



## U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

### 18.0 HUMAN FACTORS ENGINEERING

#### REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of human performance

Secondary - None

#### I. AREAS OF REVIEW

This document provides the regulatory guidance used by the U.S. Nuclear Regulatory Commission (NRC) staff while reviewing human factors engineering (HFE) considerations of operating license applications, design certifications (DCs), plant modifications, and important human actions. The purpose of these reviews is to assure safety by verifying that acceptable HFE practices and guidelines are incorporated into the plant's design as follows:

##### 1. Operating License Applications

The organization responsible for the review of human performance reviews the applicant's HFE control room design described in the operating license application. The submittal should

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#### USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC regulations. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The SRP sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to [NRO\\_SRP@nrc.gov](mailto:NRO_SRP@nrc.gov).

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address all 12 elements described in NUREG-0711, “Human Factors Engineering Program Review Model.” Areas that interface with operating programs (e.g., procedures, training) should be coordinated with the organization responsible for reviewing operating programs to determine the level of effort needed in reviewing Chapter 18 of the applicant’s safety analysis report (SAR). The purpose of these reviews is to assure safety by verifying that acceptable HFE practices and guidelines are incorporated into the control room design.

## 2. Combined License Applications

The organization responsible for the review of human performance reviews the HFE of the applicant’s control room design as described in the final safety analysis report (FSAR). In most cases a combined license (COL) application will “Incorporate by Reference” an approved DC. The staff verifies the COL applicant has addressed each COL action item from the DC and any additions and departures or exemptions from the DC. The additional material is evaluated against the applicable sections of NUREG-0711. The purpose of these reviews is to assure safety by verifying that the COL applicant’s FSAR provides any additional documentation specified by the DC.

## 3. Design Certification Application

The organization responsible for the review of human performance reviews the HFE of the applicant’s control room design described in the DC application. The submittal should address all 12 elements described in NUREG-0711. This may result in deferring site- or plant-specific elements to future COL applicants via COL action items. Elements that interface with operating programs (e.g., procedures, training) should be coordinated with the organization responsible for reviewing operating programs to determine the level of effort needed in reviewing Chapter 18 of the applicant’s SAR. Typically the evaluation of operating programs will be done within Standard Review Plan (SRP), Chapter 13, “Conduct of Operations,” as discussed in Section II, “Interfaces.” The purpose of these reviews is to assure safety by verifying that acceptable HFE practices and guidelines are appropriately applied to the plant’s design.

## 4. Plant and Control Room Modifications

The NRC reviews the HFE of certain plant and control room modifications involving changes to the FSAR as part of the change process described in 10 CFR 50.59, “Changes, Tests, and Experiments.” Such modifications may affect the control room environment (e.g., noise, temperature, lighting), interfaces to safety-related SSCs, or important human actions (as described further in Section 5). Guidance related to 10 CFR 50.59 is provided in Regulatory Guide (RG) 1.187, “Guidance for Implementation of 10 CFR 50.59, Changes, Tests, and Experiments,” Nuclear Energy Institute (NEI) publication 96-07, “Guidelines for 10 CFR 50.59 Implementation” and Regulatory Issue Summary (RIS) 2002-22, “Use of Electric Power Research Institute (EPRI)/NEI Joint Task Force Report, “Guideline on Licensing Digital Upgrades: EPRI TR-102348, Revision 1, NEI 01-01: A Revision of EPRI TR-102348 To Reflect Changes to the 10 CFR 50.59 Rule,” and EPRI/NEI publication EPRI TR-102348 Revision 1 - NEI 01-01, Guideline on Licensing Digital Upgrades: A Revision of EPRI TR-102348 to Reflect Changes to the 10 CFR 50.59 Rule.”

## 5. Important Human Actions

This SRP chapter can also be used to review changes or modifications to licenses for nuclear power plants that include or result in changes to human actions. While the HSI modification may be a large-scale modernization, even smaller-scale modifications may have important implications for plant risk, especially when they affect operator actions that are credited in the SAR. An HFE review is conducted if such a modification affects the role of personnel or the tasks they perform, the sequence of actions, the timing, or the overall workload, and is potentially significant to plant safety. Modifications affect the role or tasks of personnel if they impose new or different demands on them to operate or maintain the plant, or otherwise ensure safety. An example of such a modification would be substituting manual actions for automatic actions for performing design functions described in the SAR. (See Information Notice (IN) 97-78, "Crediting of Operator Action In Place of Automatic Actions and Modification of Operator Actions, Including Response Times." for further guidance).

Previous revisions of HFE guidance documents have focused on the review of risk-important human actions. Experience is showing that there are additional human actions that need to receive similar reviews because they are specifically credited in design analyses. Consequently the guidance has been generalized to address important human actions as identified in:

- Operator actions credited in the diversity and defense in depth analysis supporting the diverse actuation system described in SRP, Chapter 7, "Instrumentation and Controls."
- Operator actions credited in the design bases analyses described in SRP, Chapter 15, "Transient and Accident Analysis."
- Risk-important human actions identified in the human reliability analysis contained in SRP, Chapter 19, "Severe Accidents."

The review guidance may also be useful in reviewing operator manual actions associated with fires especially alternate safe shutdown, flooding, beyond design basis events, and decommissioning activities. See Attachment A, NUREG-1764, "Guidance for the Review of Changes to Human Actions," and NUREG-1852, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire" for specific review guidance.

## 6. Local Control Stations

Local control stations are not specifically addressed in the Commission's regulations. However, staff often has to review changes to important human actions (risk-important human actions and certain deterministic human actions identified by the accident analyses) that are conducted using local control stations. In these cases, the staff uses a graded approach (see Section IV, "Review Procedures") to evaluate those important human actions that are conducted from local control stations.

Applicants have found it useful to apply guidance in NUREG-0711 to the central and secondary alarm stations associated with security measures. The staff has historically not reviewed central and secondary alarm station HFE designs as there are currently no regulatory requirements that provide a basis for doing so.

The emergency operating facility (EOF) and technical support center (TSC) are also included within the scope of HFE reviews. Again, a graded approach is used. NUREG-0711 provides specific direction on which review criteria are applied to these facilities. NUREG-0696, "Functional Criteria for Emergency Response Facilities," also includes general HFE criteria for these facilities and the staff has accepted a commitment to implement these criteria as an alternative to the NUREG-0711 criteria.

## 7. Decommissioning Activities

The HFE reviews of the control room design can occur in all phases of control room activities from initial design through operation and subsequent decommissioning. In decommissioning a graded approach is again used as functional requirements decrease. The review focus is on maintaining a highly functional configuration for the controls, alarms and displays associated with the safety functions. In some cases, the controls, displays and alarms may be moved to local control panels or existing local control panels may become more important. In these cases the important human actions associated with these local control stations, and the physical design of the stations can be evaluated using the guidance in NUREG-0711 and NUREG-0700, "Human-System Interface Design Review Guidelines."

The reviews may also include an evaluation of the proposed certified fuel handler training program, and proposed administrative controls and technical specifications. Both reviews should be complete before the licensee submits its request to move into decommissioning status.

## II. REVIEW INTERFACES

Other SRP Chapters interface with this Chapter as follows:

1. Chapter 18 addresses important manual actions under the "Treatment of Important Human Actions" element of NUREG-0711. These reviews should be coordinated with the following chapters:
  - Chapter 6, "Engineered Safety Features," Section 6.3, "Emergency Core Cooling System (ECCS)," discusses the review of operator manual actions that may be necessary during ECCS operation in accident sequences up through the time of long-term core cooling.
  - Chapter 7, "Instrumentation and Controls," Section 7.8, "Diverse Instrumentation and Control Systems" addresses manual actions credited in the diverse actuation system.
  - Chapter 15, "Transient and Accident Analysis," addresses anticipated operational occurrences and postulated accidents. These analyses provide the basis for

safety system operation and operator actions which are inputs to the HFE design process of Chapter 18. Reviewers should verify all manual actions identified in Chapter 15 are addressed in Chapter 18.

- Chapter 19, “Probabilistic Risk Assessment and Severe Accident Evaluation,” addresses probabilistic risk assessments for site-specific safety risks. It identifies the risk-important human actions that are an input to the HFE design, procedures, staffing, and training. Typically the Chapter 18 material will reference the appropriate Chapter 19 table identifying risk important human actions. Reviewers should verify all risk-important manual actions identified in Chapter 19 are addressed in Chapter 18.

Manual actions may be identified in other chapters but the organizations responsible for those chapters will contact the organization responsible for Chapter 18 if additional help is needed.

2. 10 CFR 50.34(f)(2)(iv) requires a plant safety parameter display system (SPDS) console that displays to operators a minimum set of parameters defining the safety status of the plant, capable of displaying a full range of important plant parameters and data trends on demand, and capable of indicating when process limits are being approached or exceeded. Chapter 18 identifies controls, displays, and alarms needed by the operator to address abnormal operating occurrences and postulated accidents. The staff's review needs to ensure coordination in the following areas:
  - Chapter 7 addresses the adequacy of controls and instrumentation with regard to the features of automatic actuation, remote sensing and indication, and remote control. RG 1.97, “Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants,” parameters are identified within this chapter.
  - Chapter 13, Section 13.3, “Emergency Planning,” addresses emergency planning including the TSC and EOF and the implementation of SPDS in these facilities.
  - Chapter 15 addresses design basis analyses which include the parameter responses that must be monitored and controlled to maintain reactor safety.
3. Chapter 7, “Instrumentation and Controls,” describes components and characteristics included in the Chapter 18 review. As appropriate, the review results of one chapter should be considered in the review activities for the other chapter.
4. Chapter 13, Section 13.1.1, “Management and Technical Support Organization,” addresses the need for clearly defined management and organizational responsibilities. Chapter 18, under Acceptance Criteria, requires a comprehensive summary of management's role in ensuring that HFE is adequately considered in new plant design and in the modification of an existing plant. The reviews of Section 13.1.1 and Chapter 18 should be verified to be consistent.
5. Chapter 13, Sections 13.1.2-13.1.3, “Operating Organization,” addresses staffing requirements. Chapter 18 specifies a systematic analysis of operational staffing requirements that includes a thorough understanding of task requirements and

applicable regulatory requirements. Reviewers should verify that the Chapter 18 review conclusions and the Chapter 13 review conclusions are consistent.

6. Chapter 13, Sections 13.2.1, “Reactor Operator and Requalification Program; Reactor Operator Training” and SRP Section 13.2.2, “Non-licensed Plant Staff Training” address training programs. Training programs are considered operational programs as identified in SRP Section 13.4, “Operational Programs.” For a new nuclear power plant (NPP) the training program will usually be reviewed during the COL FSAR review rather than the DC. SRP Sections 13.2.1 and 13.2.2 provide specific criteria for reviewing training programs for reactor operators and non-licensed plant staff and the evaluation of the applicant’s training program is conducted in accordance with the guidance in this Chapter. While NUREG-0711 addresses training as it interfaces with the HFE design process DC applicants do not need to address this element as part of Chapter 18 since the same information is provided in Chapter 13. If information is provided, the staff will coordinate the Chapter 13 and 18 reviews. Other submittals, such as safety-related modifications meeting review requirements, should address this element if appropriate.
7. SRP Section 13.3, “Emergency Planning,” addresses emergency planning including the TSC and EOF. Chapter 18 addresses the HFE design associated with these facilities. Typically the HFE design responsibility is split between the DC applicants (identifies the displays and alarms) and the COL applicant (identifies facility layout, radiation level data, and communications). NUREG-0696 has been accepted as one method for addressing the COL applicant’s HFE design responsibilities. The Chapter 18 review results should be coordinated with the Chapter 13 reviewers to ensure review results are consistent.
8. SRP Section 13.5.1.1, “Administrative Procedures – General,” SRP Section 13.5.1.2, “Administrative Procedures - Initial Test Program,” SRP Section 13.5.2.1, “Operating and Emergency Operating Procedures,” and SRP Section 13.5.2.2, “Maintenance and Other Operating Procedures,” provide specific criteria for the content of administrative, operating and maintenance procedures. While NUREG-0711 addresses procedures as they interface with the HFE design process, DC applicants do not need to address this element as part of Chapter 18 since the same information is provided in Chapter 13. Other submittals, such as safety related modifications meeting review requirements, should address this element when applicable.
9. SRP Section 14.3.9, “Human Factors Engineering - Inspections, Tests, Analyses, and Acceptance Criteria,” verifies the Tier 1 description of the HFE program is complete and consistent with Tier 2 material. It also verifies that appropriate Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) have been identified. Reviewers need to ensure the Chapter 18 and SRP Section 14.3.9 review results are consistent.

### III. ACCEPTANCE CRITERIA

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations.<sup>1</sup>

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<sup>1</sup>For 10 CFR Part 50 applicants not listed in 10 CFR 50.34 (f), the provisions of 10 CFR 50.34(f) should be made a requirement during the licensing process.

## Requirements

1. 10 CFR 50.34(f)(2)(iii) – Provide, for Commission review, a control room design that reflects state-of-the-art human factor principles prior to committing to the fabrication or revision of fabricated control room panels and layouts. This is the most encompassing HFE related regulation. Acceptance criteria for HFE design methodology are provided in NUREG-0711. NUREG-0711 references NUREG-0700, “Human-System Interface Design Review Guidelines,” which provides detailed acceptance criteria for HFE design attributes.
2. The following regulations address general requirements related to the main control room that influence the HFE design:
  - 10 CFR 50.34(f)(2)(ii) – continuing improvement of HFE and procedures
  - 10 CFR 50.34(f)(2)(iv) – safety parameter display system
  - 10 CFR 50.34(f)(3)(i) – use of operating experience
  - 10 CFR 50.54 (i) to (m) - staffing
  - 10 CFR 52.47 – level of detail required in DCs
  - 10 CFR 52.47(a)(8) – inclusion of 10 CFR 50.34(f) for Part 52 applications
  - 10 CFR 52.79 – content of COL applications
3. The following regulations address specific requirements related to the main control room that influence the HFE design:
  - 10 CFR 50.34(f)(2)(v) – automatic indication of the bypassed and operable status of safety systems
  - 10 CFR 50.34(f)(2)(xi) – relief and safety valve indication
  - 10 CFR 50.34(f)(2)(xii) – auxiliary feedwater system flow indication
  - 10 CFR 50.34(f)(2)(xvii) – containment related indications
  - 10 CFR 50.34(f)(2)(xviii) – core cooling indications
  - 10 CFR 50.34(f)(2)(xix) – instrumentation for monitoring post-accident conditions that includes core damage
  - 10 CFR 50.34(f)(2)(xxi) – auxiliary heat removal (Boiling Water Reactor only)
  - 10 CFR 50.34(f)(2)(xxiv) – reactor vessel level monitoring (Boiling Water Reactor only)
  - 10 CFR 50.34(f)(2)(xxvi) – leakage control
  - 10 CFR 50.34(f)(2)(xxvii) – radiation monitoring

The regulatory guidance provided in NUREG-0711 addresses all the human factors elements of these requirements.

### SRP Acceptance Criteria

The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria

and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

Acceptance criteria are specific to the type of application being reviewed. Table 1 below lists the NUREGs that contain the acceptance criteria used to verify the requirements listed above have been met. The table also summarizes when the NUREGs are used. Each NUREG provides more specific direction on when and how its contents are used.

**Table 1: Acceptance Criteria Sources**

New control room design, no design acceptance criteria (DAC)	NUREG-0700 NUREG-0711
New control room design, DAC	NUREG-0711 NUREG-0700
Combined license application that does not reference a DC	NUREG-0700 NUREG-0711
Major control room modernization	NUREG-0700 NUREG-0711
Control room modification	NUREG-0700 NUREG-0711
Evaluation of important human actions	NUREG-1764 NUREG-1852 SRP Chapter 18, Attachment A
Workload evaluation	SRP Chapter 18, Attachment B
Changes resulting from plant modifications, procedure changes, equipment failures, justifications for continued operations, and identified discrepancies in equipment performance or safety analyses	NUREG-0711 NUREG-1764
Decommissioning activities	NUREG-1764 NUREG-1220 SRP Chapter 18, Attachment A Draft NUREG-1625, "Proposed Standard Technical Specifications for Permanently Defueled Westinghouse Plants"

1. NUREG-0711 describes acceptance criteria for an HFE design process that the staff has found acceptable. The NUREG identifies 12 elements needed for successful integration of human characteristics and capabilities into nuclear power plant design.
2. NUREG-0700 describes acceptance criteria for the physical and functional characteristics of HSIs. The HFE guidelines are organized into four basic parts. Part I contains guidelines for the basic HSI elements: displays, user-interface interaction and management, and controls. These elements are used as building blocks to develop HSI systems to serve specific functions. Part II contains the guidelines for reviewing six such systems: alarm system, group-view display system, soft control system, computer-based procedure system, computerized operator support system, and communication systems. Part III provides guidelines for the review of workstations and work places. Part IV provides guidelines for the review of HSI support, i.e., maintainability of digital systems.

In addition to the review of actual HSIs, the staff can use the guidelines to evaluate a design-specific HFE guideline document (e.g., style guide), control room modifications, local control station layouts, and control room reconfiguration modifications that might occur during decommissioning.

3. Chapter 18, Attachment A, "Guidance for Evaluating Credited Manual Operator Actions," provides acceptance criteria for evaluating important human actions.
4. Chapter 18, Attachment B, "Methodology to Assess the Workload of Challenging Operational Conditions In Support of Minimum Staffing Level Reviews," a methodology to identify high-workload operational conditions and analyze the workload associated with them. The methodology is rooted in task analysis and relies on the identification of appropriate challenging scenarios, realistic portrayals of task performance that is complicated by separate, but often necessary, dependent and independent tasks, and the judgment of SMEs obtained in a manner conducive to obtaining realistic workload estimation.
5. NUREG-1764 is particularly useful when evaluating changes to manual actions resulting from plant modifications, procedure changes, equipment failures, justifications for continued operations, and identified discrepancies in equipment performance or safety analyses. This guidance uses a graded, risk-informed approach that is consistent with RG 1.174, "An Approach to Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis." As such, this guidance uses risk insights to determine the level of regulatory review the staff should perform. This approach can be accomplished for licensee submittals that are either risk-informed or non-risk-informed. Human actions that are considered more risk-significant receive a detailed review, while those deemed less significant receive a less detailed review. When a human action is significant the analysis method described in Attachment A is a useful complement to the guidance in this NUREG.

NUREG-1852 provides criteria and associated technical bases for evaluating the feasibility and reliability of post-fire operator manual actions implemented in nuclear power plants. It is a reference guide for evaluating the acceptability of manual actions,

submitted by licensees as exemption requests from the requirements of Paragraph III.G.2 of Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50), as a means of achieving and maintaining hot shutdown conditions during and after fire events. The staff may use this information in the review of future post-fire operator manual actions to determine if the feasibility and reliability of the operator manual action were adequately evaluated.

#### IV. REVIEW PROCEDURES

In general, reviews should follow these steps:

1. Completion of the pre-acceptance and acceptance reviews in accordance with the applicable Office Instructions:
  - NRR- LIC-109, "Acceptance Review Procedures."
  - NRO-REG-104, "Pre-application Readiness Assessment"
  - NRO-REG-100, "Acceptance Review Process for Design Certification and Combined License Applications."
2. Verification that the licensee/applicant is using an acceptable HFE analysis and design processes. Acceptable standards include NUREG-0711, for new designs and modifications, and NUREGs 1764 and 1852, as applicable, for human actions.
3. Verification that the design conforms to HFE standards as described in NUREG-0700.
4. Verification that exemptions from regulations or alternate methods for complying with regulations have specific analyses supporting them (see NRR-LIC-103).
5. Verification that HFE design effectiveness has been demonstrated in a performance based integrated system validation test as described in NUREG-0711.

This sequence can be applied across the spectrum of HFE review areas by applying the graded approach concepts provided in the next section.

#### Graded Approach to Review

The degree to which the NRC staff applies the review methodology in this SRP will reflect the specific circumstances of individual applications. For example, the review of the HFE aspects of a new plant will entail a comprehensive, detailed evaluation, while the review of individual modifications to existing designs may be less extensive. The following elements are considered when deciding the depth of review.

- risk importance

- the similarity of the associated HFE issues to those recently reviewed for other plants or similarity with previous approved designs
- the determination of whether items of special or unique safety significance are involved (such as items deemed important to safety based on a qualitative or deterministic basis)

## Generic Review Procedure

### **1. Completion of the pre-acceptance and acceptance reviews**

Consider using audits to review the style guide, scenarios, supporting procedures, and operating simulators. The audit can often provide the additional detail needed to understand documents that have been submitted and facilitates the communication between applicant/licensee and the staff on what information needs to be docketed.

Design Certification and Combined License Applications: Office instruction NRO-REG-104, "Pre-application Readiness Assessment" provides direction on the pre-acceptance review process. Office Instruction NRO-REG-100, "Acceptance Review Process for Design Certification and Combined License Applications," provides direction on the acceptance review process. For design certification applications, "results summary reports" are preferred except for elements NUREG-0711 specified as only needing an Implementation Plan (i.e., HFE program plan, Human Performance Monitoring). If the applicant chooses to defer the final HFE design in accordance with SECY 92-053, "Use of Design Acceptance Criteria during 10 CFR Part 52, Design Certification Reviews," the reviewer should verify a basis for using DAC has been provided and that it conforms to the SECY guidance. Additional direction on using DAC is provided in section 2 below.

Operating License Submittals: Office Instruction NRR-LIC-109 addresses the Acceptance Process for operating licensee submittals. For operating licensee submittals it is preferred that the content be results-oriented, with few, if any open items. If open items are necessary, they should be addressed in a formal commitment or a license condition (NRR-LIC-105). All twelve elements of NUREG-0711 should be addressed, or omissions justified.

### **2. Verification that the licensee/applicant is using acceptable HFE analysis and design processes.**

- a. Acceptable approaches are described in NUREG-0711, with application specific guidance provided in NUREG-1764 and NUREG-1852. NUREG/CR-7190, "Workload, Situation Awareness, and Teamwork," also provides a review of human performance metrics used to measure workload, situational awareness, and teamwork. It provides a tool for evaluating the use of such metrics in applications (e.g., design certification) and proposed license amendments.
- b. Each NUREG-0711 element lists the content of the associated "Results Summary Report." This list includes the methodologies of interest. Reviews should verify

the methodology described is valid for the application in which it is used. The maturity of the design should dictate the reviewer's emphasis on methodology versus final design. Mature, complete designs typically call for a general review of the methodology and a detailed review of the design (using NUREG-0700). The evaluator may adjust the priority given to the method and the final HFE design reviews based on application specifics.

- c. Design Certifications: Under a limited number of special conditions, the NRC accepts a detailed description of an HFE design process in lieu of a final design product. These conditions are identified in SECY-92-053, and are listed below:
- rapidly changing technology could cause the approved design to be obsolete prior to construction,
  - as-built information (e.g., specific measurements) needed to complete the design is unavailable,
  - as-procured information needed to complete the design is unavailable.

If an applicant proposes using this option, the staff will verify that at least one of these three conditions exists by reviewing the basis for the applicant's proposal and that the proposal is limited to the only those elements to which the condition applies.

When DAC is applied, the HFE design process for the applicable element is submitted as an implementation plan. The reviewer evaluates this implementation plan against the acceptance criteria for the associated NUREG-0711 element. Reviewers should note that this review not only verifies method validity but also ensures the process is sufficiently detailed and measurable that there is reasonable assurance that the process will result in a safe design product. The implementation plan also establishes specific acceptance criteria for an ITAAC if it is decided that an ITAAC is needed.

- d. In addition to safety-related HSIs, the HFE reviews should include non-safety-related HSIs for the following reasons:
- On integrated digital control systems, operators use the non-safety-related control system if it is available for responding to plant events.
  - Inconsistent HFE design between the non-safety systems and the safety systems could potentially increase error rates. The operator would have to use a different, infrequently used configuration on the safety-related components.
  - Alarm systems and large screen displays are non-safety-related systems providing significant input into command and control activities, event diagnostics, and operator situational awareness.

- Non-safety systems and functions can divert the operator's attention.

### **3. Verification that the design conforms to HFE standards**

- a. An acceptable approach is described in NUREG-0700. If the applicant/licensee has incorporated the HFE design into a simulator or mockup, consideration should be given to conducting observations of the simulator/mockup. Such observations provide for an efficient way to evaluate the design against the NUREG-0700 standards.
- b. Verify the interfaces described in Section I have been properly coordinated. The following practices have proven effective for DC reviews:
  - Contact the lead I&C reviewer and provide the HFE point of contact(s) for supporting the RG 1.97, evaluation and the evaluation of manual actions credited in the diverse actuation system (DAS) design. The RG 1.97 parameters may also be significant inputs into the SPDS and large display panel designs. The DAS manual actions are contained in the Chapter 7 application. The HFE evaluator usually provides a safety evaluation input on these manual actions which is embedded in the Chapter 7 safety evaluation.
  - Verify that the "important human actions" provided by the applicant are consistent with those identified in Chapter 15. This can be done by reviewing the Chapter 15 application. If there are deviations subsequent actions should be coordinated through the Chapter 15 lead reviewer.
  - If the Chapter 18 submittal provides a separate list of risk important human actions this list should be verified against the list in Chapter 19. Often the Chapter 18 submittal will reference the Chapter 19 list directly in which case no additional interface is necessary.
  - The Chapter 18 safety evaluation related to the HFE design of the EOF and TSC should be sent to the lead reviewer for Chapter 13.3 for concurrence.

### **4. Verification that exemptions from regulations or alternative methods for complying with regulations have specific analyses that support them.**

- a. Verify that applicants/licensees clearly identify methods and practices that are different from what the acceptance criteria advocate as alternate methods/practices. Evaluate the alternative on its own merits. The applicant is expected to provide an evaluation of how the proposed alternative provides an acceptable method of compliance. The justifications may be based upon evidence such as analyses of recent literature, analyses of current practices and operational experience, tradeoff studies, and the results of engineering experiments and evaluations.

- b. Minimum staffing appears for small modular reactors to be the most imminent area where an exemption from 10 CFR 50.54(m) might be requested. The following NUREGs provide guidance in this area:
  - NUREG-1791, “Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)”
  - 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)”

Attachment B provides additional guidance on evaluating workload in support of staffing level reviews.

**5. Verification that HFE design effectiveness has been demonstrated in a performance-based integrated system validation test.**

- a. Verification that a design meets applicable HFE design criteria provides assurance that the individual design elements (e.g., individual controls, indications, alarms) support performance of discrete tasks (e.g., reading a gauge) but such verifications provide only limited assurance that collectively the elements of an HSI will constitute an effective integrated system in which these elements can be used in concert to support complex operator performance (e.g., mitigate a steam generator tube rupture). Therefore an integrated system validation (ISV) is used to validate the design effectiveness. Where feasible, the ISV should be subject to an inspection or audit to verify the HFE design supports the operator actions being credited in the licensing documentation.
- b. Because the ISV depends on operator programs (i.e., procedures, training), the ISV may sometimes be submitted at the implementation plan level with performance of the ISV tracked as an ITAAC consistent with the position described in SECY 92-053. In this case, the implementation plan must contain specific acceptance criteria describing how the ISV will be performed. The acceptance criteria should be identified as Tier 2\* information.
- c. In the case of operating reactors, the ISV must be complete prior to implementation of the proposed action or program. In the rare cases when this cannot be done, such as when the simulator configuration change is not yet complete, acceptance or approval may be based on a smaller scale “preliminary” ISV and a license condition that states that the full-scale ISV will be completed and provided to the NRC staff by a specific date.

**V. EVALUATION OF FINDINGS**

The reviewer verifies that the applicant has provided sufficient information and calculations (if applicable) to support their conclusions. The reviewer also states the bases for their

conclusions. Conclusions of the following type should be included in the staff's safety evaluation report (SER).

1. The reviewer's determination that all review criteria are satisfied, using the methods described in the SRP.
2. If applicable, the reviewer's determination that alternative means of satisfying review criteria are acceptable.
3. If applicable, the reviewer's determination that acceptable justification for deviations from review criteria exist.
4. Documentation of findings:

The evaluation for each acceptance criterion typically has three parts. The first part summarizes the information provided in the submittal and where that information is located. The second part explains how this information conforms to the acceptance criteria. The third part provides a summary conclusion that the acceptance criterion is met. The reviewer should adhere to the following guidelines when documenting evaluation or findings:

- Use the word "requirement" only when referring to the *Code of Federal Regulations*. Use specification, acceptance criterion, guidance, direction, limit, or other appropriate word when referring to other sources of direction.
- Within the SER, ensure the staff evaluation is clearly distinguishable from the submittal information summary.
- Write requests for additional information (RAIs) in parallel with writing the draft SER. This ensures a tight connection with the regulatory basis and minimizes sequential RAIs.
- When determining the review material that should be submitted on the docket versus retained by the licensee for audit or review by NRC reviewers and inspectors, the key aspect is that the amount of information submitted on the docket must be sufficient to support the staff's safety determination. That is, the submittal (e.g., design certification, final safety analysis report, proposed technical specification revision, license amendment) includes information at a level sufficient to enable the Commission to reach a final conclusion on all safety matters.
- Ensure that the rationale for the staff conclusion is explained clearly.

## VI. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." Except when the applicant

proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

## VII. REFERENCES

1. Electric Power Research Institute, EPRI TR-102348 Revision 1 - NEI 01-01, Guideline on Licensing Digital Upgrades: A Revision of EPRI TR-102348 to Reflect Changes to the 10 CFR 50.59 Rule."
2. Nuclear Energy Institute, NEI 96-07, "Guidelines for 10 CFR 50.59, Implementation."
3. U.S. *Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."
4. U.S. *Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."
5. U.S. Nuclear Regulatory Commission, "Crediting of Operator Action In Place of Automatic Actions and Modification of Operator Actions, Including Response Times," Information Notice 97-78.
6. U.S. Nuclear Regulatory Commission, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," NUREG-1852.
7. U.S. Nuclear Regulatory Commission, "Functional Criteria for Emergency Response Facilities," NUREG-0696.
8. U.S. Nuclear Regulatory Commission, "Guidance for the Review of Changes to Human Actions," NUREG-1764, Revision 1.
9. U.S. Nuclear Regulatory Commission, "Guidelines for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operating Staff Requirements Specified in 10 CFR 50.54(m) - Final Report," NUREG-1791.
10. U.S. Nuclear Regulatory Commission, "Human-System Interface Design Review Guidelines," NUREG-0700, Revision 2.
11. U.S. Nuclear Regulatory Commission, "Human Factors Engineering Program Review Model," NUREG-0711, Revision 3.
12. U.S. Nuclear Regulatory Commission, "Proposed Standard Technical Specifications for Permanently Defueled Westinghouse Plants," NUREG-1625 (Draft).
13. U.S. Nuclear Regulatory Commission, "Training Review Criteria and Procedures," NUREG-1220, Revision 1.

14. U.S. Nuclear Regulatory Commission, "Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," NUREG/CR-6838.
15. U.S. Nuclear Regulatory Commission, "Workload, Situation Awareness, and Teamwork," NUREG/CR-7190.
16. U.S. Nuclear Regulatory Commission, "Acceptance Review Procedures," NRR- LIC-109, Revision 1.
17. U.S. Nuclear Regulatory Commission, "Acceptance Review Process for Design Certification and Combined License Applications," NRO-REG-100, Revision 2.
18. U.S. Nuclear Regulatory Commission, "Exemption from NRC Regulations," NRR- LIC-103, Revision 1.
19. U.S. Nuclear Regulatory Commission, "Managing Regulatory Commitments Made by Licensees to the NRC," NRR-LIC-105, Revision 7.
20. U.S. Nuclear Regulatory Commission, "Pre-application Readiness Assessment," NRO-REG-104, Revision 0.
21. U.S. Nuclear Regulatory Commission, "An Approach to Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Regulatory Guide 1.174.
22. U.S. Nuclear Regulatory Commission, "Combined License Application for Nuclear Power Plants" (LWR Edition), Regulatory Guide 1.206.
23. U.S. Nuclear Regulatory Commission, "Guidance for Implementation of 10 CFR 50.59, Changes, Tests, and Experiments," Regulatory Guide 1.187.
24. U.S. Nuclear Regulatory Commission, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environmental Conditions During and Following an Accident," Regulatory Guide 1.97.
25. U.S. Nuclear Regulatory Commission, "Use of EPRI/NEI Joint Task Force Report, 'Guideline on Licensing Digital Upgrades: EPRI TR-102348, Revision 1, NEI 01-01: A Revision of EPRI TR-102348 To Reflect Changes to the 10 CFR 50.59 Rule,'" Regulatory Issue Summary 2002-22.
26. U.S. Nuclear Regulatory Commission, "Use of Design Acceptance Criteria during 10 CFR Part 52, Design Certification Reviews," SECY 92-053.

## **Attachment A**

### **Guidance for Evaluating Credited Manual Operator Actions**

#### **INTRODUCTION**

This attachment defines a methodology, applicable to both existing and new reactors, for evaluating manual operator actions which an applicant proposes as a means for performing, or supporting the performance of, a function important to plant safety. This attachment is based largely on, and replaces, the guidance provided in Chapter 18, Appendix 18- A, Crediting Manual Operator Actions in Diversity and Defense-In-Depth Analyses, Rev. 0. It has been written to be generically applicable to the evaluation of manual operator actions

#### **BACKGROUND**

This procedure provides generic guidance for reviewing credited manual operator actions. For some applications additional specific guidance is available. These sources are listed below. In general, the more immediate the need for an operator action the more detailed the evaluation of the action will be. No time limit has been established beyond which an operator action need not be evaluated because of the diversity of conditions that can potentially affect the successful accomplishment of operator actions.

#### **STAFF POSITION**

Credited operator actions should be demonstrated to be both feasible and reliable, given the time available, and that the ability of operators to perform credited actions reliably will be maintained for as long as the manual actions are necessary to satisfy the analysis assumptions. The time available for manual actions should be based upon the methods and criteria prescribed within the analysis crediting the operator action. The time required for the operator action should be estimated and validated using the guidance of this attachment. To demonstrate that the manual actions are both feasible and reliable, and that the ability to perform the actions reliably within the time available is maintained, the vendor/ licensee/applicant should follow a process of analysis, validation, and long-term monitoring consistent with this attachment.

Important human actions as defined by NUREG-0711, "Human Factors Engineering Program Review Model," and their associated interfaces (controls, displays, and alarms) should be specifically addressed in the applicant/licensee's human factors engineering (HFE) program related submittals.

#### **PHASE 1: ANALYSIS**

This section describes the attributes of an acceptable method of analyzing the time available and time required for manual operator actions that are to be credited in an event analysis.

## 1.A. Method

The analysis must demonstrate that:

- The time available to perform the required manual actions is greater than the time required for the operator(s) to perform the actions.
- The operator(s) can perform the actions correctly and reliably in the time available.

The time available to perform the actions should be based on analysis of the plant response to the event of concern. The time required for operator action should be based on an HFE analysis of operator response time. The basis of the documented sequence of operator actions can be task analysis, vendor-provided generic technical guidelines for emergency operating procedure development, or plant-specific EOPs, depending on the maturity of the design. The documented sequence of operator actions should be analyzed at a level of detail necessary to identify critical elements of the actions and performance shaping factors (e.g., workload, time pressure) that affect time required and likelihood of successful completion of the action sequence. The licensee/applicant should establish time estimates for individual task components (e.g., acknowledging an alarm, selecting a procedure, verifying that a valve is open, starting a pump) and the basis for the estimates, through a method applicable to the human-system interface (HSI) characteristics of the control system. The vendor/licensee/applicant should also provide a statement as to how elements such as diagnostics, communications, travel time, and work environment affect the time required for the action.

Acceptable methods for deriving time estimates for individual task components include, but are not limited to:

- Operator interviews and surveys
- Operating experience reviews
- Software models of human behavior, such as task network modeling
- Use of control/display mockups
- Expert panel elicitation<sup>2</sup>
- American National Standards Institute (ANSI)/American National Standards (ANS), ANSI/ANS 58.8, "Time Response Design Criteria for Safety-Related Operator Actions."<sup>3</sup>

Methods that are dependent on expert judgment to derive time estimates for task components are potentially subject to bias. In addition, the uncertainties associated with estimates derived through these methods are difficult to quantify. Accordingly, these methods should be employed using structured approaches that minimize bias and identify and assess uncertainties (see example: NUREG/CR-6372, "Recommendations for Probabilistic Seismic Hazard Analysis:

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<sup>2</sup> For an example of an expert panel elicitation, see NUREG-1852, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire."

<sup>3</sup> ANSI/ANS 58.8, "Time Response Design Criteria for Safety-Related Operator Actions," provides an acceptable task decomposition methodology for this purpose. However, the time intervals described in ANSI/ANS 58.8 were validated using analog controls and; therefore, may not be accurate for this application.

Guidance on Uncertainty and Use of Experts,” or “Eliciting and Analyzing Expert Judgment: A Practical Guide, Cambridge University Press,” 1991).

Prior experience with tasks or subtasks similar to the actions proposed to be credited in the analysis may provide valuable insights for the analysis/estimates of operator response times. Operating experience data used to provide input to the analysis/estimates of operator response times should be supplemented with information about the similarities and differences between the credited actions and the actions identified in the operating experience.

The analysis should demonstrate that there is adequate time margin between the time available and time required which considers and accounts for any uncertainty inherent to the analysis (see example: Section 4.2.2 of NUREG 1852, Demonstrating the Feasibility and Reliability of Operator Actions in Response to Fire”). This uncertainty could reduce the level of assurance and potentially invalidate a conclusion that operators can perform the action reliably within the time available. One acceptable method is for the time margin to equal the maximum recovery time for any single credible<sup>4</sup> operator error. The basis for the specific time margin used in the analysis should be justified and documented. Insights from the HFE program, especially the operating experience review (OER) and human reliability analysis, should be used. The identification of potential errors, error detection methods, and error recovery paths in event trees may be used to provide estimates of how much margin should be added to the operator response time estimates. For complex situations and for actions with limited margin, such as less than 30 minutes between time available and time required, a more focused staff review will be performed.

### **1.B. Review Criteria**

The responsible reviewers evaluate licensee/applicant’s submittals for compliance with the following criteria:

- An analysis establishes the time available. The basis for the time available is documented.
- The analysis of the time required is based on a documented sequence of operator actions. The basis of the documented sequence of operator actions can be task analysis, vendor-provided generic technical guidelines for emergency operating procedure development, or plant-specific EOPs, 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 sequence of actions uses only alarms, controls, displays and equipment that would be available and functional during the subject event(s). The event and

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<sup>4</sup> As used here, credible operator errors are any errors of omission or commission that are plausible considering applicable operating experience and a human reliability analysis for the task

the regulatory guidance for analyzing the event typically define the alarms, controls, displays and equipment that remain functional.

- The estimated time available for operators to complete the credited action is sufficient to allow successful use of all applicable procedure(s). This could involve implementation of a single procedure, multiple procedures in parallel, or procedures in sequence.<sup>5</sup> Where applicable the review should address the possibility that use of symptom/function-based EOPs may be necessary (e.g., instances in which event diagnosis may be particularly challenging).
- The initial operating staff size and composition assumed for the analysis of time required is the same as the minimum staff defined in the plant's Technical Specifications.
- If credited manual actions require additional operators beyond the Technical Specification minimum crew, the justification for timely availability of the additional staffing is provided and the estimate of time required includes any time needed for calling in additional personnel.
- 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 appropriate response, and the associated performance shaping factors that affect time required and the potential for operator error. Communications, travel time, and work environment are addressed.
- The analysis identifies a time margin between the time required and time available to perform the action and documents the basis for the adequacy of the margin, including consideration of the uncertainty in the estimation of the margin.

## **PHASE 2: PRELIMINARY VALIDATION**

This section describes the attributes of an acceptable method for preliminarily validating the time required for credited manual operator actions.

Note: Preliminary validation is a recommended practice for licensees implementing complex modifications and applicants for design certifications. The preliminary validation results should provide high confidence that the performance time criteria will be met in the Phase 3 ISV. Unacceptable ISV results will require modification of the design or operating strategy late in the design and licensing process.

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<sup>5</sup> The Phase 1 analysis may be conducted using a task sequence based on task analysis, vendor-provided generic technical guidelines for emergency operating procedure development, or plant-specific EOPs, depending on the maturity of the design. Accordingly, it is recognized that it will not be possible in all circumstances to directly assess time available relative to this criterion during the Phase 1 analysis.

## 2.A. Method

The preliminary validation should provide independent confirmation of the validity of the “time required” estimate derived in the Phase 1 analysis through the use of methods such as the following:

- Tabletop analysis
- Timeline analysis (such as the method shown in Appendix A of NUREG-1852)
- Walkthrough/talkthrough analysis
- Software models of human behavior, such as task network modeling
- Use of control/display mockups
- Man-in-the-loop prototype testing
- Pilot testing
- Real-time validation on a suitable<sup>6</sup> part-task simulator

Note: The preceding list is not all-inclusive – other validation methods may be used if sufficient technical justification is provided.

As the difference between time available, and time required for operator action decreases, the importance of reducing uncertainty and minimizing potential bias in the estimates increases. Accordingly, the vendor/applicant should use several diverse methods to estimate operator response times to maximize the cross-validation value of the methods (i.e., minimize the potential for bias and reduce sources of uncertainty in the estimates of operator response times). For example, when the design has advanced to the point where a part-task simulator is available, the vendor/applicant should use it to cross-validate previous time estimates derived from other activities, such as expert elicitation, tabletop analysis, or walkthrough/talkthrough. It is expected that the vendor/applicant will estimate operator response time using as realistic an environment as is available at the time of the preliminary validation.

The group of individuals who conduct the preliminary validation of the analysis should not include individuals who conducted the analysis. Independence between these groups will help to ensure that any undocumented assumptions and analytical methods used in the analysis are identified and documented during the preliminary validation. However, it is recognized that communication between the groups will be necessary, especially after the preliminary validation is complete. The processes of validation and design are iterative and feedback from the preliminary validation should be used to refine the design, the procedures, and the training provided to the operators.

The preliminary validation should be rigorous and conducted by operators, system technical experts, and human factors experts. These personnel should verify that the analysis is logical for its purpose, contains a sufficient level of detail, and that the analyzed action sequence presents no physical or spatial difficulty for performance. The language and the level of information presented in the documented sequence of manual operator actions should be compatible with the minimum number, qualifications, training, and experience of the operating staff.

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<sup>6</sup> A suitable part-task simulator is one of demonstrated scope and fidelity sufficient for the conduct of the specific validation.

Operators and system technical experts should ensure that the documented sequence of manual operator actions, independent of the time required, is technically correct and will achieve the desired technical result(s). These personnel should verify the documented sequence of manual operator actions is supported by the existing or planned displays and controls to be used by the operator. Walkthrough/talkthrough of planned displays and controls for new plants should be conducted to the extent practical, according to the state of the design and supplemented as necessary by use of such aids as arrangement diagrams, vendor drawings, and panel fabrication drawings.

Results should be documented for NRC review. Preliminary validation results should be such that there is high confidence that the time required for manual operator actions will satisfy the success criteria for the integrated system validation described below. Unacceptable preliminary validation results should result in modification of the design strategy. If successful manual actions cannot be achieved, automation should be considered.

When the vendor/applicant believes that the analysis provides high confidence that the time required for operator action will satisfy the success criteria for integrated systems validation, the complete analysis, which provides time available and time required, and the supporting analyses, is submitted for NRC review. This analysis will be submitted as part of the supporting justification for a DC, DC amendment, COL application, or license amendment. When the NRC reviewers have high confidence that the manual operator actions will be accomplished correctly, reliably, and within the time available, the NRC staff will make a safety determination as part of the safety evaluation report (SER) on the associated licensing action. Acceptable implementation shall be verified through completion of specified ITAAC or license conditions.

## **2.B. Review Criteria**

The responsible reviewers evaluate vendor/applicant's submittals for compliance with the following criteria:

- The preliminary validation is conducted as an independent confirmation of the Phase 1 analysis that compared time available and estimated time required to complete the action.
- The preliminary validation is conducted by a multi-disciplinary team with the knowledge and skills necessary to verify the rigor and assumptions of the analysis and validate the analysis conclusion regarding the ability of the operators to perform the actions reliability within the time available.
- The preliminary validation uses methods appropriate to assessing time required for the task. For complex situations and for actions with limited margin, such as less than 30 minutes between time available and time required, the primary validation uses two or more methods to validate the analysis.
- The preliminary validation results support the conclusion that the time required, including margin, to perform individual steps and the overall documented

sequence of manual operator actions is reasonable, realistic, repeatable, and bounded by the Phase 1 analysis documentation.

Note: As the difference between time available and time required for operator action decreases, there is increasing potential that uncertainty in the estimate of difference between these times will invalidate a conclusion that operators can perform the actions reliably within the time available.

### **PHASE 3: INTEGRATED SYSTEM VALIDATION**

This section describes the attributes of an acceptable method for validating manual operator actions through an integrated system validation.

#### **3.A. Method**

ISV is an evaluation using performance-based tests to determine whether an integrated system design (i.e., hardware, software, procedures, training, staffing and qualification, and physical environment) meets performance requirements and acceptably supports safe operation of the plant. The licensee/applicant should conduct an ISV of credited manual actions using a plant-referenced simulator in real time. Using the validation guidance in NUREG-0711, the licensee/applicant should measure operator response times (performance times) of all operating crews in representative event simulations. Performance times should be compared to the time available (per the event analysis results) and previous estimates of time required.

In selecting personnel for event simulations, consideration should be given to the assembly of both nominal and minimum crew configurations, including shift supervisors, reactor operators, shift technical advisors, etc., that will participate in the validation tests. The composition of operations personnel need only include personnel who are relevant to the credited actions.

Acceptable validation results will provide the basis for meeting the NRC's design certification, license application or amendment request approval requirements. Unacceptable validation results will require modification of the design strategy.

Modification of the design strategy would require reanalysis, re-validation and re-submittal for NRC staff review. If a successful manual action strategy cannot be achieved, automation should be considered.

The ISV shall be implemented and documented as an ITAAC item or license condition for plants licensed under 10 CFR Part 52 or as a license condition for operating plants that have not modified the plant-referenced simulator in advance of the control room modifications. The complete analysis, which provides time available and time required, the supporting analyses and validation results shall be submitted to the NRC for verification that the credited manual action supports the design assumptions.

#### **3.B. Review Criteria**

- The responsible reviewers evaluate vendor/licensee/applicant's submittals for compliance with the following criteria:

### General

- The ISV is completed as part of the HFE program that is implemented in accordance with NUREG-0711.

### Simulator

- The ISV is conducted using a plant-referenced simulator that meets the functional and fidelity requirements of the adopted ANSI/ANS 3.5, "Nuclear Power Plant Simulators for Use in Operator Training and Examination," and is capable of real time, high fidelity plant simulation of the event in which the operator manual action is credited.

### Local Control Panels and Plant Equipment

- If operator action is required outside the control room, these actions are validated on the actual equipment or an accurate reproduction or mockup of the equipment.
- Communication with the control room, travel time, harsh environment impacts, lighting, security measures, and supporting equipment are addressed within the validation scenario. The event analysis may contain other variables that should be considered e.g., loss of power, access restrictions). These variables and their impact on operator performance are addressed.

### Personnel

- Participants in the validation are the plant personnel who would normally perform the actions.
- Actions to be performed by licensed operators are validated using individuals holding a current operating license for the unit on which the actions are to be credited. For vendor/applicants using the 10 CFR Part 52 process for a design for which there are currently no licensed operators, the crews may be composed of individuals who hold or have held an NRC-issued license to operate a commercial nuclear reactor of the same type (i.e., pressurized water reactor or boiling water reactor) for which the design is being validated.
- Actions allocated to non-licensed operators are validated using non-licensed personnel trained in accordance with a program that meets the requirements of 10 CFR 50.120.
- The MCR operating staff size and composition used in the event simulations are the same as was used for the analysis and preliminary validation.

- All crews are included as part of the ISV. For vendor/applicants using the 10 CFR Part 52 process the minimum number of crews should be established in accordance with the guidance of NUREG-0711 (e.g., as specified in the vendor's/applicant's NRC- approved integrated system validation implementation plan).

#### Procedures

- The manual operator actions to be credited in the event analysis are directed by procedure steps included within procedures and executed from the MCR.

#### Operational Conditions

- Event simulations for the ISV include operational conditions in which credited actions may be required. For the analysis of manual actions credited for response to postulated CCFs of digital reactor protection system functions, consistent with BTP 7-19, the event simulation should include a range of CCF and digital failure modes, postulated HSI failures, and operational conditions in which the credited actions may be required.

#### Performance Times

- For each manual action, the mean performance time of the crews is less than or equal to the estimated time required derived from the analysis phase.
- For each manual action, the performance time for each crew, including margin determined in the time required analysis, is less than the analyzed time available.

### **PHASE 4: MAINTAINING LONG-TERM INTEGRITY OF CREDITED MANUAL ACTIONS**

#### **4.A. Method**

Among other factors, changes in plant design, procedures, and operator training can affect the ability of operators to correctly and reliably perform manual actions. Accordingly, the licensee/applicant should establish a strategy for long-term monitoring of operator ability to reliably perform the manual operator actions credited in an event analysis. The scope of the performance monitoring strategy should provide adequate assurance that integrated system performance will be maintained within the bounds established by the ISV and continue to support the associated event analysis.

There is no expectation for the licensee/applicant to periodically repeat the full ISV; however, there should be sufficient controls to provide reasonable confidence that operators will maintain the skills necessary to accomplish the credited actions. The results of the monitoring need not be reported to the NRC, but should be retained onsite for inspection.

Consistent with 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," Criterion III, "Design Control," Criterion V, "Instructions, Procedures and Drawings," and Criterion VI, "Document Control," the vendor/licensee/applicant

should have in place sufficient configuration and design controls to assure that procedure steps that direct the credited action are administratively protected from inadvertent change, and that the design program has sufficient controls to assure that the design will continue to support the event analysis when the plant or MCR is modified.

Consistent with 10 CFR Part 50, Appendix B, Criterion II, "Quality Assurance Program," in addition to the operations organization, training also should be provided to design personnel for the purpose of understanding the critical link between manual operator actions performed in response to an event and the plant equipment used to implement these actions. Instructors should ensure that trainees understand the philosophy behind the approach of the procedures.

Consistent with 10 CFR Part 50, Appendix B, Criterion III, "Design Control," and Criterion XVI, "Corrective Action," long-term monitoring should have a formal mechanism for feedback such that results, including problems identified by the operating staff during operations or training, are brought to the attention of the reference plant operations department management and the design organization. The licensee/applicant may integrate, or coordinate, their long-term monitoring with existing programs for monitoring operator performance, such as periodic operator surveys or the licensed operator training program.

#### **4.B. Review Criteria**

The responsible reviewers evaluate licensee/applicant's submittals for compliance with the following criteria:

A long-term monitoring strategy is developed and documented by the vendor/licensee/applicant that is capable of tracking performance of the manual operator actions to demonstrate that performance continues to support the associated event analysis.

The program is structured such that corrective actions are formal, effective, and timely.

#### **Rationale**

Guidance for HFE analyses that would be suitable to support the event analyses is described in NUREG-0711. The NRC staff has a high degree of confidence that a licensee/applicant using the NUREG-0711 model will provide adequate HSI design to allow operators to accomplish the manual actions required by their designs. However, the typical HFE Program per NUREG-0711 does not conclude until just before fuel load or startup. This attachment provides guidance for a methodology that provides early feedback in the design and regulatory review process and allows the licensee/applicant to move forward with relative confidence that credited manual operator actions will be demonstrated as both feasible and reliable in the ISV. Ultimately, the ability to reliably perform credited manual operator actions will be verified through completion of ITAAC or license conditions related to the actions credited in the analyses. Furthermore, the ability to reliably perform the credited manual actions within the time available shall be maintained through a long-term monitoring strategy.

## Additional Resources

- Manual actions – General
  - Consistency in NRC's Treatment of "Manual Actions" Across Regulatory Applications (ADAMS Accession No.ML111960336)
- Manual actions associated with common cause failure of I&C software
  - Branch Technical Position (BTP) 7-19, "Guidance for Evaluation of Diversity and Defense-in-Depth in Digital Computer-Based Instrumentation and Control Systems."
  - DI&C-ISG-05, "Task Working Group #5: Highly-Integrated Control Rooms — Human Factors Issues."
- Manual actions associated with fires
  - NUREG-1852: "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire".
  - Regulatory Guide 1.62: "Manual Initiation of Protective Actions."

## REFERENCES

1. ANSI, "Nuclear Power Plant Simulators for Use in Operator Training and Examination" (ANSI/ANS-3.5-1998), La Grange Park, IL.
2. ANSI, "Time Response Design Criteria for Safety-Related Operator Actions" (ANSI/ANS 58.8-1994), La Grange Park, IL.5. U.S. Nuclear Regulatory Commission, "Revision 1 to Interim Staff Guidance on Highly-Integrated Control Rooms – Human Factors Issues" (DI&C-ISG-05).
3. U.S. *Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy
4. U.S. *Code of Federal Regulations*, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."
5. U.S. Nuclear Regulatory Commission, Standard Review Plan (SRP), NUREG-0800, BTP 7-19, "Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems," Revision 6.
6. U.S. Nuclear Regulatory Commission, "Human Factors Engineering Program Review Model," NUREG-0711, Revision 3.

7. U.S. Nuclear Regulatory Commission, "Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire," NUREG-1852.
8. U.S. Nuclear Regulatory Commission, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts," NUREG/CR-6372.

## **Attachment B**

### **Methodology to Assess the Workload of Challenging Operational Conditions In Support of Minimum Staffing Level Reviews**

The following material is adapted from Brookhaven National Laboratory (BNL) Technical Report No. 20918-1-2015. The report is available on the U.S. Nuclear Regulatory Commission (NRC) public website within the Agencywide Documents Access & Management System (ADAMS) public document subdirectory under Accession No. ML15083A205.

#### **INTRODUCTION**

This attachment provides a methodology to identify high-workload operational conditions and analyze the workload associated with them. The methodology is rooted in task analysis and relies on the identification of appropriate challenging scenarios; realistic portrayals of task performance that is complicated by separate, but often necessary, dependent and independent tasks; and the judgment of subject matter experts (SME) obtained in a manner conducive to obtaining realistic workload estimation.

#### **BACKGROUND**

Plant personnel play diverse roles in plant operations and safety. They monitor plant systems and performance and various barriers that prevent release of radioactive material. They take actions to initiate, adjust, and terminate operations as needed. They also respond to transients, accidents, and other failures. They also are responsible for managing operations-related administrative duties. Personnel are supported in these tasks by human-system interfaces (HSIs), procedures, and training. To accomplish their responsibilities, personnel typically work in teams.

The minimum number of operators needed to fulfill all personnel roles and responsibilities is a complex question that depends on assumptions related to what the credible high-workload scenarios will be and the timeline along which additional staff are needed and available. Licensees establish a minimum staffing level to address immediate and “short-term” actions that need to be taken and the time required to augment the staff with additional personnel as needed over time.

The focus of this Attachment is the minimum staffing level needed to address immediate and short-term actions. Scenarios that evolve slowly and within time envelopes required to bring in additional staff are easier to address from a staffing perspective.

The U.S. Nuclear Regulatory Commission (NRC) has established minimum acceptable staffing levels in Title 10 of the Code of Federal Regulations (10 CFR) 50.54(m). However, technological advances and changes in the conduct of operations have led to an interest in staffing levels below those specified in the regulations. To evaluate applicant requests for staffing exemptions that allow for reduced staffing levels, the NRC needs criteria by which these requests can be evaluated.

A top priority criterion is task performance. An acceptable minimum staffing level is one that can successfully accomplish the most demanding tasks, under conditions that reflect real-world challenges including the demands of multi-tasking. Tasks have to be performed accurately and on time, so that overall plant operational and safety goals can be achieved. Successful task performance is the main criterion for evaluating a proposed staffing level. That is, if the crew at the minimal staffing level cannot perform their tasks, the staffing level is not acceptable. However, while task performance is an important acceptance criterion, it's not the only one.

Crew task performance can be negatively impacted by many factors and some of these factors need to be considered as well. One of the factors that can negatively impact a crew's ability to accomplish their tasks is workload. High workload can delay task completion until it is too late or cause a task to be missed altogether. Even when tasks are performed accurately and on time, high workload causes performance to be "fragile," in that there may be little or no margin for dealing with added complications. If additional complications are encountered, the workload level may rise to the point where task performance is negatively impacted. Thus it's important to know that not only is task performance acceptable, but workload levels are not excessive.

In addition to workload, there are other factors that impact task performance. For example, failure to properly monitor the plant, or inattention, can also cause tasks to be delayed or overlooked. This condition is sometimes caused by "underload," i.e., insufficient workload. Insufficient workload is a concern in highly automated plants where the operator's primary role is monitoring and supervisory control. Operators perform best when workload is neither too high nor too low.

Another factor impacting task performance is situation awareness. A crew may not perform a task accurately and on time because they have a misunderstanding of the current plant state. In this case they may not perform the necessary tasks because they do know they need to be done. Poor situation awareness can result from high workload because the workload does not provide staff with the time necessary to maintain accurate situation awareness.

High workload, inattention, and poor SA are examples of the factors that can lead to poor task performance and hence should be considered in staffing evaluations. NUREG-7190 provides additional information on analysis methods for these factors.

This appendix supplements the guidance in the body of this chapter, NUREG-0711 and NUREG-1791, and is primarily focused on methods to assess workload during the task analysis phase of HFE design. The task analysis results, in turn, support the staffing and qualification analysis.

## METHODOLOGY TO ASSESS THE WORKLOAD OF CHALLENGING OPERATIONAL CONDITIONS

The methodology to assess workload of challenging operational conditions is divided into seven steps, see Figure 1. Each of these steps is described below:

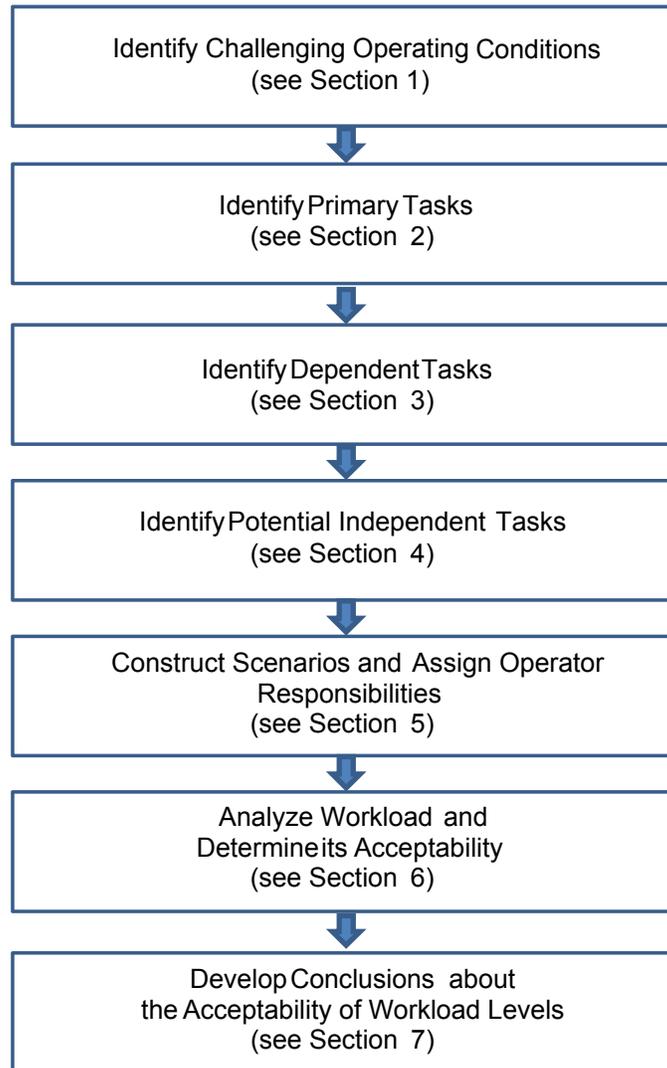


Figure 1: Methodology to assess the workload of challenging operational conditions

### 1. Identify Challenging Operating Conditions

The applicant should identify the plant specific operating conditions that are challenging and create high workload using the considerations presented below. Unlike integrated system validation scenario development where all operational conditions identified are addressed in a scenario, this activity should be focused on identifying conditions that most challenge the minimum staffing level. The objective of identifying these conditions is the evaluation of the

minimum staffing level needed to address immediate and short-term actions. Scenarios that evolve slowly and within time envelopes necessary to bring in additional staff are easier to address from a staffing perspective.

The applicant should consider the following plant conditions, personnel tasks, and situational factors in their sample of challenging conditions for workload analysis.

a. Plant Conditions

- Consider transients and accidents starting during normal operations, plant startup, shutdown, and refueling
- Consider instrumentation and control (I&C) and human-systems interface (HSI) failures and degraded conditions that encompass:
  - the I&C system, including the sensor, monitoring, automation and control, and communications subsystems
  - common cause failure of the I&C system during a design basis accident (as defined by Branch Technical Position (BTP) 7-19)
  - HSIs including, loss of processing or display capabilities for alarms, displays, controls, and computer-based procedures
- Consider transients and accidents, such as:
  - transients (e.g., turbine trip, loss of off-site power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or main control room (MCR) power supplies, and safety and relief valve transients)
  - accidents (e.g., main-steam-line break, positive reactivity addition, control rod insertion at power, anticipated transient without scram, and various-sized loss-of-coolant accidents)
  - reactor shutdown and cooldown using the remote shutdown system
  - reasonable, risk-significant, beyond-design-basis events that should be determined from the plant-specific probabilistic risk assessment (PRA)
  - external events (fires, floods, seismic events, and loss of large area of the plant)

*Additional Information:*

Typically, the most demanding staffing requirements that a shift faces is the first hour of an operational event, before the emergency response facilities can be staffed. Staffing and activating the operational support center (OSC), technical support center (TSC) and the emergency operations facility (EOF) reduce the burden on the shift. The OSC, TSC, and the EOF are typically required to be operational within thirty minutes to one hour of an emergency declaration. The emergency facility staffing would generally include extra senior reactor operators. Operating conditions selected need only be carried out far enough to address the period up to when added staffing is in place.

Following the March 2011 tsunami-induced loss of all power at the Fukushima Dai-ichi nuclear power plants the NRC issued Order EA-12-049 on March 12, 2012, requiring all U.S. nuclear power plant licensees to implement strategies that would allow them to cope without their permanent electrical power sources for an indefinite period of time. In response, the U.S. nuclear power industry developed and implemented Flexible Coping (FLEX) strategies, consistent with NEI 12-06, Diverse and Flexible Coping Strategies (Flex) Implementation Guide, Revision 1A (ML15279A426). These strategies are based on a three-phase approach: 1) initially cope by relying on installed plant equipment, 2) transition from installed plant equipment to on-site FLEX equipment, and 3) obtain additional capability and redundancy from off-site equipment until power, water, and coolant injection systems are restored or commissioned. Onsite administrative minimum shift staffing levels are assumed for the first two phases. Staffing analyses are to evaluate minimum staffing, so typically these analyses should include Phase 1 and 2 of the selected scenarios. For the second or transition phase, some plants may involve off-site or recalled personnel. If a plant's mitigation strategy specifies recalled/offsite personnel for selected events, then those events do not need to be included in the staffing analyses for minimum staffing.

- b. The applicant should consider the following types of personnel tasks:
- *Important Human Actions* – The sample should include all important HAs, as determined in NUREG-0711, Section 7.
  - *Manual Initiation of Protective Actions* – The sample should include manual system-level actuation of critical safety functions.
  - *Automatic System Monitoring* – The sample should include situations in which humans must monitor a risk-important automatic system.
  - *Operating Experience - Identified Problematic Tasks* – The sample should include high-workload personnel tasks identified as problematic during the applicant's review of operating experience.

- *Range of Knowledge-Based Tasks* – The sample should include tasks that are not well defined by detailed procedures (see NUREG-0711 for additional information).
  - *Range of Human Cognitive Activities* – The sample should include the range of cognitive activities that personnel perform, including:
    - detecting and monitoring (e.g., of critical safety-function threats)
    - situation assessment (e.g., interpreting alarms and displays to diagnose faults in plant processes and in automated control and safety systems)
    - planning responses (e.g., evaluating alternatives to recover from plant failures)
    - response implementation (e.g., in-the-loop control of plant systems, assuming manual control from automatic control systems, and carrying out complicated control actions)
    - obtaining feedback (e.g., feedback of the success of actions taken)
  - *Range of Human Interactions* – The sample should include the range of interactions among plant personnel, including tasks performed independently by individual crew members, and those undertaken by a team of crew members. These interactions among plant personnel should include interactions between:
    - main control room operators (e.g., operations, shift turnover walkdowns)
    - main control room operators with auxiliary operators and other plant personnel performing tasks locally (e.g., maintenance or instrumentation and control (I&C) technicians, chemistry technicians)
    - main control room operators and the TSC and the EOF
    - main control room operators with plant management, the NRC, and other outside organizations
- c. The applicant should include the following situational factors or error-forcing contexts known to challenge human performance. It also should include situations specifically designed to create human errors to assess the system's error tolerance, and the ability of personnel to recover from any errors, should these occur, for example:

- Fatigue Situations – To the extent possible, the sample should include situations that may be associated with fatigue, such as work on backshifts and tasks performed frequently with repetitive actions, such as repeated inputs to a touch screen during plant operations or pulling rods.
- d. The applicant should include the following considerations with respect to emerging technology in NPPs, as described in more detail in Section 3 of NUREG/CR-6947.
- Automation (Section 3.1.1)
  - Specific changes to operations (Section 3.1.3)
  - Advances in HSI technology (Section 3.1.3)
  - Complexity (Section 3.1.3)
  - Disturbance and emergency management (Section 3.1.4)
  - Design and evaluation of digital systems and software (Section 3.1.5)
- e. The applicant should include the following considerations for human performance issues related to design and operation of SMRs, if pertinent. These topics are described in more detail in Section 6 of NUREG/CR-7126.
- Plant mission (Section 6.1)
  - Roles and responsibilities. This includes multi-unit monitoring and teamwork, and high levels of automation (Section 6.2)
  - Management of normal operations. This includes 10 issues of which the first seven relate to staffing and workload. (Section 6.4)
  - Management of off-normal conditions and emergencies. This includes nine issues which the first seven relate to staffing and workload. (Section 6.5).

## 2. Identify Primary Tasks

- a. For each of the challenging operating conditions, the applicant should identify the primary plant control tasks which operators need to perform to a level of detail to support workload analyses.

*Additional Information:* If available, plant-specific procedures can be used to identify the tasks and task sequences for addressing each operational condition. If the actual detailed operating, off-normal, and emergency procedures are not available there may be vendor procedure guidelines or predecessor plant procedures that can be used.

Depending on their level of detail, procedures may only define the tasks that operators perform at a high level. In that case, applicants should conduct task

analyses to develop the detail needed to support workload analyses. For example, one cannot determine the workload of a primary task like ‘Start Pump A,’ without breaking it down to more-detailed subtasks not typically described in procedures. The subtasks may include detailed actions such as: navigate to the feedwater display, locate the pump to be controlled, verify that the correct pump has been selected, assess that the preconditions for starting the pump are acceptable, click on the pump icon to access the pump controls, select “on” and click “Enter,” and finally verify that the pump has been turned on and is operating properly. These subtasks are the detailed means by which the higher-level plant control task is accomplished.

- b. The applicants should include an analysis of the operator tasks associated with new design features, even when the tasks are mainly cognitive activities such as monitoring.

*Additional Information:* For example, in a highly automated plant, operators will spend considerable time and effort monitoring the automation and assessing its performance. Cognitive task analysis techniques may be useful for analyzing such cognitive tasks.

In summary, the analysis of the operators’ primary tasks may require a combination of procedures, procedure guidelines, and task analyses to identify all of the detailed tasks and activities that operators will need to perform during the challenging operating conditions.

### **3. Identify Dependent Tasks**

- a. For each of the challenging operating conditions, the applicant should identify the dependent tasks, which operators need to perform in support of the primary tasks.

*Additional Information:* Dependent tasks are those not specifically part of the procedure-driven primary tasks, but which operators still have to perform in the same time frame. When such tasks are performed in the same time period as the primary tasks, they contribute to crew’s workload, may introduce distractions or interruptions, and reduce the time available to perform primary tasks.

Dependent tasks are divided into two categories: Generic dependent tasks and plant-specific dependent tasks. Generic tasks are those that apply to all or most plants and can be further categorized as administrative tasks, communications, and system/equipment-related actions. Examples of generic dependent tasks are shown in Table 1.

Plant-specific dependent tasks are unique to the applicant’s design. Applicants should systematically analyze the plant design, the use of new technologies and new concepts of operations to identify plant-specific dependent tasks that should be included in the scenarios to be analyzed (as determined in Section 5).

Applicants should consider the following in their analysis of plant-specific dependent tasks:

- Special work needed to access underground equipment
- Work related to passive systems
- Work related to operate backup systems to the passive systems
- Fuel loading
- Load-following operations
- Novel refueling methods
- Any special situation related to the primary task that results in reduced time for operators to respond
- Monitoring requirements for multiple reactor configurations

**Table 1: Generic Dependent Tasks**

Type of Dependent Task	Example Activities
Administrative	Initiate technical specification
	Apply error-prevention tools, such as independent verification of valve repositioning, related to primary tasks
	Log keeping
Communications	Communicate with auxiliary operators
	Task briefings
	Manage command and control challenges
	Interface with in-plant emergency or support organizations
	Communicate with offsite emergency organization
	Communicate with the NRC
System/equipment-related actions	Alarm monitoring and response for primary task equipment
	Initiate emergency response actions

#### 4. Identify Potential Independent Tasks

- a. For each of the challenging operating conditions, the applicant should identify any independent tasks which operators may need to perform.

Additional Information: Independent tasks are not specifically linked to the primary tasks, but may need to be performed within the same time frame as primary tasks, thus may increase operator or overall staff workload. Even when independent tasks do not significantly add to workload, they can still create distractions that may impede primary task performance. An activity that shifts attention away from the primary tasks, even momentarily, can interfere with performance even if little workload is added.

An example of such an independent task is provided in NRC Information Notice (IN) 91-77 (NRC, 1991). The IN documented two instances of plants' difficulty in staffing the fire brigade during a plant fire. In another more recent example, The licensee event report (LER) 50-259/22013-005-01, (TVA, 2014), describes a

situation where the plant’s minimum staffing analysis did not fully consider the impact on staffing of the fire brigade, an Appendix R safe shutdown, and the emergency response organization.

In another recent example a senior reactor operator (SRO) who was the fire brigade leader in case of fire was called for drug testing. After he left a fire occurred. The fire brigade responded with no leader for about 30 minutes. The SRO did not leave drug testing because previous communications had reinforced that anyone who did not complete drug testing within prescribed time frame was considered “unfit for duty.”

Another example of a common independent task is communicating with plant staff on matters unrelated to the primary task.

Generally it is assumed that independent actions will be stopped when any plant transient occurs. However, operating experience shows there have been cases where confusion arises. Such conflicts should be addressed in plant administrative procedures to guide operators in how to manage independent tasks when they may impact operational primary tasks. Without such specific guidance, operators will make decisions on an ad hoc basis.

Like dependent tasks, we can divide independent tasks into generic and plant-specific tasks. Further, the independent generic tasks can be categorized as: administrative tasks, communications, and system/equipment-related. Table 2 provides independent tasks in each of these categories. Note that some of these activities that can be either a primary, dependent, or independent task (e. g., technical specifications related activities).

**Table 2: Generic Independent Tasks**

<b>Type of Independent Task</b>	<b>Example Activities</b>
Administrative	Technical specifications activities
	Apply error-prevention tools, such as independent verification of valve repositioning, unrelated to primary tasks
	Log keeping
	Drill participation
	Corrective action generation and processing
	Drug testing
	Outage schedule reviews
	Scheduling of operations, maintenance, and testing
	Training
Communications	Manage standard communications
	Communicate with auxiliary operators or fire brigade
	Shift turnover
	Staff meetings
System/equipment-related actions	Alarm monitoring and response for equipment unrelated to primary task

	Trouble shooting and investigations
	Manage in progress activities (operations and maintenance)
	Manage plant configuration, e.g., equipment tag-outs, operational lineups, and operability evaluations
	Monitor plant risk using the safety or risk monitor
	Perform surveillance testing and post-maintenance testing
	Plant walkdowns
	Work related to unplanned shutdowns
	Participate in fire brigade

Applicants should also systematically analyze the plant design and the use of new technologies and new concepts of operations to identify if there are any plant-specific independent tasks that should be included. The following are examples of the types of activities to consider for identifying plant-specific independent tasks:

- Work-related handling of conditions of one unit that impact other units
- Data entries needed for using automation and computer-based human-system interfaces
- Managing novel maintenance hazards (e. g., reactor cooling system (RCS) partial drain for steam generator (SG) tube inspections)
- Modular construction and component replacement
- Control actions and operations and maintenance (O&M) planning related to multiple modules

A representative set of independent tasks should be included in the scenarios to be analyzed (see Section 6). The applicant need not include independent tasks that are characterized by the following conditions:

- An independent task that can be delayed or stopped to permit operators to accomplish the scenario-required primary tasks, and
- An applicant has established guidance for prioritizing and/or postponing independent tasks that may arise during plant events

- b. Applicants should identify their assumptions regarding the status of these excluded independent actions, e.g., “we have not included drug testing actions in our analysis because we assume such actions will not interfere with the primary control tasks based on administrative procedures.”

## 5. Construct Scenarios and Assign Operator Responsibilities

Applicants should construct scenarios based on combining the primary, dependent, and independent tasks. These scenarios will be used to conduct the workload analysis described in Section 6. Scenario construction should follow the guidance contained in NUREG-0711, Sections 11.4.1.2, Identification of Scenarios, and 11.4.1.3, Scenario Definition) as adapted below.

- a. analysis. A given scenario may combine many of the characteristics identified in the “identification of challenging operating conditions” and other analyses. Five to ten scenarios should be sufficient provided they define what the applicant/licensee believes to be a set of the highest-workload conditions the operator might face. The applicant should use risk and cases of anticipated high workload to screen the scenarios and items contained in the scenarios.

Additional Information:

Workload can be anticipated to be high Selection and construction of scenarios: The applicant should use the results of Sections 1 through 4 to identify a reasonable set of scenarios for subsequent staffing for scenarios with the characteristics listed in Table 3. This table is not meant to be comprehensive, and the characteristics identified are not mutually exclusive, but they may be useful for identifying/constructing scenarios likely to induce high workload.

- b. Scenario Definition: For each scenario, the following information should be defined to reasonably assure that important dimensions of performance are addressed:
  - a description of the scenario and any pertinent prior history necessary for analysts to understand the state of the plant at the start-up of the scenario
  - specific initial conditions
  - 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
  - dependent tasks related to each primary task
  - independent tasks that may occur during each scenario
  - definition of workplace factors, (e.g., environmental conditions)
  - needs for task support (e.g., procedures and technical specifications)
  - staffing level (should be the minimum levels are identified in the exemption request)

- responsibilities of each operator
  - communication requirements between control room personnel and remote personnel (e.g., load dispatcher via telephone)
- c. The applicant's scenarios should realistically represent operator tasks in the plant; so that the findings from the analysis can be generalized to the plant's actual operations. One important aspect of this is the timing for plant dynamics and postulated accidents. This would be provided by a full-scope plant simulator later in the design stage, but at the time of initial staffing evaluations, it may need to come from analytic work by the design team.
- d. When work (e.g., operations, maintenance) external to the MCR must be coordinated with the control room crew, the scenarios should include work associated with such coordination.

**Table 3: Scenario Characteristics Associated with High Crew Workload**

Characteristic	Considerations
Scenarios with Complex Relationships Among Primary Tasks	NUREG-0711 Task Analysis Criterion 4 addresses the relationships among tasks, e.g., some tasks can be carried out in any order or in parallel, some tasks have to be performed in a linear sequence, while for others the relationship is conditional (if such a condition exists, perform task A). Some tasks may involve coordinated actions among crew members or control room crew members and local personnel. These relationships can introduce task delays and multitasking requirements that contribute to the complexity and workload of performing primary tasks.
Scenarios that are unfamiliar or unusual	The scenario is not one that operators encounter frequently or on which they train. Thus, even with procedures the scenario has high uncertainties and operators have to analyze many parameters, select among many possible mental models for the situation, and evaluate multiple outcomes.
Scenarios that require knowledge based behavior	Knowledge-based task demands occur during scenarios for which there are no detailed procedures or for which procedures are not having their intended effects. Operators must assess the situation and develop response plans as they manage the situation.
Scenarios with distracting and interrupting demands	Some scenarios may produce a high level of distractions and interruptions, which raises workload and disrupts performance. An example would be a second failure occurring while operators are addressing the first failure.
Scenarios that are highly dynamic	In dynamic scenarios, the frequent onset of new or changing information makes it difficult to assess plant conditions, plan appropriate responses, or execute complex tasks. In such scenarios, operators have to

	frequently update and revise their understanding of the situation and how they manage the event.
Scenarios with time pressure	Complex tasks that need to be completed within a limited period of time may require operators to make a trade-off between the thoroughness of performing tasks (e.g., continuing data monitoring to assure the assessment, evaluating alternatives, confirming the actions before moving to the next step) and completing tasks in time.
Scenarios causing prolonged stress	Scenarios that require operators to work long working hours on non-routine, stressful tasks.
Rapid workload transitions	Periods of rapid workload transition are difficult to operators. For example, if an automatic system fails and operators have to suddenly perform the tasks manually, the workload experienced is typically high.
Scenarios with significant consequences	The potential consequences of the operator's performance impact workload. If the consequences are significant, then more workload is experienced than if the consequences are less severe.
Scenarios with actions having little margin for error	When operator tasks require very precise responses with little performance margin, the demands on attention are great and workload high.

## 6. Analyze Workload and Determine Its Acceptability

- a. The applicant should identify the method or methods to be used to analyze staff workload and the workload acceptance criteria for each. NUREG/CR-7190 provides guidance regarding the selection of measures for workload, situation awareness, and teamwork.
- b. The applicant should have a detailed task analysis of the scenarios to be analyzed.

**Additional Information:** To provide reasonable estimates, subject matter experts (SME) should have a detailed analysis of crew tasks so they know not only what tasks need to be performed, but how they are performed. The task analysis should meet the review criteria provided in Section 5 of NUREG-0711, Applicants may use a combination of traditional task analysis methods, along with cognitive task analysis (CTA) methods.<sup>8</sup> The latter may be especially useful for cognitive

<sup>8</sup> The CTA addresses limitations in current task analysis methods, such as:

- Traditional task analysis methods mainly focus on physical activity (observable behaviors). However, as modern plants become much more highly automated, the role of personnel becomes less-and-less activity oriented, and more-and-more cognition oriented. Traditional methods are limited in their ability to analyze cognitive, supervisory control tasks.
- Traditional methods tend to focus on the ways tasks should be performed from the perspective of designers, procedure developers, and trainers. These perspectives do not always capture how work is actually performed in the plant under the demands of the real work environment. (This is one of the primary concerns addressed in this new guidance.)
- Traditional methods do not address well what makes situations demanding and difficult. However, in real world settings, task difficulty is an important determinant of performance and safety.

and supervisory control activities and when the task situation is not well-defined from an operator's perspective. Applicants may also use human performance modelling techniques, provided they can show that those techniques can provide reasonable results. In addition, SMEs should have system descriptions to fully understand the tasks and how they are performed.

- c. The applicant should conduct a timeline analysis of the time required to complete tasks with respect to the time available. The analysis should consider:
- system timing, such as the time the system takes to respond to an action before another action can be taken
  - the time required to perform covert cognitive tasks, such as situation assessment and response planning
  - the effects of multitasking and the potential for primary task disruption created by overlapping primary tasks, dependent tasks, and independent tasks
- d. The applicant should analyze the physical and cognitive workload associated with task performance. The analysis should consider the effects of multitasking and the potential for primary task disruption created by overlapping primary tasks, dependent tasks, and independent tasks.

Additional Information: Applicants can use or adapt a subjective workload measure to obtain SME workload estimates along workload dimensions.

- e. The applicant should evaluate the acceptability of workload by comparing time and workload results to the established criteria.
- f. The applicant should evaluate unacceptable results to determine root cause and corrective actions.

Additional Information: Note that the root cause of unacceptable workload for individual scenarios may not be due to staffing levels. For example, the high workload may be due to poor HSI design rather than insufficient staff. The human engineering discrepancy (HED) evaluation process described in NUREG-0711, Section 11.4.4, can be used for this analysis.

## **7. Develop Conclusions about the Acceptability of Workload Levels**

- a. Applicants should provide overall conclusions about the acceptability of workload levels and the basis for that conclusion considering:

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• Traditional methods are well-suited to clearly-defined situations, but are less well suited to analyzing unplanned and unanticipated situations, such as situations that have not been assessed by designers and not been experienced by operations experts. Yet it's just these types of situations that can pose the greatest risk to safety.

- Both time and workload analyses
- Consistency of results across the different challenging scenarios
- The results of HED evaluations of any findings where workload fails to meet acceptability criteria

## REFERENCES

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3. U.S. *Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."
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8. U.S. Nuclear Regulatory Commission, "Human Factors Considerations with Respect to Emerging Technology in Nuclear Power reactors," NUREG/CR-6947.
9. U.S. Nuclear Regulatory Commission, "Workload, Situation Awareness, and Teamwork," NUREG/CR-7190.

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**PAPERWORK REDUCTION ACT STATEMENT**

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

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