle simplifies training and provides the operator with a base level of comprehension regardless of the specific automated task.
- Automated processes are incorporated into the task analysis and procedures so they can be referenced for pre-job discussions. Automated tasks are described in the database and accessed similarly to other procedures.

C.4 Plant modifications

Plant modifications that result in new or altered plant functions require updates to the FRA and FA to maintain alignment with plant safety and performance objectives. The HFE design team is responsible for evaluating the impact of proposed modifications on the existing functional hierarchy and allocation decisions. This evaluation is performed in accordance with the roles and procedures described in the HFE program plan.

When a plant modification is initiated, the HFE design team determines whether the change introduces new functions, alters the degree of integration between systems, modifies the use of shared plant resources such as power or data buses, or affects the level of automation. These changes may create new safety functions or affect how existing functions are implemented. For example, the introduction of a higher level of automation may shift control from operators to automated systems or combine previously independent functions under a common controller.

The FRA is updated to reflect any new or revised functions associated with the modification. The scope of the analysis may be limited to those functions directly affected by the change. Function allocation is also reviewed to determine whether there are any changes in the assignment of responsibilities between personnel and plant systems. If the modification alters the role of personnel, the impact is evaluated in the context of their overall responsibilities to ensure that roles remain clearly defined and balanced.

All changes to the FRA and FA are reviewed and confirmed by the HFE design team. Any updates resulting from the modification are entered into the HFE issues-tracking system. This system ensures traceability of decisions, coordination with related HFE elements, and formal documentation of resolution. Tracking is performed in accordance with the HFE program plan.

If the modification impacts other HFE elements such as task analysis, staffing and qualifications, or HSI design, those elements are also reviewed and updated as needed. This integrated approach ensures that all related analyses remain aligned and current throughout the modification process.

C.5 Results summary report

FRA and FA are performed iteratively throughout the design process as part of implementation of the HFE program plan and elements. The product of the FRA is the complete set of functional requirements necessary to satisfy the plant's goals. The product of the FA is the identification of how personnel and automatic systems perform the functions.

This IP provides the methodology for conducting the FRA and FA to ensure that functions necessary to accomplish plant goals are sufficiently defined and analyzed so that the allocation of functions, subfunctions, and controls, where necessary, can take advantage of human and machine strengths and limitations. When the FRA and FA element is complete, an RSR is generated that contains, at a minimum, summaries of the following items, provided that references are given for more detailed documents:

- An explanation of the methodology used to define safety functions
- The set of safety functions for the facility
- An explanation of the methodology used to allocate functions and the final set of allocations
- A complete set of functional requirements necessary to satisfy the plant goals
- Identification of how personnel and automatic systems perform the functions
- The technical basis for all function allocations

Appendix D Task Analysis Methodology Implementation Plan

This implementation plan (IP) describes Oklo's methodology for conducting task analysis as part of the overall human factors engineering (HFE) program. Task analysis is an iterative process that matures alongside the plant design and plays a critical role in ensuring that human roles, responsibilities, and performance requirements are fully integrated into the system. The approach described in this plan is informed by the guidance provided in Chapter 5 of NUREG-0711, "Human Factors Engineering Program Review Model," Revision 3, November 2012, which outlines the objectives, scope, and review criteria for task analysis within a comprehensive HFE program.

D.1 Purpose

Task analysis (TA) is performed to determine the requirements for information, control, and task support. These requirements include human-system interface (HSI) inventory, such as alarms, controls, displays, procedures, and knowledge and skills requirements (input to training programs).

TA results are used to establish the instrumentation and control requirements needed for a crew to perform a task. A detailed description of both manual and mental activities, task and element durations, task frequency, task complexity, workload, environmental conditions, and necessary clothing and equipment must be analyzed. TA confirms the task allocations developed by the functional requirements analysis (FRA) and function allocation (FA) processes.

The results of the TA are used as follows:

- Provide a basis for making decisions on HSI detail design and be used to develop information and control system design requirements and basic inventories of alarms, displays, and controls HSIs
- Verify that human performance requirements do not exceed human capabilities
- Serve as basic input for developing procedures
- Serve as basic input for developing the staffing and communication requirements
- Provide the foundation for training program development (knowledge and abilities (K/As))
- Inform design of tools or equipment needed by humans to accomplish assigned tasks
- Form the basis for specifying the design requirements for the displays, data processing, and controls needed to carry out tasks
- Assist in the verification of the design in the HFE verification and validation program

- Assist in identifying and reducing excessive task demand on plant personnel, decreasing the potential hazard for human errors, and increasing the effectiveness of plant operations

D.2 Scope

The scope of the task analysis includes the following:

- Tasks and activities performed by licensed operators during normal, abnormal, and emergency operating conditions
    - Includes tasks assigned to licensed operators and performed in the powerhouse support center that support the operating crew in ensuring that the Aurora powerhouse is operating within its safety envelope
- Tasks spanning the full range of operating modes, including startup, normal operations, low-power and shutdown conditions, transient conditions, abnormal conditions, emergency conditions, and severe accident conditions

D.3 Methodology overview

An iterative and augmented approach is used to implement task analysis in a manner that aligns with the evolving maturity of the Aurora powerhouse design. The analysis is updated throughout the design process to ensure that tasks remain accurate and reflective of evolving system capabilities, operational concepts, and interface designs. Task analysis relies on multiple sources of input, including design documentation, subject matter expert input, and relevant operating experience from both internal development and commercial nuclear applications.

Task analysis is performed either in sequence with or parallel to the FRA and FA, depending on the complexity of the functions and tasks under consideration. When functions and tasks are relatively simple, have low safety significance, or are expected to be similar to those performed in existing nuclear facilities, the analysis sequence may extend directly into early development of HSIs, procedures, and training. This flexibility in sequencing reflects the iterative nature of both plant design and the HFE process. For example, newly identified or modified tasks may require updates to the FA table, while changes in FA may in turn require updates to task definitions. These changes are either incorporated directly or documented as HFE issues and tracked using the HFE issues-tracking system.

A task analysis selection process is used to determine the appropriate level of analysis for each task. This process, illustrated in Figure D-1 guides the decision to perform either a basic or a more detailed task analysis. The approach prioritizes detailed analysis for tasks that are critical to plant safety and operational reliability. These tasks include important human actions (IHAs) identified through deterministic analyses, such as transient and accident scenarios or probabilistic risk assessments. They also include human actions identified through the FRA and FA process that are necessary to achieve high-level plant safety functions. Less critical tasks may undergo a basic analysis sufficient to support interface design, procedure development, or training.

The outputs of the task analysis include a structured description of the task, its objectives, initiating conditions, required information, operator decisions, actions, timing considerations, and expected outcomes. These outputs are used to inform the design of HSIs, development of procedures, staffing and qualification assessments, training programs, and the identification and treatment of IHAs. Task analysis results also support the verification and validation of the overall HFE program by providing traceability from plant functions to operator responsibilities.

D.4 Task selection and screening

The task analysis screening process forms the foundation of the augmented approach to task analysis. Important human actions and human actions required to be successfully completed to ensure critical safety functions are achieved, as defined in FRA and FA, undergo a full, detailed task analysis. Tasks deemed to warrant selection during the screening process that are not required to undergo a detailed task analysis will still undergo a basic task analysis. Detailed and basic task analyses are described in subsequent sections.

Figure D-1 depicts the high-level process for identifying tasks for analysis and for selecting the level of analysis (e.g., basic or detailed) for each task.

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The determination of whether a task may result in potentially negative consequences is made by a multidisciplinary team composed of system engineers, design engineers, and plant operations personnel with relevant nuclear plant experience.

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D.4.1 Basic task analysis

A basic task analysis is generally required to be performed on most tasks. However, the depth of detail obtained from the basic analysis does not include determining time availability or time required to perform the task, as the task does not impact public health or safety or result in negative consequences. The minimum components of a basic task analysis include the following:

- Develop a task narrative
- Decompose the task into elements
- Evaluate the task by
  - documenting task considerations,
  - determining the number and type of personnel resources need to perform the task, and
  - determining the knowledge, skills, or abilities needed to perform the task.

Additional elements, such as developing operational sequence diagrams, may be performed to supplement the elements required for a basic task analysis based on the complexity of the task, but they are not required.

D.4.2 Detailed task analysis

Detailed task analysis is performed on IHAs, tasks identified through the FRA and FA that are needed to achieve high-level plant safety functions, and tasks identified to have negative consequences. These tasks require additional scrutiny due to their significance in supporting safety and operational performance. In addition to the information captured in a basic task narrative, the detailed task analysis includes further components to evaluate the feasibility, timing, and integration of the task within the broader operational context.

As part of this analysis, an operational sequence diagram (OSD) is developed. The operational sequence diagram provides a visual representation of the temporal relationships and dependencies between tasks, decisions, system responses, and other operator actions. It helps identify task flow, potential overlaps or conflicts, and key transitions that may affect workload or coordination across roles. The OSD also supports validation of function allocation by confirming that operator responsibilities are appropriately sequenced and distributed.

In conjunction with the OSD, a time availability analysis is performed that involves determining the time available to perform the task based on system or event timing and comparing it to the time required for an operator to complete the task under expected conditions. This assessment ensures that operators have sufficient time to perform the task without exceeding cognitive or physical workload limits. The analysis includes margin to account for variability in operator performance and uncertainty in system response times. This step is essential for confirming that the task is not only necessary and well defined, but also realistically executable under operational constraints.

These components of the detailed task analysis contribute to ensuring that the identified human actions are achievable, well integrated with system design, and consistent with the overall goals of safety and reliability.

D.5 Task analysis component descriptions

D.5.1 Develop a task narrative

A task description is written to be clear as to who should perform the task, what they are trying to accomplish, and why. The task description should be as clear and succinct as possible. However, the task narrative should also be written to the complexity of the task (e.g., a simpler task may have simpler descriptions, and complex tasks may require longer descriptions). Detailed task analysis narratives include the following:

- Task title and identifier
- Operator notifications (alarms, alerts, messages, and prompts) associated with the task or that aid in the completion of the task
- Parameters the operator must know or be able to locate during performance of the task and a means of knowing if actions taken to attain parameters are adequate (feedback)
- Decisions the operator must make in performing the task (the type of decision and how the operator evaluates choices before reaching a decision)
- Action(s) expected of the operator, accuracy requirements for the action(s), required action sequence, time available for the action(s), and ergonomic properties of the controls for completion of the action
- Communication needs for the operator and associated teammates and alternative communication methods
- Workload (the anticipated or measured cognitive and physical workload needed to complete the task)
- Tools, equipment, protective clothing, job aids, or procedures needed for the task workspace needed to perform the task and environmental conditions applicable for the task's situational considerations (ways that situations affect the outcome of the task such as time pressure, extreme environments, and team staffing shortages)
- Hazards and the means for identification and mitigation of hazards for completion of the task

Task narratives for basic task analysis include only those necessary to successfully complete the task. Task narratives are revised as relationships among tasks are better defined. The order and sequence of tasks selected for TA are crucial to understanding workload and communication needs and supporting the development of operating procedures.

D.5.2 Decompose the task into elements

Tasks should be broken down into logical elements. For example, for a maintenance task, the task may be broken down into preparation (system alignment, administration, etc.), execution (actual conduct of the work), and return to service or system restoration. This breakdown helps the analyzer consider unique task considerations for each element (or stage) of the task. For detailed task analysis, decomposition of the task can help with initial drafting of the operational sequence diagram.

D.5.3 Task evaluation

Table D-1 identifies the considerations that should be determined and documented when evaluating tasks and is based on the task consideration provided in NUREG-0711, Section 5.4.

Table D-1: Task considerations

Topics	Examples
Operator notifications	• Alarms • Warnings • Messages • Prompts
Information	• Parameter (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) • Physical position (stand, sit, squat, etc.) • Biomechanics
Teamwork and communication	• Coordination needed among the team performing the work • Personnel communications for monitoring information or control actions (communication needed between onsite and offsite)
Workload	• Cognitive • Physical • Overlap or task requirements (elements performed in series vs. parallel)
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 work site • Workspace needed to perform the task • Typical environmental conditions (lighting, temperature, noise)
Situational and performance-shaping factors	• Stress • Time pressure • Extreme environmental conditions • Staffing conditions
Hazards	• Identification of hazards (e.g., personal hazards)

The number of personnel required to perform each task is determined by the task narrative, the complexity of the task, the time required to perform the task, and the time available. The task narrative developed for a basic TA includes such information as

- job function and title of persons who perform the task,

- requirements for communication with other operations personnel while performing the task,
- how different levels of staffing affect the performance of a task, and
- the task time estimate.

Where detailed TA determines that workload for an individual task or analyzed sequence of tasks is excessive, an HFE issue is entered into the human factors issues-tracking system (HFITS) database. Designers then have options such as reallocation of functions, changes to operator roles and responsibilities, changes to the number of operators, and changes to the HSI design to address the issue.

Task support requirements are defined during the early TA. However, if not known, a later TA iteration captures additional considerations, such as the following:

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D.5.4 Operational sequence diagrams

An operational sequence diagram (OSD) is created and used to aid in evaluating the flow of information from the point where the operator first becomes involved with the system to the completion of the task. The functional allocation and task description provide the objective and operating parameters for operator tasks. OSD can aid in determination of time available and workload assessment. Similar depictions can be either hand drawn or developed using software tools. In an OSD, the sequence of actions should only use alarms, controls, and displays that would be available and operable during the assumed scenario(s). The analysis of the action sequence is conducted at a level of detail sufficient to identify individual task components, including cognitive elements such as diagnosis and selection of an appropriate response.

D.5.5 Determination of time available, time required, and time margins

Time available to perform actions is based on analysis of plant response to anticipated operational occurrences, accidents, and infrequent and special events, in accordance with NUREG-0711.

$T_{available}$ = Length of time from initiation of event to when an action must be completed

The basis for the time available should be documented. This information can come from the deterministic analyses or probabilistic analyses and should be based on analysis of the plant response to the anticipated operational occurrence or event/accident. NUREG/CR-3331, Appendix B, "Checklist for Human Limitations/Tasks Man Cannot Perform." Data is provided within the guidance that aids in establishing assumptions relative to determining time estimates for specific task elements, such as the following:

- Reaction time comparisons of sensory inputs (response time for alarms)
- Reaction time given number of choices (as the number of choices increases, so does response time)
- Reaction time for manual entry tasks
- Decreased probability of detection

$T_{required}$ = Length of time it takes to complete a task

Based on a documented sequence of operator actions (based on task analysis, vendor-provided generic technical guidelines for emergency operating procedure development, or plant-specific emergency operating procedures, depending on the maturity of the design). Techniques to minimize bias are used when estimates of time required are derived using methods that are dependent on expert judgment. Uncertainties in the analysis of time required are identified and assessed.

The estimated time for operators to complete the credited action is sufficient to allow successful execution of applicable steps. Acceptable methods for deriving analysis time estimates for individual task components include, but are not limited to, the following:

- Operator interviews and surveys
- Operating experience reviews
- Software models of human behavior, such as task network modeling
- Use of control and display mockups
- Expert panel elicitation

T_{margin} = Margin determined by designers. This margin is applied to address uncertainties in the time assessment.

If $T_{required} + T_{margin} \geq T_{available}$, then the task and elements of the task are redesigned.

If $T_{required} + T_{margin} < T_{available}$, the task design is accepted. Impacts to accepted task design due to design changes or modification are evaluated through existing engineering/design change processes.

D.6 Human-system interface inventory

The HSI inventory is developed as a product of the task analysis process. As operator tasks are defined and analyzed, each task is reviewed to identify the specific interface elements required to support task performance. These elements include displays, controls, alarms, and system status indicators. The information is compiled into an HSI inventory that establishes a traceable link between operator tasks and the interface features they rely upon. The inventory is organized by task and operating mode and includes references to the function or system involved. The HSI inventory is used throughout the HFE program to support interface design, ensure consistency across systems, and serve as a baseline for subsequent verification and validation activities. It also supports interface requirement development, layout planning, and design traceability.

D.7 Knowledge, skills, and abilities

As part of the task analysis process, the knowledge, skills, and abilities (KSA) required for successful task performance are identified. Cognitive demands such as situational awareness and decision making, as well as procedural knowledge, system familiarity, and physical interaction capabilities, are included. KSA data is gathered through subject matter expert input, task observation, and review of operating experience. These attributes are documented for each task and used to inform the development of a design-specific K/A catalog. The catalog serves as a structured reference that supports the development of staffing and qualification requirements, training programs, and licensing materials. It ensures that personnel assigned to operational roles have the necessary competencies to perform their responsibilities under the expected range of plant conditions.

D.8 Tools

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D.9 Results summary report

Upon completion of the task analysis, a Results Summary Report (RSR) is developed to document the outcomes of the analysis and demonstrate compliance with the methodology described in this IP. The RSR provides a comprehensive summary of the task analysis activities and is prepared in accordance with the review criteria in Section 5.4 of NUREG-0711. The RSR serves as the formal record of the task analysis results and provides traceability to the methods, data sources, and evaluations conducted under the HFE program.

The RSR includes the following elements:

- A list of the human actions addressed by task analysis, including IHA identified through deterministic or probabilistic analyses, as well as human actions derived from FRA and FA
- A summary of the task analysis methodology, consistent with the approach described in this IP
- A description of personnel tasks, including narratives of the activities to be performed, applicable task attributes such as initiating conditions, required information, decision-making requirements, timing considerations, and expected outcomes
- Descriptions of task relationships and dependencies, including how tasks interact within sequences and across roles
- Time estimates for task performance and available time margins, based on operational sequence analysis or scenario assumptions
- Estimated workload associated with each task, with consideration given to cognitive, physical, and coordination demands
- A list of alarms, information, controls, and task support elements identified as necessary to enable successful task performance
- Identification of the number of personnel required to complete each task, based on the demands of the task and the allocation of responsibilities
- Designation of the KSAs required to perform each task to support the development of the design-specific K/A catalog

Where appropriate, summaries are used for specific items, with references provided to supporting documentation for detailed task analysis records, modeling results, or source inputs. If the methodology described in this IP has been previously reviewed and accepted by the U.S. Nuclear Regulatory Commission, the RSR is developed consistent with that methodology and clearly references the applicable sections of the plan.

The RSR supports verification and validation activities, training development, procedure design, staffing evaluations, and regulatory submittals related to operator roles and human-system performance.

Appendix E Site-Specific Staffing Plan [example]

[Note: This example is a draft for illustrative purposes only and is intended to demonstrate the anticipated structure and content of a site-specific staffing plan. It supports the U.S. Nuclear Regulatory Commission's (NRC's) review of Oklo's "Staffing Plan Validation Methodology" topical report and illustrates how fleet-based roles and resources may be coordinated with unit-specific staffing plans. Final content, scope, and implementation details are developed and submitted as part of license applications and may differ from the example shown here.]

E.1 Purpose

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E.2 Responsibilities

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E.3 Onsite staffing requirements during operations

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Table E-1: { *}*

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E.4 { }{viii}

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E.5 Personnel qualifications

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E.6 Staffing plan validation and approval

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E.7 References

- Aurora powerhouse combined license application, Part IV, “Technical Specifications”
- Oklo’s “Product-Based Operator Licensing Framework” topical report
- Oklo’s “Staffing Plan Validation Methodology” topical report

Appendix F Fleet-Support Staffing Plan [example]

[Note: This example is provided for illustrative purposes only and is intended to demonstrate the anticipated structure and content of a fleet-support staffing plan. It supports the U.S. Regulatory Commission's (NRC's) review of Oklo's staffing methodology topical report and illustrates how fleet-based roles and resources may be coordinated with unit-specific staffing plans. Final content, scope, and implementation details are developed and submitted as part of license applications and may differ from the example shown here.]

F.1 Purpose

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F.2 Responsibilities

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F.3 Powerhouse support staffing requirements during fleet operations

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Table F-1: { }{viii}

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F.4 { }{viii}

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F.6 Personnel qualifications

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F.7 Staffing plan validation and approval

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F.8 References

- Aurora powerhouse combined license application, Part IV, “Technical Specifications”
- Oklo’s “Product-Based Operator Licensing Framework” topical report
- Oklo’s “Staffing Plan Validation Methodology” topical report