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CASE STUDY

The framework was applied to a **High-Temperature Gas-cooled Reactor (HTGR)**, specifically focusing on the **Reactor Cavity Cooling System (RCCS)**. The RCCS ensures that residual heat is effectively removed from the reactor cavity, even when active cooling fails.

Tailored MBSE Approach for SMR Gen IV Architecting

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INTRODUCTION

Generation IV Small Modular Reactors (Gen IV SMRs) offer a promising solution for decarbonized energy production, but they face numerous challenges including complex licensing processes and architectural issues. A tailored **Model-Based Systems Engineering (MBSE)** approach is proposed to address these challenges, focusing on digital continuity, safety integration, and scalability.

PROJECT SCOPE

The tailored MBSE approach for Generation IV SMRs focuses on:

- **Safety integration**: Embedding safety considerations throughout the design process using FMEA and FTA.
- **Digital continuity**: Ensuring data traceability across all project phases to support consistent communication and regulatory compliance.
- **Stakeholder alignment**: Incorporating regulatory and stakeholder requirements into system design to meet international safety standards.
- **Scalability and flexibility**: Adapting the approach for SMR projects to enable agile and responsive project management.

CONCLUSION

The tailored MBSE approach delivers significant advantages for the development of Generation IV SMRs. By integrating safety at every stage, ensuring seamless digital continuity, and adapting to diverse regulatory environments, this approach accelerates project timelines. The framework not only simplifies complex engineering challenges but also promotes faster, more efficient development.

MODELING FRAMEWORK AND CASE STUDY

NuclearGrid Project: HTGR Powerplant

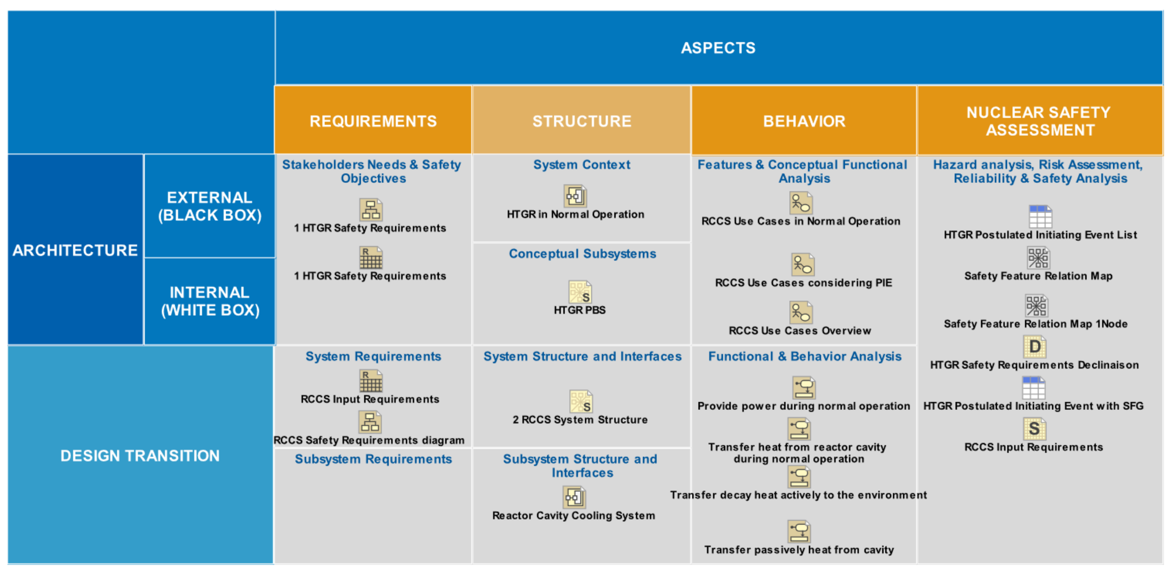

Fig 1. *Overview of MBSE framework tailored for Gen IV SMR.*

The tailored MBSE framework comprises four main aspects: **requirements**, **functional analysis**, **system structure**, and **nuclear safety assessment**.

This extension ensures that safety concerns are considered early and throughout the system's development.

SAFETY CONCERNS AND REQUIREMENTS CAPTURE

Captures stakeholder safety concerns, using them to derive system requirements that are integrated into the architecture. The integration of postulated initiating events (PIEs) into the model is crucial for capturing safety concerns.

#	
1	Loss of PCU and Power Grid
2	Loss of PCU, Power Grid and Emergency Diesel
3	Postulated Initiated Event to Treat
4	Pressurized Loss of Forced Cooling
5	Failure of Primary Circulating Equipment
6	Other Events Activating Reactor Protection
7	Loss of Power Supply
8	Primary Piping Leak or Rupture
9	Reactor Shutdown with SCS Failure
10	Station Blackout
11	Loss of Grid Load
12	Depressurized Loss of Forced Cooling
13	Safety Valves Opening

Fig 2. *Extracted list of postulated initiating event integrated into the model*

FUNCTIONAL ANALYSIS

Identifies system missions and how they contribute to key safety functions: reactivity control, cooling, and confinement of radioactive materials.

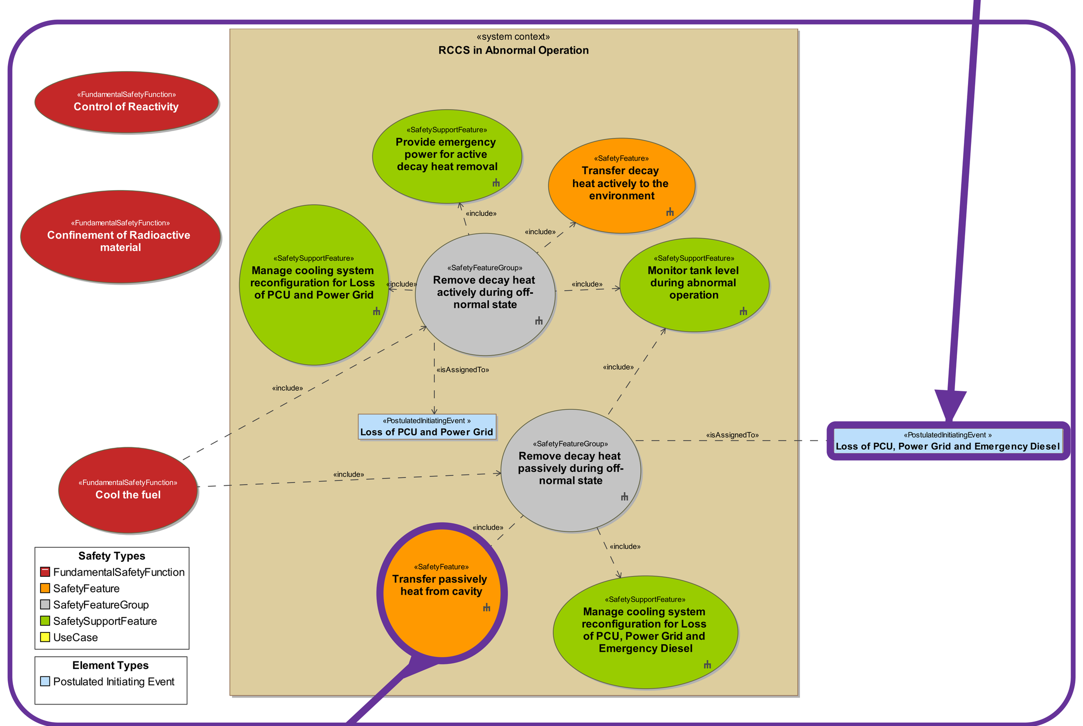

Fig 3. *Missions of the system with the consideration of the postulated initiating events*

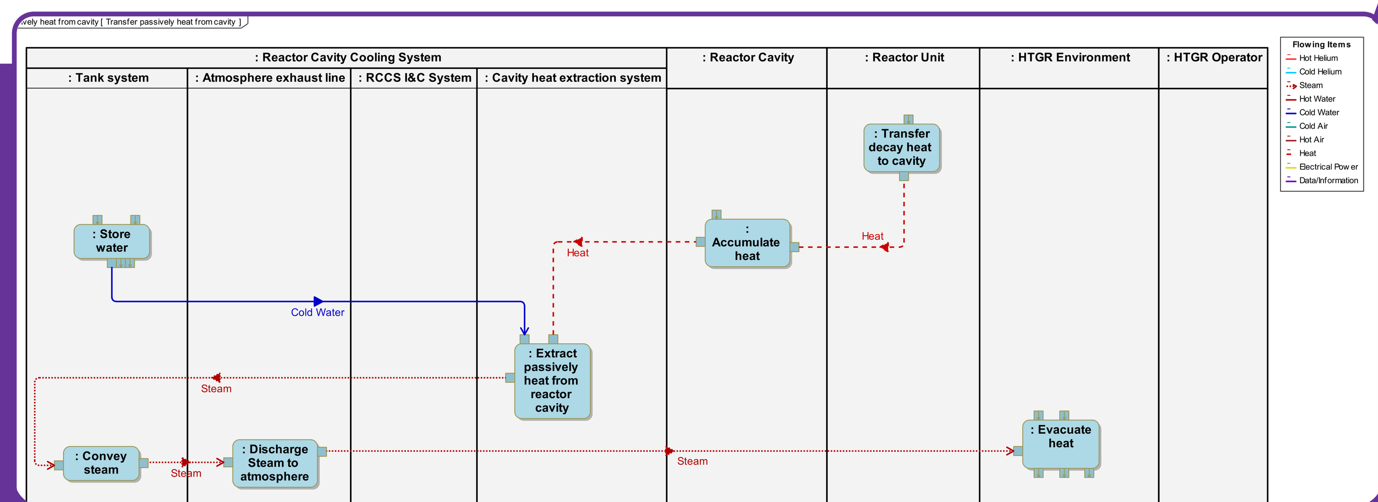

Fig 4. *RCCS functional diagram and safety response in passive mode*

The mission is accomplished through specific functions, which are then assigned to subsystems or external systems to ensure effective execution of the passive cooling process.

STRUCTURE AND TRACEABILITY

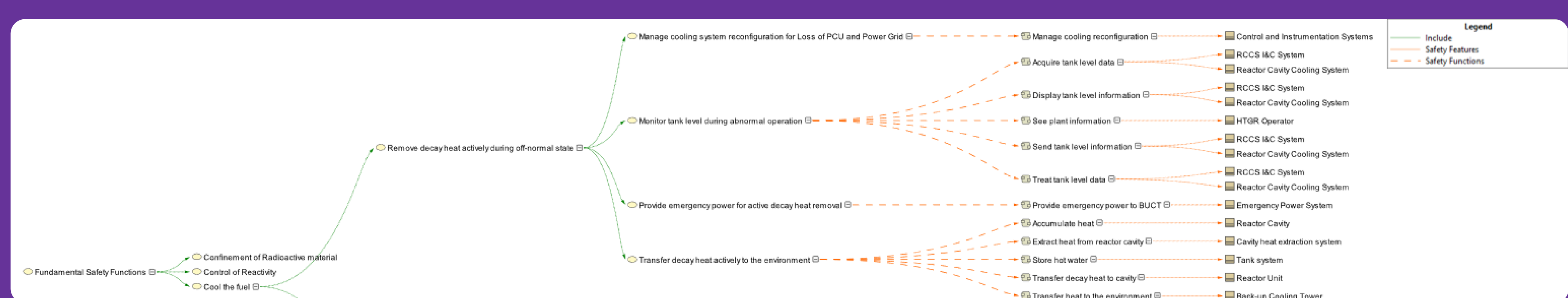

Fig 5. *Traceability map linking safety goals, requirements, and system components.*

The traceability framework enables the identification of safety-critical elements linked to fundamental safety functions, such as reactivity control, cooling, or confinement. This process ensures that each element is clearly associated with its role in the system, allowing for a comprehensive understanding of their contributions to overall safety objectives.