Application Strategy of NUREG-0700 (Rev.3) and NUREG-0711 (Rev.3) for Long-Term Operation of Nuclear Power Plants

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1. Introduction

NUREG-0700 (Rev.3) and NUREG-0711 (Rev.3) provide comprehensive guidance for Human Factors Engineering (HFE) in nuclear power plants. These documents emphasize the critical role of human-system interface (HSI) design and programmatic HFE processes in ensuring plant safety and efficiency. For plants preparing for license renewal or life extension, however, direct application of these guidelines can be challenging. This is because many plants were not originally designed with these frameworks in mind, and large-scale redesigns may not be feasible due to cost, regulatory, and operational constraints. Moreover, operators have built strong familiarity with existing systems, and abrupt changes could introduce new risks.

Therefore, a tailored strategy is needed to apply the principles of NUREG-0700 and NUREG-0711 in a way that maximizes safety improvements while minimizing disruption. This paper proposes a pragmatic approach that integrates programmatic steps, procedural and training enhancements, and low-cost interface improvements.

2. Background

Human Factors Engineering has become an essential part of modern nuclear regulation. Historically, operating experience has shown that inadequate alarm design, inconsistent procedures, and poorly integrated human-system interfaces can contribute significantly to human error. Major events in the nuclear industry have demonstrated the importance of designing systems that support operators under both normal and emergency conditions.

To address these challenges, the NRC developed two cornerstone documents. NUREG-0700 provides detailed HSI design review guidelines, focusing on displays, controls, alarms, and workstation layout. NUREG-0711, on the other hand, establishes a structured Human Factors Engineering Program Review Model (HFE PRM) that spans the lifecycle of plant design, construction, operation, and modernization. Together, these documents ensure that human performance considerations are integrated from conceptual design to daily operations.

However, many plants seeking continued operation were constructed long before these guidelines were published. Consequently, full compliance is rarely achievable without major retrofits. Thus, adaptation requires a balanced approach—leveraging procedural updates, training programs, and incremental interface adjustments to achieve the intent of NRC guidance without wholesale redesign.

3. Application Principles

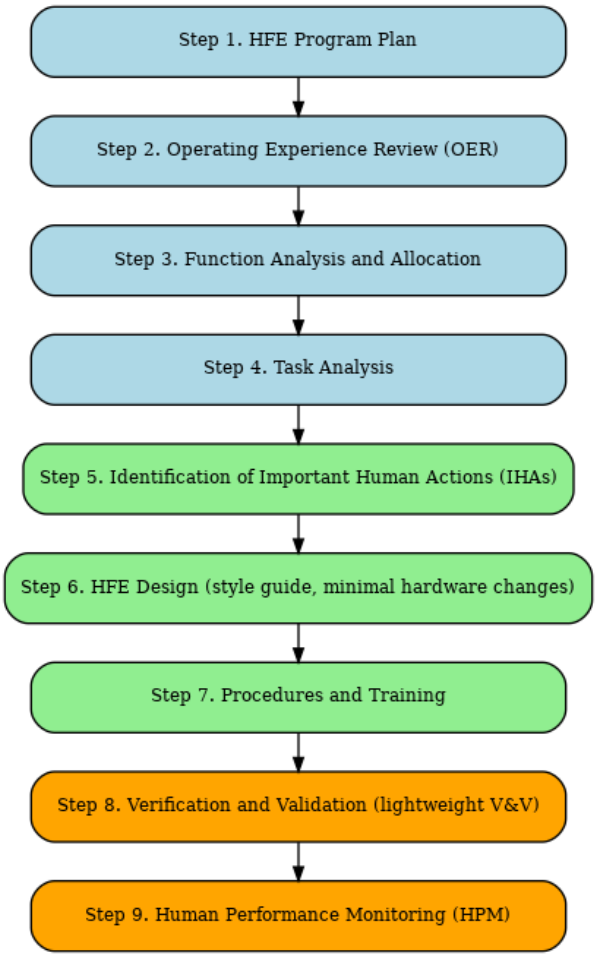
NUREG-0700 should be applied as a style guide to harmonize labeling, abbreviations, coding, and alarm messages. This ensures internal consistency and supports operator familiarity. NUREG-0711 should be applied as a programmatic framework, guiding the systematic review of operating experience, task analysis, and human performance monitoring.

In practice, full adherence to every detailed design guideline is often unrealistic for existing plants. Instead, a graded approach should be used. This includes documenting existing practices, benchmarking them against NUREG standards, and addressing discrepancies through operator training, improved procedures, and harmonization of interface elements. Such measures preserve operator familiarity while still aligning with the intent of NRC guidance.

4. NUREG-0711 Based Stepwise Application

Step 1~4: Preparation Phase (Blue)
Step 5~7: Execution Phase (Green)
Step 8~9: Verification Phase (Orange)
※ Refer to a figure on the next page

Importantly, each step can be tailored for minimal system modification. OER can be based on existing event databases and operator interviews; task analysis may focus on high-priority tasks during transient and accident scenarios; and lightweight V&V can be carried out using simulators or mock-ups rather than full-scope system upgrades. This flexible approach ensures applicability while controlling costs and operational impacts.



5. NUREG-0700 Based Low-Cost Improvements

Seven practical measures can yield safety benefits with minimal redesign:

1) Alarm philosophy rationalization
   Alarm labeling & prioritization is the basic design concept of nuclear power plants, but the suitability is reaffirmed through detailed HSI evaluation.
2) Display formatting consistency

Before		After
TEMP: 350c	→	TEMP = 350 ℃
Prss=150 bar	→	PRESSURE = 150 bar
Flow- 27L/S	→	FLOW = 27 L/S
Volt:450V	→	VOLTAGE = 450 V

3) User interaction rules
   - Ensure users can handle systems in the same way without confusion
   - Minimize unnecessary clicks, redundant inputs, confusing shortcuts, and more
4) Analog instrument/controls improvements
5) Workstation/environment enhancement
6) Procedure formatting improvements
7) Degraded HSI provisions
   - Maintain minimal operability in the event of a partial failure of the display, controller, network, etc
   - Early response before a complete failure

Even small-scale improvements can deliver substantial safety benefits. Examples include standardizing abbreviations across displays, clarifying alarm labels, and introducing consistent demarcation lines on panels. These changes reduce cognitive workload, enhance operator situational awareness, and improve error tolerance under stressful conditions. Additional focus should be placed on ensuring alarm visibility and prioritization during abnormal events.

6. Deliverables

- HFE Program Plan (HFEPP)
- OER report and HED list
- Style guide, naming rules, abbreviations, coding standards
- Alarm philosophy and response procedures
- Task analysis matrix and IHA mitigation table
- Standardized procedure format and training program
- Lightweight V&V results and HED closure
- Human performance monitoring (HPM) metrics

By preparing these deliverables in a structured package, plants can demonstrate compliance with NRC intent, facilitate regulatory review, and provide operators with consistent, reliable tools for decision-making.

This graded and tailored application provides operators with an environment that enhances safety while preserving system familiarity, and offers regulators a practical case of compliance that minimizes cost and operational burden while ensuring effectiveness.

7. Minimal Design Changes

Only when IHAs are safety-significant and procedural or training mitigations are insufficient should hardware modifications be considered. Such changes must be justified through human reliability analysis and validated through operator-in-the-loop testing. Collaboration between human factors experts, system engineers, and operators ensures that modifications are both effective and practical.

When design changes are unavoidable, they should be narrowly scoped and strongly justified. Verification should include compliance checks against guidelines and practical operator evaluations. This approach minimizes disruption while maximizing safety improvements.

REFERENCES

[1] NUREG-0700(Rev.3), Human-System Interface Design Review Guidelines
[2] NUREG-0711(Rev.3), Human Factors Engineering Program Review Model