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Insights into the Role of the Operator in Advanced Reactor

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Nuclear power plant personnel play a vital role in the productive, efficient, and safe generation of electric power, whether for conventional light water reactors or new advanced reactors. It is widely recognized that human actions that depart from or fail to achieve what should be done can be important contributors to the risk associated with the operation of nuclear power plants. Advanced reactors are expected to present a concept of operations and maintenance to the power plant staff that is different from what is currently the case at conventional reactors. Therefore, regulatory staff will need new tools, developed from the best available technical bases, to support licensing and monitoring tasks. This paper addresses the development of regulatory review guidance to address these needs. The guidance will ensure that advanced reactor personnel have the tools, knowledge, information, capability, work processes, and working environment (physical and organizational) to safely and efficiently perform their tasks.

Nuclear power plant personnel play a vital role in the productive, efficient, and safe generation of electric power, whether for conventional light water reactors (LWRs) or for advanced reactors. Operators monitor and control plant systems and components to ensure their proper functioning. Test and maintenance personnel help ensure that plant equipment is functioning properly and restore components when malfunctions occur.

It is widely recognized that human actions that depart from or fail to achieve what should be done can be important contributors to the risk associated with the operation of nuclear power plants. Studies of operating experience demonstrate that human performance contributes to a large percentage of events and has a significant impact on the risk associated with nuclear power generation. Studies of probabilistic risk assessment (PRA) results found that:

- human error is a significant contributor to core damage frequency (CDF)
- by improving human performance, licensees can substantially reduce their overall CDF
- a significant human contribution to risk is in failure to respond appropriately to accidents
- human performance is important to the mitigation of and recovery from failures [1]

Advanced reactors are expected to present a concept of operations and maintenance to the power plant staff that is different from what is currently the case at conventional reactors. For example, operators may be expected to concurrently control multiple modules, which could be in different operating states, from a common control room. Operators may be required to monitor online refueling in one module, while other modules are in normal operating states, and another module could be facing a transient. The control rooms are expected to be fully computer-based, using glass cockpit concepts. Procedures are likely to be computerized and control actions may be taken directly from the procedure display, or semi-automated, with the operator authorizing the procedure to take actions. Different training and qualifications may be required for the plant staff to maintain digital systems and to focus decision-making on monitoring and bypassing automatic systems rather than the active control that LWR operators now take. Higher-levels of knowledge and training may be needed to respond to situations when automatic systems fail.

These activities will pose new and challenging situations for operators and maintainers. Regulatory staff will need new tools, developed from the best available technical bases, to support licensing and monitoring tasks. This will ensure that advanced reactor personnel have the tools, knowledge, information, capability, work processes, and working environment (physical and organizational) to safely and efficiently perform their tasks. The ultimate goal is to ensure minimal human error contribution to the risk associated with the design, construction, operation, testing, and maintenance of these new design facilities.

In accordance with 10 CFR 52, the staff of the Nuclear Regulatory Commission (NRC) reviews the human factors engineering (HFE) programs of applicants for construction permits, operating licenses, standard design certifications, and combined operating licenses. [2] The purpose of these reviews is to help ensure safety by verifying that acceptable HFE practices and guidelines are incorporated into the applicant's HFE program. The review methodology in NUREG-0711, "Human Factors Engineering Program Review Model," [3] and Standard Review Plan (SRP) Chapters 13 [4] and 18 [5] is the basis for performing reviews. The reviews address 12 elements of an HFE program: HFE Program Management; Operating Experience Review; Functional

Requirements Analysis and Allocation; Task Analysis; Staffing; Human Reliability Analysis; Human System Interface Design; Procedure Development; Training Program Development; Human Factors Verification and Validation (V&V); Design Implementation, and Human Performance Monitoring.

Current regulations and guidance (for example: 10 CFR 26 [6], 10 CFR 50 [7], 10 CFR 52 [8], and 10 CRF 55 [9], Regulatory Guides 1.8 [10], 1.134 [11], 1.149 [12], NUREG-0700 [13], NUREG-0899 [14], NUREG 1220 [15]) that address human performance issues were developed for review of LWRs and advanced LWRs. The current approach is based on the concept that the HFE aspects of advanced reactors should be developed, designed, and evaluated on the basis of a structured systems analysis using accepted HFE principles at the same time as other systems are being designed. The needs of personnel must be considered as a part of the system design from the initial concept development stage so that the role allocated to personnel is appropriate, as specified in regulatory review guidance such as NUREG-0711 and industry design guidance such as IEEE 1023 [16].

Though many of these rules and guidelines may be applicable to new reactor designs with little or no adaptation, as more advanced reactor and control technology is developed, e.g., Generation IV designs, new regulations and guidance may need to address the new and substantially different concepts of operations. The NRC is currently developing a technical basis for the new guidance.

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