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RECENT EFFORTS TO RISK-INFORM THE OPERATING REACTOR PROGRAM AT THE U.S. NUCLEAR REGULATORY COMMISSION

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ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) has a longstanding commitment to increase use of probabilistic risk assessment (PRA) in a manner that complements its deterministic approach (USRNC,1995) and has continuously improved how it uses risk insights to make better informed decisions in meeting its important safety and security mission. This includes advancement of risk-informed operational programs for operating reactors such as risk-informed categorization and treatment of structures, systems and components under 10 *Code of Federal Regulations* (10 CFR) 50.69 (USNRC, 2004) and risk-informed technical specifications completion times, or TSTF-505 (USNRC, 2018). With industry's increased implementation of risk-informed programs, NRC is also ensuring appropriate oversight, including inspection guidance and training updates. Additionally, the NRC is implementing the *Be riskSMART* framework (USNRC, 2021) to apply risk insights more broadly in decision-making, enabling better focus on those items of greatest importance. For example, NRC is applying *Be riskSMART* to better risk-inform its response to emergent operating reactor events, licensing reviews, and oversight efforts (e.g., the Risk-informed Process for Evaluations (RIPE), the Very Low Safety Significance Issue Resolution Process (VLSSIR)).

This paper provides an overview of a few of NRC's recent efforts to risk-inform the operating reactor program including a brief historical context for these initiatives, a summary of current licensing and oversight initiatives, and examples from recent reviews and process enhancements.

INTRODUCTION

Even in its formative years, the NRC recognized that the greatest safety benefits and resource efficiencies may be gained when likelihood is considered in conjunction with postulated accident scenarios and their consequences (i.e., the "risk triplet"). This early recognition is embodied, in part, through the publication of the 1975 Reactor Safety Study, WASH-1400 (USNRC, 1975), which provided a quantitative assessment of the risk of severe accidents. Insights from WASH-1400 and the Three Mile Island Unit 2 plant accident prompted NRC to aggressively embark on its nearly five-decade journey to leverage risk insights to become a more risk-informed regulator.

Despite the NRC's pioneering role in the area, factors at the time (e.g., less mature and diverse PRA methods, limited operating experience data) led to a continued reliance on a regulatory framework primarily dependent on design criteria. Thus, the NRC maintained a largely deterministic regulatory framework in which structures, systems, and components (SSCs) credited for mitigating and preventing design basis accidents are of equal importance, versus a risk-informed framework focusing protective measures for SSCs according to risk significance.

Although a largely deterministic regulatory framework has ensured protection of public health and safety for over four decades, numerous key efforts embodied in Commission policy statements, regulatory review standards, reactor oversight and enforcement practices, and staff processes and procedures, highlight the NRC's commitment to embracing and increasing the use of risk-informed decision-making (RIDM). Among the most foundational policy setting documents are the Commission policy statements on safety goals (USNRC, 1986) and on use of PRA (USRNC, 1995). These policy statements established goals that broadly define an acceptable level of radiological risk and formalized the NRC's commitment to increasing the use of PRA technology to the extent supported by the state of the art in PRA methods and data, and in a manner that complements the NRC's deterministic approach and supports its traditional defense-in-depth philosophy. The Commission later defined relevant terminology and reaffirmed its expectations in a white paper on a risk-informed, performance-based approach to regulatory decision-making (USNRC, 1999).

The staff developed and executed several plans to implement Commission policy related to RIDM, including the PRA Implementation Plan (USNRC, 1994), the Risk-Informed Regulation Implementation Plan (USNRC, 2000), and the Risk-Informed and Performance-Based Plan (USNRC, 2007). These initiatives helped shape foundational guidance and regulations, such as Regulatory Guide (RG) 1.174 issued in 1998 (USNRC, 2018), that articulates NRC's philosophy whereby risk insights are considered in conjunction with other factors to better focus licensee and regulatory attention on design and operational issues, commensurate with their importance to public health and safety, and regulations such as 10 CFR 50.65 (USNRC, 1991), and 50.69 (USNRC, 2004), regarding maintenance and SSC classification, respectively. In addition, these plans spurred efforts to develop the risk-informed reactor oversight process, representing a significant change to the NRC's regulatory approach to characterize inspection findings and violations (USNRC, 1999) and RG 1.200 issued in 2004 (USNRC, 2020) that endorses consensus industry PRA standards and describes the expected level of PRA acceptability (i.e., scope, level of detail, plant representation, and technical elements) for use in risk-informed applications. The NRC's involvement in the refinement and development of PRA standards continues today (e.g., trial RG 1.247, USNRC, 2022). A proposed Risk Management Regulatory Framework (USNRC, 2012) also provided a strategic vision and options for adopting a more comprehensive, holistic, risk-informed, and performance-based regulatory approach leading to a continued affirmation of the importance of making risk-informed regulatory improvements on an incremental basis.

Examples of the use of PRA risk insights dating back to the mid-1980's include the issuance of Generic Letter 88-20 and supplements regarding severe accident vulnerabilities (USNRC, 1998), the anticipated transients without scram (ATWS) rule in 10 CFR 50.62 (USNRC, 1984), the station blackout (SBO) rule in 10 CFR 50.63 (USNRC, 1988), and the previously mentioned maintenance rule in 10 CFR 50.65. In the 2000s, NRC published two additional risk-informed regulations, 10 CFR 50.69 (50.69) and 10 CFR 50.48(c) (USNRC, 2004), that provided voluntary risk-informed alternatives for complying with regulations while enhancing safety focus. The regulations in 10 CFR 50.48(c) allows for the adoption of the National Fire Protection Association (NFPA) Standards Standard 805 (NFPA, 2001) and describes a methodology for light-water nuclear power plants to apply risk-informed, performance-based requirements and fundamental fire protection design elements to establish fire protection systems and features, as opposed to the deterministic fire protection requirements which were developed before the staff or the industry had the benefit of PRAs for fires and before recent advances in performance-based methods.

More recently, in 2017, the NRC developed a plan to better risk-inform its activities in the Office of Nuclear Reactor Regulation's (NRR) Risk-Informed Decision-Making (RIDM) Action Plan

(USNRC, 2017). The RIDM Action Plan (1) formalized an integrated review team approach that increases collaboration between risk analysts and traditional engineering technical reviewers; (2) provided plans for a systematic, graded approach for expanding the use of risk insights within the existing regulatory framework; (3) created training modules used during the rollout of improved guidance documents and procedures; and (4) laid the groundwork for continued advancement of NRC and industry risk-informed initiatives and for enhanced communication and awareness of RIDM activities.

In 2018, the NRC embarked on a journey to become a modern risk-informed regulator that focuses its efforts on the most important aspects of its work and simplifies its processes to enable quality decisions without undue delay. One way the NRC reinvigorated its longstanding goal in the area of ensuring a focus on issues of greatest safety and security was the development of the *Be riskSMART* framework. *Be riskSMART* is a holistic, high-level framework providing staff confidence to consistently apply and communicate risk information for all NRC decisions without compromising NRC mission. The framework is used across NRC corporate, technical, and legal programs and allows for effective communication of how risk information is used to make the best decisions. NUREG/KM-0016 (USNRC, 2021) provides a one-stop resource for using the Be *riskSMART* framework, including example case studies, mapping of discipline-specific processes and guidance, and initial diagnostic tool and survey data.

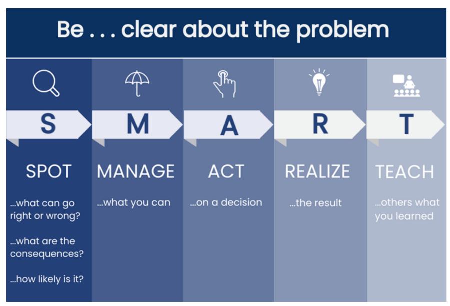

Figure 1. NRC *Be riskSMART* Framework

Figure 1 summarizes the key steps of the *Be riskSMART* framework. The first step is to Be…clear about the problem. The problem could range from a simple binary question to a more complex decision involving multiple individuals or organizations such as how to enhance a process to realize the NRC's Principles of Good Regulation more fully. Spotting involves evaluation of the risk triplet: what can go wrong, how likely is it, and what are the consequences. This step also explicitly includes consideration of the opportunities associated with a decision (i.e., what can go wrong or right). It can involve both quantitative and qualitative considerations. Secondly, in the manage step, users consider strategies to reduce the likelihood of negative consequences or enhance opportunities. These strategies could take many forms, from increased communications or training to additional inspections or review resources. Third, the Act on a decision step includes considering all stakeholder perspectives and evaluating what was "spotted" and "managed" in the context of the risk appetite for the decision. In plain language, risk appetite or risk tolerance, is simply the amount of risk one is willing to accept. Depending on the decision, it can be defined by an individual, a group of individuals, or an entire organization and it can also be different for different aspects of a decision. While simple decisions may not require extensive documentation, the framework does provide a tool from enterprise risk management, a heat map, to help decisionmakers visualize the challenges and opportunities, the effects of management techniques, and the risk appetite associated with the decision. Fourth, the realize step involves implementing the decision while managing and measuring performance and progress. Realizing could involve effectiveness reviews and other similar assessment tools to measure results that can then be used as part of a continuous performance management strategy to adjust and fine tune. The last step, teach, involves sharing knowledge to a broader audience, enabling staff to apply best practices in new contexts to address novel problems. Finally, as a continual learning organization, the arrow reflects the iterative nature of the framework encouraging staff to revisit any of the steps at any time or to even formulate a new problem.

Through the many historical initiatives discussed and the more recent efforts, such as *Be riskSMART* framework, that reinvigorate the Agency's commitment to risk-informed decision-making, the NRC is focusing its efforts to the matters of greatest importance to our safety and security mission.

RISK-INFORMED INITATIVES FOR THE OPERATING FLEET

10 CFR 50.69 Risk-Informed Categorization

The voluntary rule in 50.69 provides for a risk-informed alternative for classifying SSCs based on their safety significance. The rule provides for alternative treatment for safety-related equipment that is found to be of low safety significance in areas such as quality assurance, inservice testing, inservice inspection, environment qualification. As a performance-based rule, 50.69 allows licensees to establish the alternate treatment, but requires them to ensure, with reasonable confidence, that SSCs remain capable of performing their safety-related functions under design basis conditions, including seismic and environmental conditions and effects throughout service life.

Categorization under 50.69 is a multi-disciplinary, risk-informed effort that considers quantitative risk information along with more traditional design criteria elements. The 50.69 process excels at balancing the input of different fields to find the appropriate considerations for SSC safety significance. Figure 2 shows an overview of the categorization process as described by the guidance in NEI 00-04 (NEI, 2005) as endorsed by RG 1.201 (USNRC, 2006). The process relies on risk inputs based on PRA, or PRA type bounding methods, that address all initiating events, internal and external, and plant operating modes, as well as deterministic inputs, including evaluation of defense in depth, and certain qualitative considerations. The use of an integrated decision-making panel (IDP) is central to the classification process. The IDP is a group of experts with comprehensive collective expertise that makes final decisions on the categorization of SSCs. Another important aspect is the requirement for periodic review and process adjustment to either the categorization or treatment processes so that the categorization process and results are maintained valid. To date, licensees for approximately 50% of U.S. nuclear units have received an NRC amendment to use the 10 CFR 50.69 program with many others submitted or expressed interest in applying for the program.

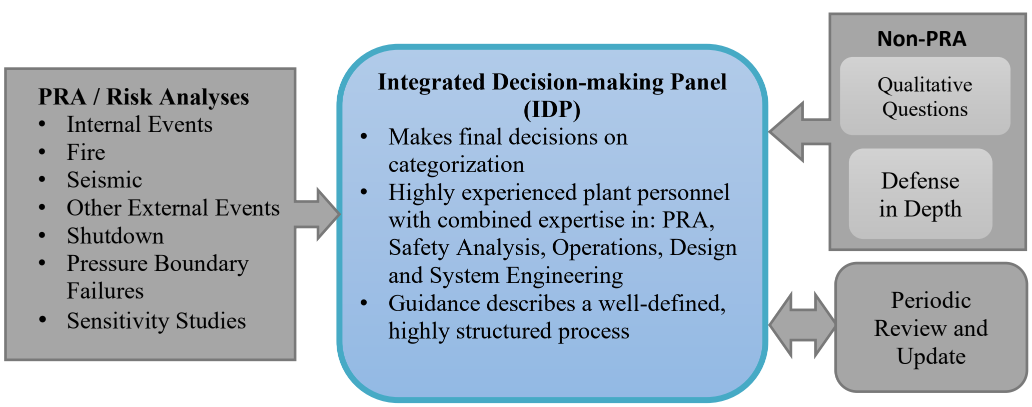

Figure 2. An overview of the 10 CFR 50.69 categorization process endorsed by RG 1.201

Risk-Informed Completion Times: Technical Specification Task Force (TSTF) - 505

Over the years, since the PRA policy statement in 1995, the NRC has seen many initiatives for improving and risk-informing the operating fleet Technical Specifications under the Risk-informed Technical Specifications Initiative (RITS). Technical Specifications dictate plant operations by defining which SSCs must be in service, how long SSCs can be out of service before certain actions would be required and required surveillance testing to establish whether an SSC is operational. The increased use of risk information has enabled enhanced operational flexibility while ensuring safety. Some of the initial initiatives were modest in use of the risk information, for example by using bounding methods for deriving new and longer, but fixed, fleet-wide completion times. These initiatives culminated in the risk-informed completion times TSTF-505 (USNRC, 2018) initiative, which allows licensees to use their plant-specific PRA and real-time configuration risk to inform decisions about inoperability of plant equipment and determine the duration of select Technical Specification completion times. In addition to determining duration, the licensees also use the risk insights derived from the PRA to inform risk management and compensatory actions. To obtain approvals for this program, a high level of PRA acceptability is expected (i.e., scope, level of details, conformance with the PRA standard elements), with PRAs subject to a robust regulatory review. The TSTF-505 program is a transformative program that leverages the maturity in PRA technology and provides increased operational flexibility while maintaining safety and reducing the need for license amendment requests for single changes to completion times or emergency Notices of Enforcement Discretion (NOED) requests. To date, licensees for approximately 30% of U.S. nuclear units have received an NRC amendment to use the TSTF-505 program with many others submitted or expressed interest in applying for the program.

RISK-INFORMED PROCESS ENHANCEMENT

Very Low Safety Significance Issue Resolution

The NRC established the very low safety significance issue resolution process (VLSSIR) initiative in 2020 to efficiently address licensing basis questions of very low safety significance that otherwise could not be resolved without a significant effort. The VLSSIR process enables NRC staff to focus on items of greater significance. This initiative resulted in revisions to NRC inspection procedures and the process has been used to close 11 issues to date. A recent self-assessment indicates that VLSSIR provides a predictable framework to review, assess, and disposition issues of very low safety significance that are not clearly within a plant’s licensing basis (Masters, 2021).

Risk-Informed Process for Evaluations

The Risk-Informed Process for Evaluations (RIPE) is complementary to VLSSIR in that it establishes a more efficient process to address low safety significance issues within the licensing basis. RIPE leverages existing regulations (e.g., 10 CFR 50.12 and 50.90) and risk initiatives (e.g., 50.69 and TSTF-505) as a basis for creating a streamlined NRC review process for plant-specific exemptions and license amendments for low safety significant issues. To use the streamlined review process, the safety impact of the issue under consideration should be determined as none or minimal, as described in the RIPE guidance (USNRC, 2021). This process ensures that the resources associated with the NRC’s review are commensurate with the safety significance of the issue being evaluated. This process necessitated that the licensee has a PRA that was previously reviewed by the NRC staff, such that the NRC staff has confidence in the risk evaluations provided by the licensee. Therefore, licensee adoption of TSTF-505 was one entry criterion for using RIPE, due to the increased needs for PRA acceptability required to support an NRC approval of the TSTF-505 program (Nieh, 2021). Subsequently, RIPE was expanded in Revision 1 (Zoulis, 2021) to allow licensees to demonstrate they have a technically acceptable PRA using an approved program for risk-informed technical specifications surveillance frequencies TSTF-425. The NRC has recently applied this process successfully and issued a partial exemption from the ATWS requirements in 10 CFR 50.62(c)(1) to remove the Diverse Auxiliary Feedwater Actuation System from the Palo Verde licensing basis (USNRC, 2022).

Office Instruction LIC-206, Integrated Risk-Informed Decision-Making for Licensing Reviews

To support a robust licensing and oversight framework the NRC has updated its internal processes for regulatory decision-making to increase the use of risk insights in traditionally deterministic applications. Specifically, the NRC issued LIC-206 (USNRC, 2020), an internal office instruction that enables NRC staff to better consider risk insights in routine and non-routine licensing reviews through the establishment of integrated review teams, where risk analysts work together with traditional deterministic reviewers to ensure greater consistency and transparency for outlining the basis for decision-making and safety conclusions. LIC-206 establishes a framework that empowers the NRC staff to seek and use risk information that may not be provided in the submittal, but available to the staff from other sources, external to the submittal, such as information from previous reviews, regulatory guidance, operating experience, NRC simplified PRA (Standardized Plant Analysis Risk (SPAR)) models, etc. This process increases the use of risk information in establishing the necessary scope of review and achieving reasonable assurance findings.

Office Instruction LIC-504, Integrated Risk-Informed Decision-making for Emergent Issues

LIC-504 (USNRC, 2020) is another internal office instruction which utilizes risk-informed decision-making principles to determine whether immediate regulatory action would be necessary for emergent safety issues and document the bases of those decisions. The LIC-504 analysis process is a two-step process that could result in four different scenarios: (1) determining whether to take prompt regulatory action, such as issuing an order to shut down the unit(s) or take compensatory measures at the site where the concern is identified; (2) determining whether it is necessary to take prompt regulatory action for other operating nuclear power plants (i.e., if a generic concern exists), such as issuing shutdown orders or ordering compensatory measures; (3) developing risk-informed options to resolve the issue at the unit or site where the concern is identified; and (4) developing risk-informed options to resolve the issue at potentially other affected units, as appropriate. The NRC is using the process described in LIC-504 to identify if there are any potential safety issues that may be applicable to operating light-water reactors in the United States and develop risk-informed options to disposition them.

For example, NRC used LIC-504 following a loss of offsite power event that occurred at Duane Arnold Energy Center (DAEC) due to a derecho event, in order to evaluate potential safety impacts to other nuclear power plant licensees. On August 10, 2020, the DAEC experienced severe thunderstorms and high winds associated with a derecho, a widespread, long-lived, straight-line windstorm associated with a band of rapidly moving thunderstorms. This storm included wind gusts of 80–100 miles per hour (mph), with the most extreme winds in the area measured at approximately 130 mph (USNRC, 2021). During its LIC-504 evaluation, the NRC staff analyzed plants with different design characteristics that estimated the risk increases due to a similar combined event (i.e., concurrent challenges to offsite power supplies and the functionality of the Emergency Service Water system due to a sudden inrush of debris to the intake structure) and concluded that the safety implications can vary significantly based on site, plant design, and plant operating characteristics. The risk analyses performed by the staff confirmed that the potential increases in risk associated with the issue were below the value for which the NRC would consider taking immediate regulatory action, such as issuing shutdown orders or imposing compensatory measures to ensure public health and safety.

CONCLUSIONS

The NRC's efforts explored in this paper are resulting in better focus on the most important aspects of the work, simplified processes that enable quality decisions without undue delay, and flexibility in the NRC's regulatory framework while maintaining focus on safety and security.

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