The U.S. nuclear industry is facing a strong challenge to ensure maximum safety while enhancing economic performance. Safety is a key parameter to all aspects related to light water reactor (LWR) nuclear power plants—especially cost-savings. The LWRS Program is conducting R&D to maximize nuclear power plant safety, economics, and performance, which is being accomplished by optimizing the safety margin and reducing fuel requirements constituting the main targets of the “Plant Reload Process Optimization” (PRPO) project, as observed in Figure 9. Optimization of a plant’s reactor core fuel load is a top priority because it can help to reduce fuel costs. Safety margin optimization will also be proposed by developing independent methods for design basis accident (DBA) analysis that will be compliant with current rules, pending rulemaking, and associated regulatory guidance.

**Project Overview**

The PRPO project is developing technologies that can have a near-term impact in the nuclear power industry. To aim for immediate benefit: (1) all tools must be mature enough to accurately reflect the physics under investigation; and (2) simulation models must have enough detail to accurately represent the physics. In addition, scenario results must be credible and representative of the models to be submitted to the U.S. NRC for approval.

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**Figure 9. Plant Reload Licensing Optimization Framework.**

- **RAVEN**
  - Risk
  - External Model
  - Hypothetical Model
  - Scenario Model
  - Post Process
  - Data Structures
  - Steps & Job Handler
  - Output

- **Physics Framework**
  - Risk-Informed Licensing Process
    - Design Basis Accidents in Risk-informed space
    - Thermal limits’ optimization
    - Safety margins’ characterization
  - Optimized Reload Patterns
    - Risk Weightedreload patterns optimization
    - Improved fuel utilization
    - Reduced fuel batch (enrichments)
  - Expected Outcomes
    - Operational costs’ reduction
    - Analysis costs reduction with high modeling automation
    - Independent fuel reload licensing methodology

- **System Simulator**
  - RELAP5-3D
  - COBRA-TF

- **Fuel Performance**
  - BISON
Successful project execution is envisioned to act as an accelerator to risk-informed commercial initiatives for the deployment of vendor independent safety analysis capabilities to U.S. utilities, enabling the creation of a workable framework for realistic scenarios and analysis methodology that will demonstrate the feasibility and readiness for licensing applications. The goals of the project are: (1) to optimize fuel thermal limits to reduce the feed fuel batch size; (2) to develop methods/tools that are independent from fuel vendors that can be used in-house to reduce reload costs; and (3) to develop a complete set of methods/tools for reload analysis that will commoditize the nuclear fuel market.

The project has been organized into four phases:

1. Phase I - DBA Methods: From a deterministic perspective, this phase focuses on studying the limiting events in Chapter 15 (NUREG-0800) for a prototypical Pressurized Water Reactors (PWR) and on the investigation of optimization algorithms for the fuel pattern and thermal limits optimization.

2. Phase II - RISA Methods Development: Develop the methods to optimize the thermal limit.

3. Phase III - RISA Benefit Quantification: Demonstrate the methodology with plant reloading using a management method developed using optimized safety limits.

4. Phase IV - RISA Methodology Acceleration Phase: Conclude the project, focusing on acceleration techniques for the methodological and software framework.

**PHASE I – DBA METHODS**

In 2020, Phase I of the project was deployed with the goal of demonstrating the gains of the RISA Pathway with a collaborating U.S. nuclear power plant to implement and license risk-informed scenarios, building a foundation of trust that the analysis outcomes would reflect operating nuclear power plants. The first stage of Phase I was a careful analysis of NUREG-0800 [1] to determine the key thermal limit scenarios that should be simulated with the RISA framework for benchmarking to the DBAs of an operating nuclear power plant. Phase I focused on the investigation of possible ways to move from the classic requirements in NUREG 0800 Chapter 15 to the risk-informed space outlined in NUREG-0800 Chapter 19. Throughout Phase I and with a comprehensive RELAP5-3D model, the team reviewed and simulated the Chapter 15 limiting events, as shown in Table 1, which demonstrated good accuracy [2] in comparison with typical PWR results. In collaboration with the RISA Pathway, the second stage of Phase I revolved around the development of optimization methods. Considering the nature of the problem, heuristic approaches were the most suitable methods and, subsequently, genetic algorithms were deployed in RAVEN [3], which is the main software platform for the development of the framework. Phase II is scheduled to be completed in 2021 and Phases III and IV are scheduled to be completed in 2023.

**References**


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Table 1. Identified Limiting Events in Chapter 15.