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HFE Process Guidance and Standards for Potential Application to Updating NRC Guidance

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1. BACKGROUND

For systems to operate safely and effectively, they must be designed to support the people who operate them. It is increasingly recognized in all industries that human factors issues must be considered as an early and central part of development. Experience shows that it is ineffective and risky to address human factors issues as an afterthought. The risks associated with inadequate attention to human factors issues can best be avoided by starting human factors engineering (HFE) activities as early as possible in the design process and continuing the activities throughout the development and implementation process.

Whatever type of system is being developed, the appropriate action is suggested by some underlying principles of good human factors practice. The overall objective should be to ensure that the development process is "human-centered".

The NRC recognizes the crucial role of the human element in nuclear facility design, operation and maintenance for safety. This requires the integration of Human Factors with other engineering disciplines. It cannot be conducted in isolation, and is very dependent on relationships with the large number of other role players who have a stake in the people aspects of usability and capability, and hence a stake in HFE. Best practice is thus only achieved when the principles of human factors are integrated into the mainstream of systems development. From both a quality and a regulatory point of view, HF activities must be shown to influence engineering and other decisions about original designs, operational procedures, procured equipment, and work force and training requirements. NUREG-0711, the *Human Factors Engineering Program Review Model*, was developed to encourage the application of human factors to the entire development process and is used by thr NRC in their licensing review process.

Good management is needed to address human factors comprehensively. In most cases, the activities of different parts of the development team must be closely coordinated, especially if the system being designed involves human tasks. The international nuclear industry has implemented successful approaches to controlling human factors activities and ensuring that they are integrated with the mainstream of development. It is not only a regulatory requirement, but also industry best practice to implement a rigorous methodology to ensure that human factors

activities proceed in parallel with technical development and timed to maximize influence on system and plant design.

This summary examines the international standards and guidelines needed for the programs, processes and procedures that must guide this integration within licensee organizations. It also highlights the applicability of particular standards or guidelines to the proposed updates of NUREG-0800, the *Standard Review Plan*, NUREG-0711 and NUREG-0700, *Human-system Interface Design Review Guidelines*.

2. THE NEED FOR HFE PROCESS STANDARDS AND GUIDELINES

2.1 REQUIREMENTS FOR A HUMAN FACTORS INTEGRATION PROCESS

Conducting HFE in nuclear engineering organizations requires a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to functions, structures, systems, components, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, effective human performance.

The core process of HFE is very simple, and is focused on an understanding of human-related issues that might represent risks, requirements or opportunities for the project. Five key processes characterize the integration:

- Identifying and managing human factors issues – this is the driving process
- Supporting analyses – necessary to underpin decisions and plans
- Co-ordination – essential to avoid duplication and mismatch
- Contribution to project outputs – how the value gets added
- Verification of compliance - ensuring that human factors requirements are implemented.

In particular, the HFE process must make provision for the following:

1. General requirements

The practical implementation of these processes as a multidisciplinary effort requires a Human Factors Integration process that focuses on:

- Identification and definition of requirements for the interaction between humans and technical system components and environments.
- The analysis and definition of the human activities and processes required to support the technical system.

- Supporting the design of systems, procedures, jobs and organizations to ensure that they match human capabilities and limitations.

2. Integrating human characteristics into system design to optimize performance within the human/machine system. This includes consideration of the following topics:
   - Equipment design
   - Workstation/ console design
   - Workplace layout
   - Maintenance access and ease of maintenance
   - Operator interface design (e.g. computing facilities and screen design)
   - Function allocation (between humans and automation)
   - Interaction among workers
   - Working environments (e.g. climate, lighting, noise).
3. Avoiding the safety risks which humans might cause by operating or maintaining the system improperly. This includes processes to assess the effects of, and prevent the consequences of:
   - Human reliability and sources of human error
   - Effects of misuse or abuse
   - External and environmental hazards
4. The short or long term hazards to health resulting from normal operation of the system. This includes processes to assess the effects of, and prevent the consequences of exposure to:
   - Nuclear radiation
   - Toxic materials
   - Electric shock
   - Mechanical injury
   - Musculoskeletal injury (e.g. heavy lifting; repetitive movement)
   - Extreme heat/cold
   - Extreme vibration
   - Extreme noise
   - Optical hazards
   - Electro-magnetic radiation
5. Assessment of the number of people required to operate and maintain the system. This includes processes to analyze and make recommendation to other stakeholders in the team on the following:
   - Staffing levels
   - Workload
   - Team organization
   - Anthropometric and general physical characteristics
   - Knowledge and ability requirements

- Job specifications

2.2 INTERNATIONAL HFE PROCESS STANDARDS AND GUIDELINES

There are several international standards and guidelines that describe how to achieve the integration of human factors in engineering processes. These standards and guidelines all address the following to a greater or lesser degree:

- A life cycle perspective on the application of HFE within a project, from concept onwards
- A common approach for identifying and managing human-related risks and opportunities
- How to undertake the core HFE activities in support of project objectives
- HFE contributions to add value to project outputs
- Guidance on the contribution that can be made by specialist technical activities
- Guidance on coordinating HFE activities with other stakeholders.

The standards discussed below were judged to be the most appropriate to the NRC and licensees' requirements. They all provide guidance on the development and management of the HFE process and the human-system products produced as a result of this process. Two groups of guidelines are included: those directly applicable to nuclear installations, and more generic ones not specifically related to nuclear installations.

2.3 STANDARDS AND GUIDELINES SPECIFIC TO NUCLEAR POWER PLANTS

No.	Standard		Applicability for update of NUREGs
1	IEEE 1023-1988	IEEE Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations	Applicable to the management of the human factors engineering process, in conjunction with NUREG-0711 and IEEE 1220-1998. The combination of NUREG-0711, IEEE 1023-1988 and IEEE 1220-1998 forms the basis of a methodology that employs sound system engineering practices in the management of PBMR's HFE process.

No.	Standard		Applicability for update of NUREGs
2	IEEE 1289-1998	IEEE guide for the application of human factors engineering in the design of computer-based monitoring and control displays for nuclear power generating stations	Applicable to the design of HSI displays in conjunction with NUREG/CR-6633, NUREG/CR-6634 and NUREG-0700. The document provides additional information not covered in NUREG-0700
3	IEC 60964	Design of Control Rooms for Nuclear Power Plants	Applicable to the design of control rooms. See IEC 60965 for specific requirements for the Independent Shutdown Room. To be read in conjunction with ISO11064. The combination of ISO 11064 and IEC 60964/5 provides a coherent set of HF criteria for PBMR control rooms.
4	IEC 60965	Supplementary control points for reactor shutdown without access to the main control room	Applicable to the design of the Independent Shutdown Room. To be read in conjunction with ISO11064. As for IEC 60964
5	IEC 61771	Control Rooms - Verification and Validation of Design	Applicable to the verification and validation of PBMR control rooms. To be read in conjunction with NUREG/CR- 6393. Can be used together with NUREG/CR-6393 to develop V&V requirements and plans for integrated systems.
6	IEC 61839	Design of Control Rooms - Functional Analysis and Assignment	Applicable to the analysis of functions related to control rooms. The document provides valuable guidance on functional analysis for control rooms not found in any other document. As such it can also provide valuable guidance for the development of Operating Descriptions.

No.	Standard		Applicability for update of NUREGs
7	IEC 62241	Main Control Room - Alarm Functions and Presentation	Applicable to the development of an alarm philosophy and general requirements for the presentation of alarms in the control room. To be read in conjunction with ISA 18.02 and EEMUA 191. These three documents provide important guidance on the development of comprehensive alarm documentation. They can be used by all disciplines involved (HFE, I&C and Operations).

2.4 STANDARDS AND GUIDELINES NOT SPECIFIC TO NUCLEAR POWER PLANTS

No.	Standard	Title	Applicability for update of NUREGs
8	ISA 18.02	Management of Alarm Systems for the Process Industries	Applicable to the development of an alarm philosophy and general requirements for the presentation of alarms in the control room. To be read in conjunction with IEC 62241 and EEMUA 191. See item 7
9	ISO 10075:1991	Ergonomic principles related to mental work-load -- General terms and definitions and Part 2: Design principles	Applicable to the development of HF Design Criteria and the analysis of operator workload (part of Task Analysis)
10	ISO 10551:1995	Ergonomics of the thermal environment -- Assessment of the influence of the thermal environment using subjective judgement scales	Valuable guidance for work environments where operators may be subject to thermal stressors.

No.	Standard	Title	Applicability for update of NUREGs
11	ISO 11064, Part 1 – 7	Ergonomic design of control centers	Applicable to Main Control Rooms and post-event/shutdown facilities and would be a valuable enhancement of NUREG-0700 as the standard provides valuable guidance on the principles of control center design arrangement of control suites, control room layout and control center verification and validation.
12	ISO 11226:2000	Ergonomics -- Evaluation of static working postures	Important guidance for the design of workspaces, inside the MCR and in the plant.
13	ISO 11228-1:2003	Ergonomics - Manual handling - Part 1: Lifting and carrying	Important guidance for the design of workspaces where workers are exposed to physical hazards.
14	ISO 11399:1995	Ergonomics of the thermal environment -- Principles and application of relevant International Standards	See item 13, 21 – 25, etc.
15	ISO 11428:1996	Ergonomics -- Visual danger signals -- General requirements, design and testing	Supplemental guidance for NUREG-0700
16	ISO 11429:1996	Ergonomics -- System of auditory and visual danger and information signals	Supplemental guidance for NUREG-0700
18	ISO 13406-1:1999	Ergonomic requirements for work with visual displays based on flat panels -- Part 1: Introduction, and Part 2: Ergonomic requirements for flat panel displays	Applicable to the development of Design Criteria for specific hardware layouts in control rooms (e.g. Reactor Protection System displays).
19	ISO 13407	Human-Centered Process for Interactive Systems	Applicable to the design and development of all human-system interfaces. The document is a general methodological guide to a human-centered process in al HFE activities and could be used as supplemental guidance in NUREG-0711 (in conjunction with IEEE 1023) for the development of integrated HFE processes.

No.	Standard	Title	Applicability for update of NUREGs
20	ISO 13688:1998	Protective clothing - General requirements.	General guidance on the use of PPE in the plant
21	ISO 15534-1:2000	Ergonomic design for the safety of machinery -- Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery	Important guidance for the design of workspaces where workers are exposed to physical hazards.
22	ISO 15534-2:2000	Ergonomic design for the safety of machinery -- Part 2: Principles for determining the dimensions required for access openings	
23	ISO 15534-3:2000	Ergonomic design for the safety of machinery -- Part 3: Anthropometric data	
24	ISO 6385:1981	Ergonomic principles in the design of work systems	General guidance on physical ergonomics – can be used in conjunction with NUREG-0700.
25	ISO 7243:1989	Hot environments -- Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature)	See item 21 - 23
26	ISO 7726:1998	Ergonomics of the thermal environment -- Instruments for measuring physical quantities	See item 21 – 23, 25
27	ISO 7730:1994	Moderate thermal environments -- Determination of the PMV and PPD indices and specification of the conditions for thermal comfort	See item 21 – 23, 25 - 26
28	ISO 7731:2003	Ergonomics - Danger signals for work places -- Auditory danger signals	See item 21 – 23, 25 - 27
29	ISO 7933:1989	Hot environments -- Analytical determination and interpretation of thermal stress using calculation of required sweat rate	See item 21 – 23, 25 - 28
30	ISO 8996:1990	Ergonomics -- Determination of metabolic heat production	See item 21 – 23, 25 - 29

No.	Standard	Title	Applicability for update of NUREGs
31	ISO 9241 Parts 1 – 17	Ergonomic requirements for office work with visual display terminals	NOTE that much of ISO 9241 is being updated and renumbered at present and many improvements are being made. Some existing parts are outdated (e.g. parts related to physical HSI components such as displays and input devices) and the updated parts should thus be consulted for updated NUREG-0700.
32	ISO 9355-1:1999	Ergonomic requirements for the design of displays and control actuators -- Part 1: Human interactions with displays and control actuators, and Part 2: Displays	Applicable to the development of Design Criteria for specific controls and displays in control rooms.
33	ISO 9886:1992	Evaluation of thermal strain by physiological measurements	See item 21 – 23, 25 - 30
34	ISO 9920:1995	Ergonomics of the thermal environment -- Estimation of the thermal insulation and evaporative resistance of a clothing ensemble	See item 21 – 23, 25 – 30, 33
35	ISO 9921:2003	Ergonomics - Assessment of speech communication.	Supplemental guidance for NUREG-0700
45	ISO/DIS 15536	Ergonomics - computer manikins and body templates.	See item 21 – 23, 25 – 30, 33 - 34
46	ISO/IEC 18035:2003	Information technology - Icon symbols and functions for controlling multimedia software applications.	Supplemental guidance for NUREG-0700
47	ISO/PAS 18152:2003	Ergonomics of human-system interaction - Specification for the process assessment of human-system issues.	To be used in conjunction with ISO 13407 and ISO 18529 for guidance in NUREG-0711 for development of human-centered systems development processes. This might also be used for Supplemental guidance in NUREG-0800 and 0711 on integration of human factors in the Systems Engineering Process.

No.	Standard	Title	Applicability for update of NUREGs
48	ISO/TR 16982:2002	Ergonomics of human-system interaction -- Usability methods supporting human-centered design	To be used in conjunction with ISO 9241-11
49	ISO/TR 18529:2000	Ergonomics -- Ergonomics of human-system interaction -- Human-centered lifecycle process descriptions	To be used in conjunction with ISO 13407 and ISO 18152 for guidance in NUREG-0711 for development of human-centered systems development processes. See also item 47
50	ISO/TS 13732-2:2001	Ergonomics of the thermal environment -- Methods for the assessment of human responses to contact with surfaces -- Part 2: Human contact with surfaces at moderate temperature	See item 21 – 23, 25 – 30, 33 – 34, 45
51	ISO/TS 16071:2003	Ergonomics of human-system interaction - Guidance on accessibility for human-computer interfaces	Important guidance on accessibility – should be added to NUREG-0800 and -0700
52	ISO/IEC 9216 Part 1 - 4	Information Technology — Software Product Quality	For reference only in NUREG-0700 and - 0711. This standard deals with software quality in the software engineering life cycle. It has a section on usability (referred to as “quality in use”) and thus overlaps with ISO 9241-11.
53	ISO/PAS 20282 Part 1 - 4	Ease of operation of everyday products	Important supplemental guidance on usability of commercial products, including metrics and usability testing. Although it is aimed at consumer products, the principles are equally applicable to industrial HSIs.