U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy University Programs (NEUP) Fiscal Year (FY) 2013 Annual Planning Webinar

RC-5: Risk-Informed Safety Margin Characterization(RISMC): Advanced Mechanistic 3D Spatial Modeling and Analysis Methods to Accurately Represent Nuclear Facility External Event Scenarios

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August 22, 2012

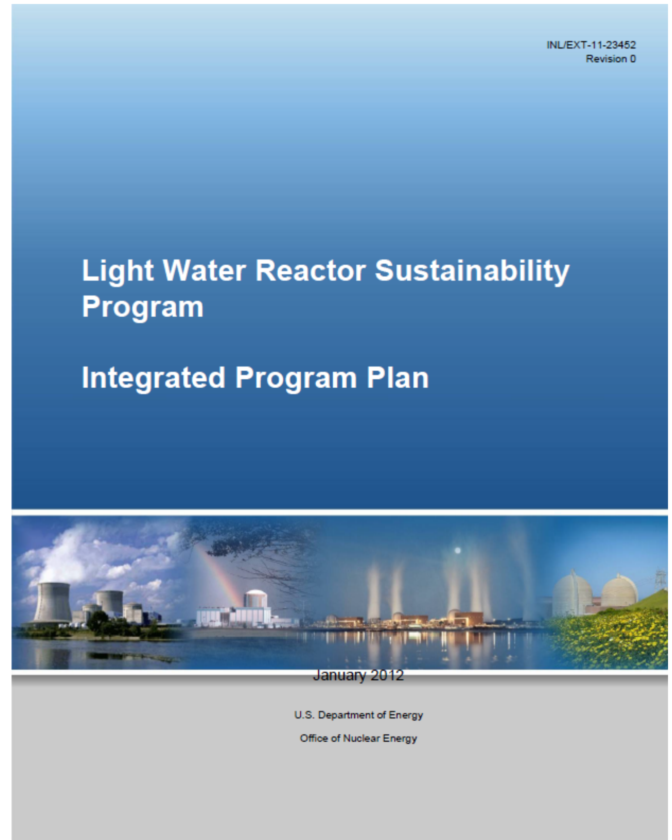
LWRS Vision and Goals

Vision

- Enable existing nuclear power plants to safely provide clean and affordable electricity beyond current license periods (beyond 60 years)

Program Goals

- Develop fundamental scientific basis to understand, predict, and measure changes in materials as they age in reactor environments
- Apply this knowledge to develop methods and technologies that support safe and economical long-term operation of existing plants
- Research new technologies that enhance plant performance, economics, and safety



U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Technical Focus Areas Summary

Nuclear Materials Aging and Degradation

- Develop scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants
- Provide data and methods to assess performance of systems, structures, and components essential to safe and sustained nuclear power plant operations
- Develop means to detect and characterize aging degradation processes

Risk-Informed Safety Margin Characterization (RISMC):

- Develop a significantly improved safety analysis tool (RELAP-7) and a framework (RAVEN and Grizzly codes) to analyze the safety margin of aging plants.
- RELAP-7 is a “systems” code that will model the whole plant compared to existing codes (including the Hub) that are focused on highly localized phenomena in great detail.
- RAVEN is the simulation controller.
- Grizzly is the component aging and damage evolution model

Technical Focus Areas Summary

- **Advanced Instrumentation, Information, and Control Systems Technologies**
  - Address long-term aging and obsolescence of existing instrumentation and control technologies and develop and test new technologies
  - Establish a strategy to implement long-term modernization of I&C systems
  - Develop advanced condition monitoring technologies for reliable plant operation
- **Advanced LWR Nuclear Fuel**
  - Improve scientific basis for understanding and predicting fundamental nuclear fuel performance at existing nuclear power plants
  - Develop high-performance, higher burn-up fuels with improved safety, cladding, integrity, and economics for existing LWR applications
  - Closely coordinated with the Fuel Cycle R&D program activities, which are oriented toward applications in advanced reactors
- **Systems Analysis and Emerging Issues**
  - Address high impact emerging issues such as potential backfit of cooling towers
  - Review potential research needs in response to Fukushima lessons learned

RISMC Pathway Research and Development Topics

- **Margins Analysis Techniques**
  - Develop techniques to conduct margins analysis, including methodology for carrying out simulation-based studies of margin
- **Simulation components of the RISMC Toolkit**
  - RELAP-7
    - Systems code that will simulate behavior at the plant level
    - Advanced computational tools and techniques to allow faster and more accurate analysis
  - Simulation Controller (RAVEN – Reactor Analysis and Virtual control Environment)
    - Provides input on plant state to RELAP-7 (including operator actions, component states, etc.)
    - Integrates output from RELAP-7 with other considerations (e.g., probabilistic and procedures information) to determine component states
  - Aging Simulation (Grizzly)
    - Component aging and damage evolution will be modeled in separate modules that will couple to RELAP-7 and RAVEN

Overview of the RISMC Pathway

- **The purpose is to support plant decisions for risk-informed margins management to support improved economics, reliability, and sustain safety of current NPPs**
- **Goals of the RISMC Pathway are twofold:**
  1. Develop and demonstrate a risk-assessment method coupled to safety margin quantification that can be used by NPP decision makers as part of their margin recovery strategies
  2. Create an advanced “RISMC toolkit” that enables more accurate representation of NPP safety margin

Margin Management Techniques

- Determine methods to model, measure, and maintain margins for active and passive SSCs for normal and off-normal conditions
- Develop techniques to conduct margins analysis, including methodology for carrying out simulation-based studies of safety margins

Grand Challenges

- **Since RISMC is looking at potential impacts, a holistic view needs to be taken**
- **As noted by the recent ASME report "Forging a New Nuclear Safety Construct" (June 2012)**
  - The U.S. nuclear industry has been addressing the need for operational safety —regardless of cause...
  - These challenges should be addressed in a risk-informed manner…and events exceeding the design basis, to include rare yet credible events
  - In particular, cliff edge effects for credible events and scenarios should be explored, and pertinent mitigation approaches should be implemented
- **While RISMC is evaluating mechanistic models for a large variety of affects including aging, we are not currently treating "external events" in an equivalent fashion**

RISMC Research Needs

- **In risk assessment, we consider two types of events**
  1. *Initiating Event* A departure from desired operation to a state where a response is required either by operators or machine intervention
  2. *Enabling Event* Conditions that provide the opportunity to challenge system safety, potentially leading to an accident
- **"External Events" are a class of initiating event that**
  - Has the initial deviation caused by a hazard external to the plant
  - Physical impacts such as thermal (fires), floods, and motion (earthquake) are included
- **Traditionally, these types of models in risk assessment have been both simplistic and conservative**

Pathway challenges

- **A pathway challenge concerns spatial risk assessment methods**
  - Current limitations exists related to fire, flooding, and seismic modeling issues
    - Fidelity is low and model uncertainties are large in current models
    - How to leverage the RISMC Toolkit to help solve issues?
    - Validation of applicable methods, data, and tools is an important
    - Safety modeling for nuclear facilities needs robust external events modeling such as spatial impacts and interactions from seismic events
- **Consequently, the proposed research aims to solve these issues**

“Advanced Mechanistic 3D Spatial Modeling and Analysis Methods to Accurately Represent Nuclear Facility External Event Scenarios”

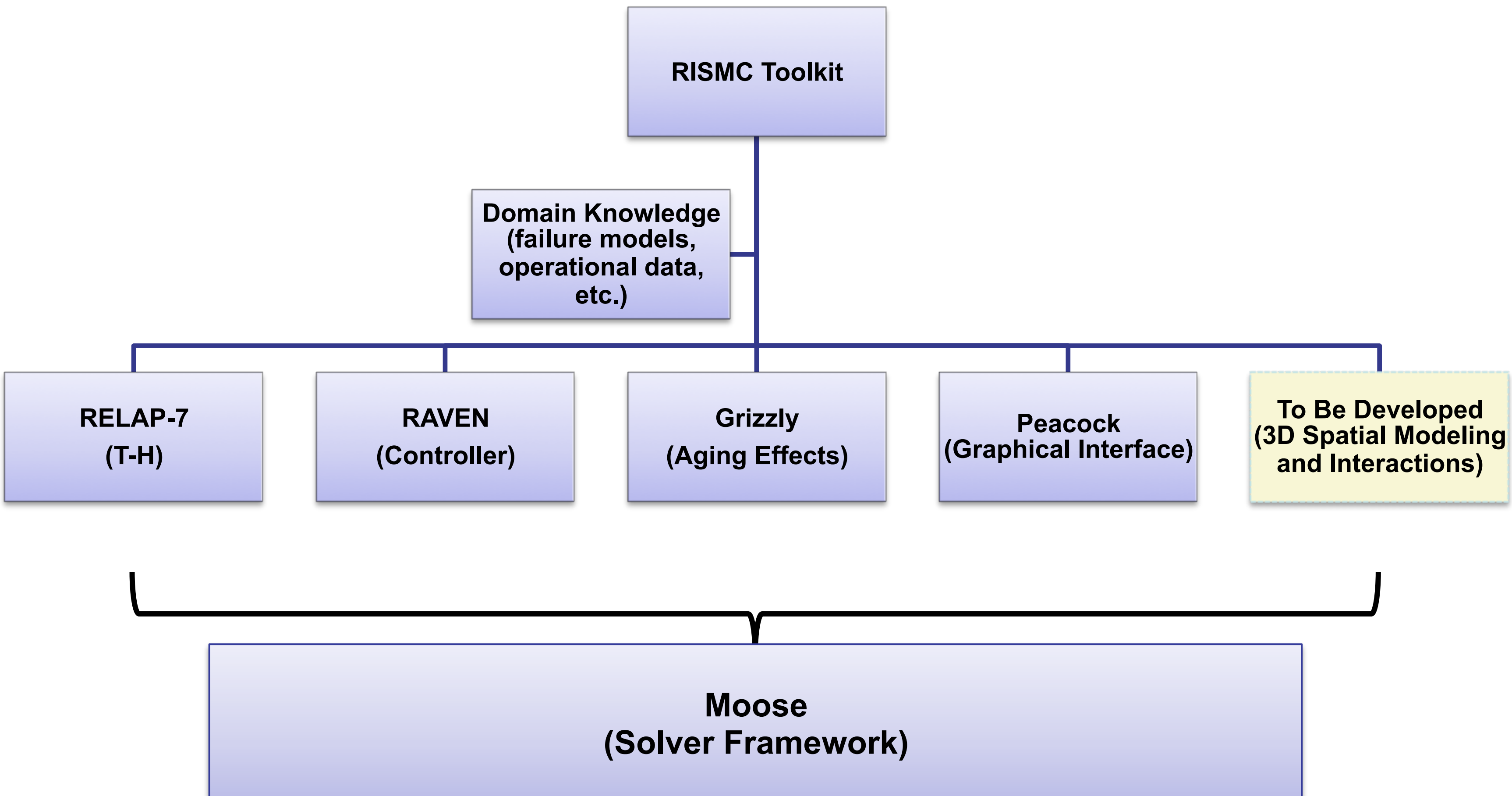
- **The R&D goal is to couple probabilistic and mechanistic calculations together such that we will be able to search for potential vulnerabilities resulting from external events**

Statement of need

- **Advanced Mechanistic 3D Spatial Modeling and Analysis Methods to Accurately Represent Nuclear Facility External Event Scenarios**
  - Modeling complex spatial phenomena at NPPs related to external environmental impacts will be important for predictive performance and safety evaluations
  - To capture both normal and off-normal conditions, the plant behavior and response will seek to allow for mechanistic scenario representations, wherein the developed methods mimics the complicated behavior
  - The R&D will be expected to provide mechanistic approaches that represent spatial types of interactions through a physics-based 3D environment – these environments should be capable of mimicking realistic physics such as
    - Water through building flow paths
    - Failures of components and structures
    - Objects impacting other objects

The RISMC Toolkit

Methods should be compatible with the INL-developed MOOSE platform which is used in other modeling activities in the RISMC program



Workscope Description

- **The activities will focus on coupling probabilistic and mechanistic models specific to external events**
  - Initially the target will be on seismic event representation
- **Major activities include:**
  - Determine applicable NPP spatial phenomena for seismic events
    - Representation of earthquakes at a “typical” NPP site
    - Representation of shock on systems, structures, and components
  - Determine how to capture these phenomena in off-normal scenarios
  - Determine how to represent NPP behavior conditional upon a seismic event
    - Representation of how to simulate spatial types of interactions through a physics-based 3D environment including failures of components and structures (for example, objects impacting other objects)