Task 3: Probabilistic Risk Assessment Activities

The U.S. Nuclear Regulatory Commission (NRC) uses probabilistic risk assessment (PRA) to estimate risk in order to investigate what can go wrong, how likely it is, and what the consequences could be. The results of PRAs provide the NRC with insights into the strengths and weaknesses of the design and operation of a nuclear power plant. PRA is used in a wide range of NRC regulatory activities, including many risk-informed licensing and oversight activities (e.g., Risk-Informed Technical Specifications initiatives, the Significance Determination Process portion of the Reactor Oversight Process). These activities make use of both plant-specific licensee PRA models and plant-specific NRC PRA models. The former are used predominantly for licensing and operational activities, while the latter are used predominantly for oversight activities. A key tenet of risk-informed decision-making is that these models reflect the as-designed, as-operated plant, meaning that they must be updated to reflect significant plant modifications. The introduction of significantly different fuel in to the reactor core has the potential to affect these models, particularly once the reactor core composition significantly influences the plant's response to a postulated accident (e.g., time to fuel heatup and degradation, amount of total hydrogen generation).

Activities associated with developing capabilities to support risk-informed regulatory activities following implementation of accident tolerant fuels (ATF) could be significant and information about industry's intended approach is needed to create a meaningful plan. Early interactions within the PRA community on ATF activities, including early pre-application meetings, are encouraged to ensure that the approach being pursued is consistent with the related regulatory requirements and staff guidance. This plan recognizes that there are multiple separate, but closely-related, aspects to PRA-related preparatory work by the staff:

1. Preparation for, and review of, PRA-related information submitted as part of the licensing process for both batch loading of ATF and incorporation of the safety enhancements of ATF into the licensing basis, and
2. Development of PRA-related capabilities that allow the staff to effectively:
    a. Review risk-informed licensing applications, including assurance that acceptable PRA models are being used, once ATF is implemented, and
    b. Perform risk-informed oversight evaluations (e.g., Significance Determination Process) once ATF is implemented.

The nature of item #1 is highly dependent on the approach taken by each vendor and/or licensee in its licensing application. Item #2, however, is somewhat independent of the licensing approach for batch loading of ATF and therefore this plan currently focuses more attention on item #2.

As illustrated by the above categorization, PRA is relevant to ATF more broadly than incorporating the safety enhancements of ATF into the licensing basis. Again, this stems from the fact that the NRC uses a risk-informed licensing and oversight approach that relies on plant-specific PRAs that represent the as-built and as-operated plant. Evolutionary ATF designs may have a limited impact on PRA modeling, while revolutionary ATF designs may have a more significant impact on PRA modeling. In general, the PRA modeling changes in question relate to:

- Selection of core damage surrogates used in defining PRA end-states (e.g., peak nodal clad temperature of 1204C, water level at 2/3 active fuel height);
- Accident sequence modeling assumptions used to create event tree models that define the high-level successes and failures that can prevent core damage (e.g., late containment venting is required for avoiding core damage);
- System success criteria used in fault trees for defining the minimum hardware needed to fulfill specific mitigation functions (e.g., two relief valves needed to prevent injection pump dead-head when feed and bleed cooling is used for a transient with no feedwater);
- Sequence timing assumptions used in accident sequence modeling, success criteria determinations, and human reliability analysis to establish relevant time windows (e.g., feed and bleed cooling must be initiated within 20 minutes of low-low steam generator water level).

The staff will need to ensure that licensees' PRAs continue to use acceptable models and assumptions as part of the implementation of ATF and update internal models (as necessary) to reflect the ATF plant modifications.

Much of the needed underlying deterministic knowledge to address these points can leverage the work covered elsewhere in this plan, particularly the fuel performance, thermal hydraulics, and severe accident analysis capability development. It is envisioned that much of the analytical investigation needed to assess PRA-related impacts and support PRA-related changes in the agency's Standardized Plant Analysis Risk (SPAR) model, can utilize the MELCOR modeling and analysis discussed elsewhere in this plan. If needed, additional confirmatory analysis could also be pursued using MELCOR plant models developed for other NRC initiatives (such as those documented in NUREG-1953 and NUREG-2187). This leveraging of resources between severe accident analysis tools and PRAs is routine.

In the nearer-term, PRA-related impacts can be assessed using the general knowledge being developed in these other ATF project plan areas, in conjunction with one or more pilot efforts using the existing SPAR models. Such pilots would serve to gain risk insights, assess the potential changes in core damage frequency (CDF) and large early release frequency (LERF)[1], and highlight areas where existing guidance[2] or methods may require refinement to address the implementation of ATF.

As a final introductory point, engagement on PRA-related topics both within the staff and with external stakeholders is important at all stages. Effective interaction will foster a common understanding regarding the acceptability of PRA methods used to model plant modifications and the impact that will ultimately be realized when these modifications are integrated into PRAs and risk-informed processes. Effective interaction can also ensure that information required to

[1] Difference in LERF could manifest for several different reasons, such as: (i) differing fuel heatup and degradation time windows, (ii) the generation of differing amounts of in-vessel hydrogen, (iii) changes to the fission product release rates, and (iv) shifts in the balance of challenges to other vessel and connected piping system components stemming from higher in-core temperatures prior to debris relocation.

[2] Guidance here is intended to refer to the full set of guidance used in risk-informed licensing and oversight (e.g., the Standard Review Plan, relevant Regulatory Guides, Inspection Manual Chapter 0609, the Risk Assessment Standardization Process manual, etc.) In reality, most of this guidance would not require revision because the concepts and processes would continue to apply. However, some aspects could require modification, such as LERF multipliers utilized in IMC 0609 Appendix H, while some guidance may benefit from additional discussion of ATF impacts.

develop PRA modeling assumptions related to plant modifications is properly coordinated with the deterministic review. In this case, PRA relevance has been identified early in the process, and time is available to address the PRA-related needs in a thoughtful and symbiotic manner.

For the purpose of identifying the PRA-related milestones, a few key assumptions are needed, some of which are re-statements of assumptions made elsewhere in this plan:

1. The timing of PRA-related efforts will be cross-coordinated with those of the previously-identified partner areas (e.g., severe accident analysis), such that deterministic work can be leveraged to make the PRA-related efforts efficient. A different approach might be needed if there is a strong desire to assess the industry's early perspective on the potential risk significance of ATF designs, as they relate to future submittals aimed at leveraging ATF to reduce regulatory requirements.
2. For all designs in question, the earliest topical report (TR)/license amendment request (LAR) review would start in 2020, with "revolutionary" ATF design licensing reviews occurring no earlier than 2023.
3. This plan does not account for new regulatory initiatives that might be requested in order to maximize the operational or economic benefit of ATF, such as:
    a. Modifications to the Title 10 of the *Code of Federal Regulations* (10 CFR) 50.69 categorization process associated with the use of relative (as opposed to absolute) CDF/LERF criteria[3];
    b. Reduction of requirements associated with security and emergency preparedness programs.

[3] This has been mentioned as a potential limitation in the degree of benefit that would be gained in risk-informed licensing space, and contrasts to the use of absolute risk measures in other relevant risk-informed licensing activities like risk-informed technical specification initiatives.

Table 1: PRA Activities - Milestones

	Milestone	**Input Needed**	**Lead Time / Duration**	**Needed By**
1	Participate in internal and external discussions and knowledge development related to ATF (e.g., internal working group meetings, public meetings)	N/A	Ongoing	N/A
2	Complete licensing reviews, including potential TRs or industry guidance, related to the risk-informed aspects of ATF licensing	More information regarding the specific licensing approach	TBD	TBD
3	Complete a SPAR pilot of an evolutionary ATF design for a BWR and PWR subject plant to assess CDF/LERF impact, gain risk insights, and identify potential improvements to guidance	Deterministic knowledge base being developed under other tasks (e.g., MELCOR analysis)	6 months	1 year prior to 1st evolutionary ATF core load[1]
4	Complete a SPAR pilot of a revolutionary ATF design for a boiling water reactor (BWR) and pressurized water reactor (PWR) subject plant to assess CDF/LERF impact, gain risk insights, and identify potential improvements to guidance	Deterministic knowledge base being developed under other tasks (e.g., MELCOR analysis)	6 months[2]	1 year prior to 1st revolutionary ATF core load[1]
5	Update guidance (as necessary) to support licensing and oversight functions for plants making ATF-related modifications	Completion of the items above	1 year	Prior to ATF core load[1]
6	Update agency PRA models to reflect ATF-related changes to the as-built, as-operated plant for relevant plants/models	Details of the plant modifications	1 year[3]	As needed to support agency risk evaluations

[1] Here, core load is intended to mean the replacement of a large proportion (e.g., 50% or more) of the core with ATF assemblies, under the assumption that non-ATF fuel will be generally more limiting to PRA impacts if a mixed core exists.

[2] This task should be performed sequentially after the equivalent task for evolutionary ATF designs, so long as both evolutionary and revolutionary designs remain of regulatory interest.

[3] This would occur after approval of the associated licensing action.

Table 2: PRA Activities - Deliverables

Title	Lead Time
Safety Evaluation contributions for TRs and LARs related to ATF	TBD
Report documenting results and recommendations from evolutionary ATF SPAR pilot study	1 year prior to 1^{st} evolutionary ATF core load
Report documenting results and recommendations from revolutionary ATF SPAR pilot study	1 year prior to 1^{st} revolutionary ATF core load
Updated guidance (e.g., Risk Assessment Standardization Project guidance changes) to support licensing and oversight functions for plants making ATF-related modifications	Varies depending on the documents requiring modification
Updated agency PRA models to reflect ATF-related changes to the as-built, as-operated plant for relevant plants/models	As needed to support agency risk evaluations

Technical Lead: NRR/DRA/APLB