Risk-Informed, Performance-Based Licensing Approach

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Agenda

- Purpose
- Background
- Design overview
- Development of RIPB regulation
- Probabilistic risk assessment approach
- NuScale RIPB licensing approach
- Feedback and next steps

Purpose

- Provide NuScale overview of unique plant features that provide low risk to public safety and ensure adequate defense-in-depth (DID)
- Provide NuScale views on risk-informed, performance-based (RIPB) design and licensing approach
- Present NuScale approach to fundamental RIPB licensing elements, including
  - use of probabilistic risk assessment (PRA) to inform NuScale selection of licensing basis events.
  - structures, systems, and components (SSCs) safety classification.
  - defense-in-depth adequacy.
- Obtain NRC feedback on proposed Design-Specific Review Standard (DSRS) Chapter 19 requirements, including interfaces to other chapters

Background

- June 2010, NuScale Meeting with the NRC
- October 2011, NuScale Meeting with the NRC

Background

- **June 2010, NuScale meeting with the NRC**
  - Tool to evaluate potential design improvements for risk-significant scenarios
  - Tool for decision-making in selecting among alternative design features and operational options
  - Tool for preventing human error
  - Evaluate tolerances to severe accidents initiated by either internal or external events
  - Defense against risk-significant, common-cause failures
  - Safety margins to address uncertainty
  - Single failure criteria

Background

- **June 2010, NuScale meeting with NRC**
  - NuScale adopting individual safety goals for following events: internal core damage frequency (CDF), seismic CDF, other externals CDF, security CDF, and large release frequency design goals
    - Single modules
    - Cluster of four modules (not currently being considered)
    - Whole plant of 12 modules
    - Whole plant without credit to non-safety-grade systems
    - Integrated result of design safety goals will exceed the NRC safety goals and surrogate objectives requirements

Background

- **October 2011, NuScale Meeting with the NRC**
  - Presentations on source term and beyond-design-basis accidents (BDBAs)
    - Highly robust design with very low core damage frequency

      (<10^{-7} reactor year for internal events)
    - Small source term
    - Additional radionuclide barriers
    - No large break loss-of-coolant accident (LOCA)
    - No large early release fraction
    - Multi-module plant with shared systems

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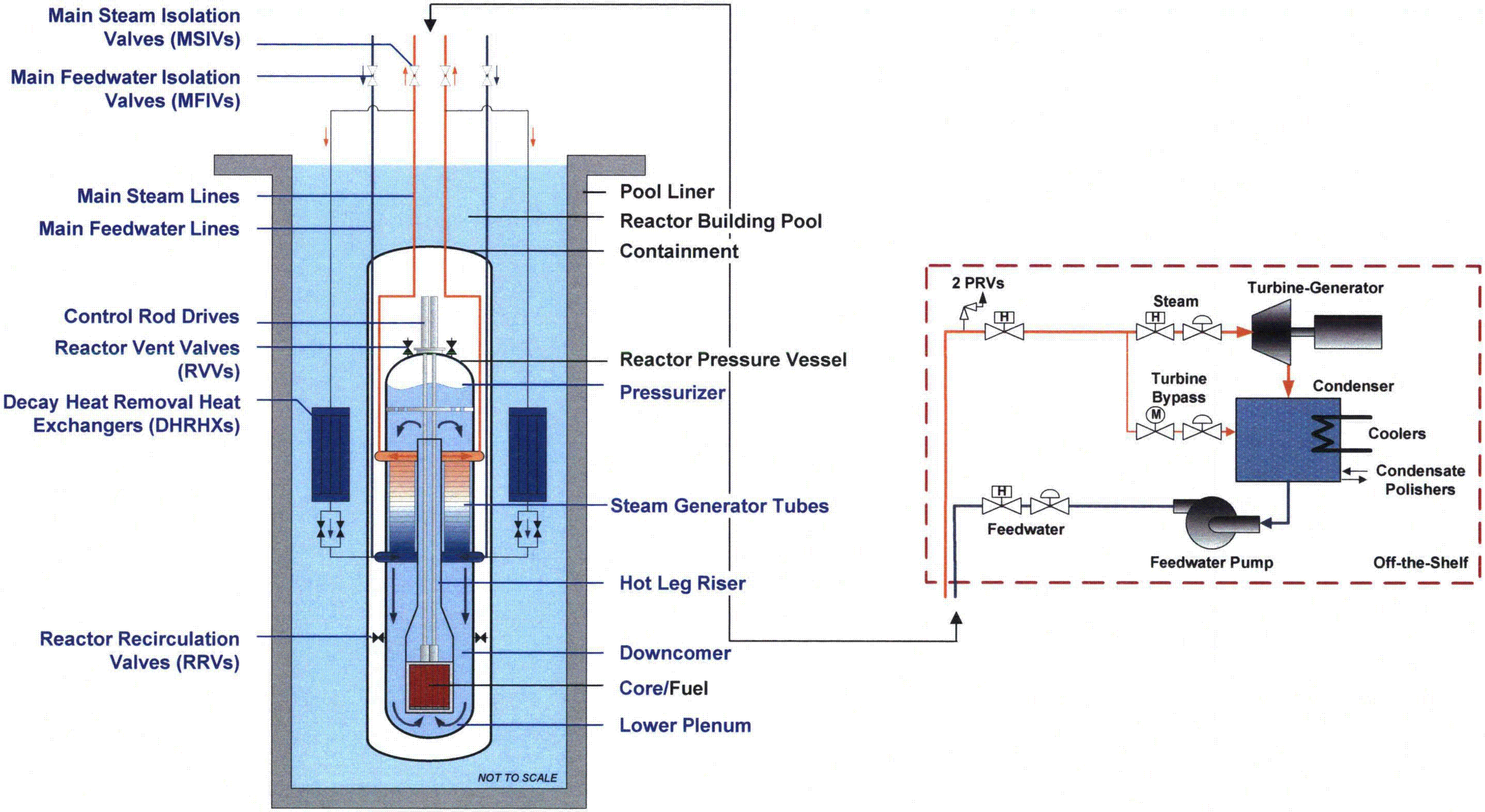
Background

- **October 2011, NuScale meeting with the NRC**
  - No applicable NRC guidance on quantitative-risk metrics for advanced passive plants
  - Limited set of BDBAs to be analyzed for NuScale plant
  - Alternate source term (AST)
    - developed for large light-water reactors (LWRs)
    - does not apply to NuScale design

Design Overview

- Identification of radionuclide barriers
- Reactor building
- Heat removal systems
- Passive cooling

Identification of Radionuclide Barriers



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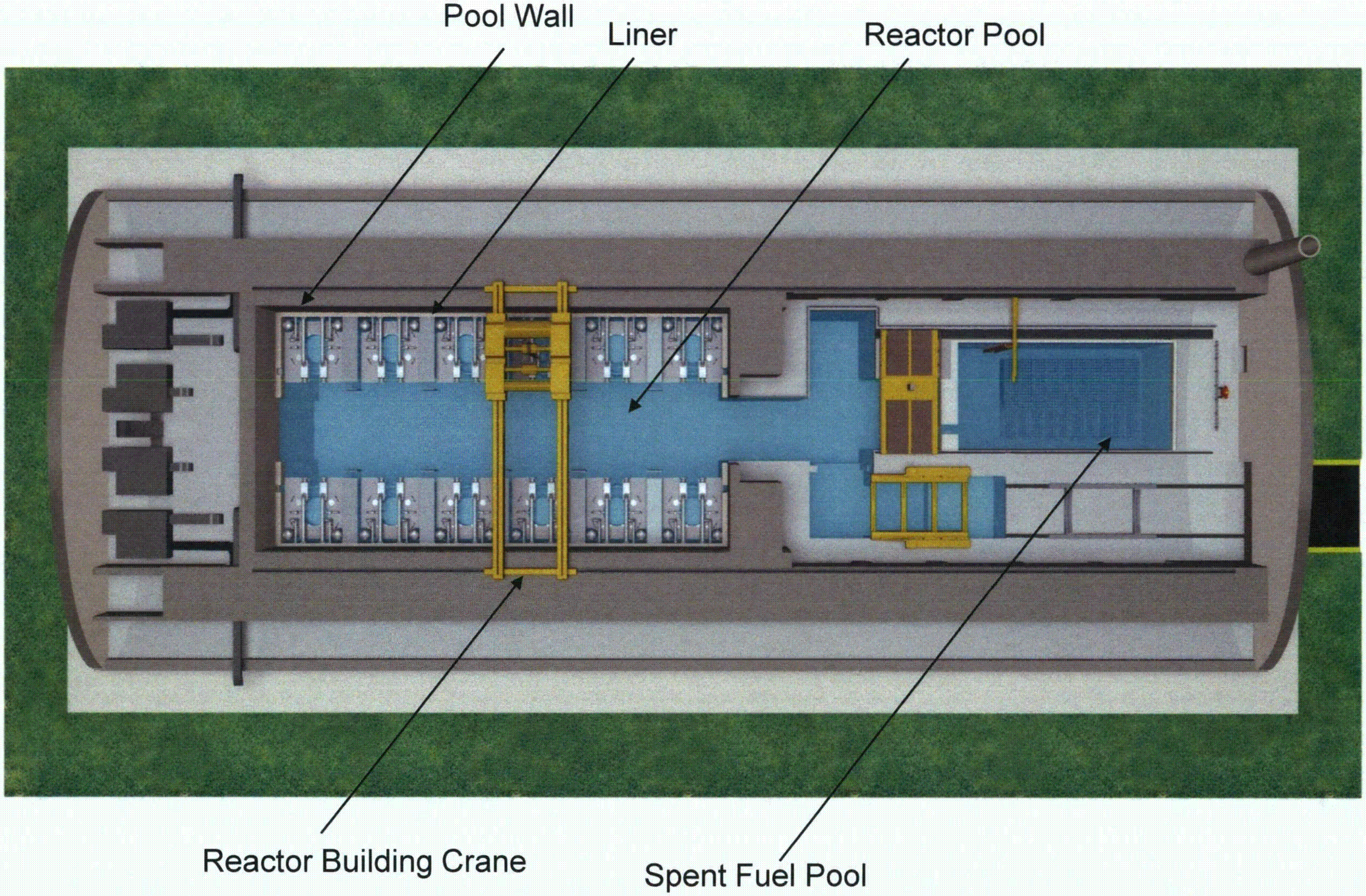
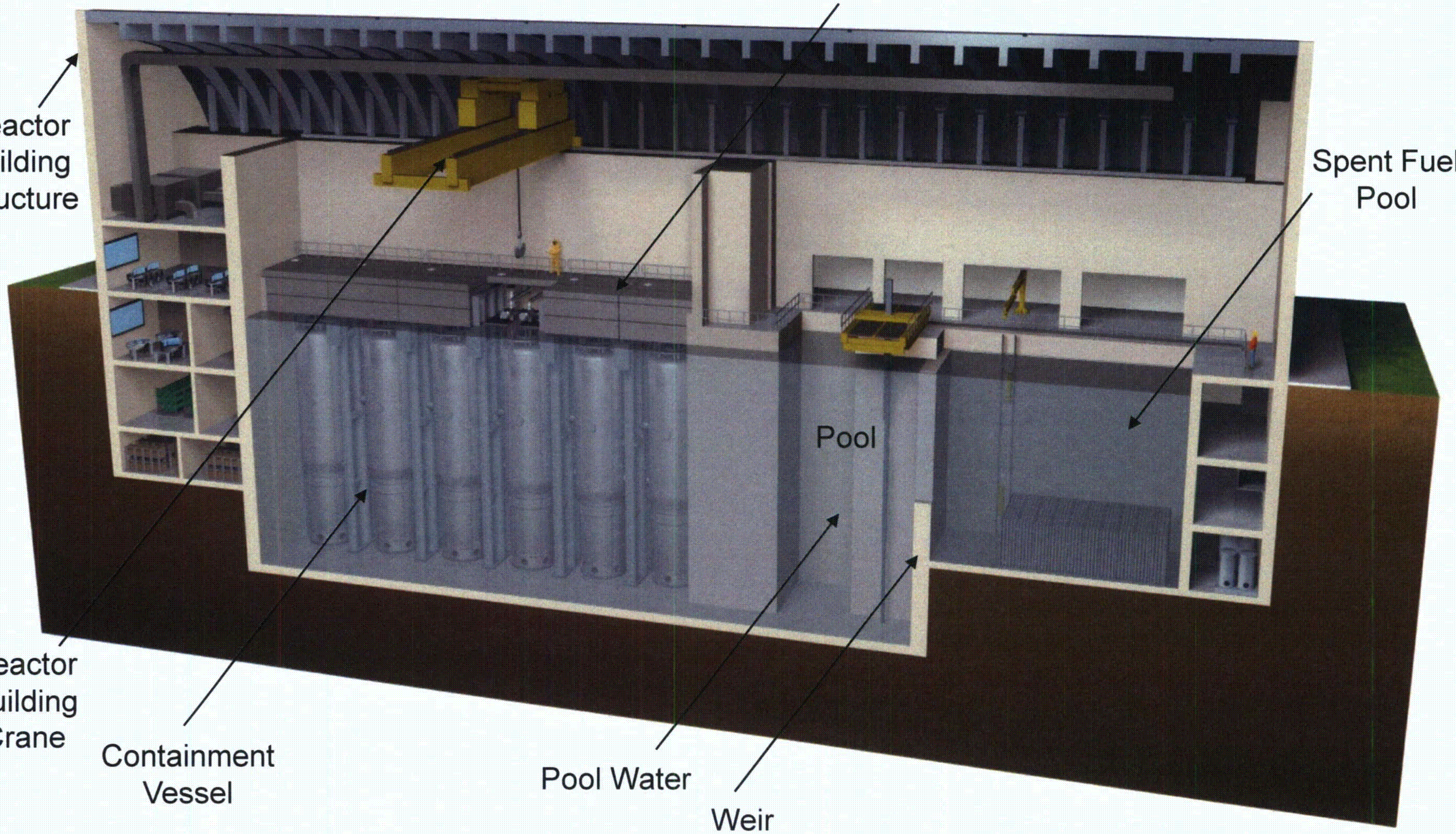
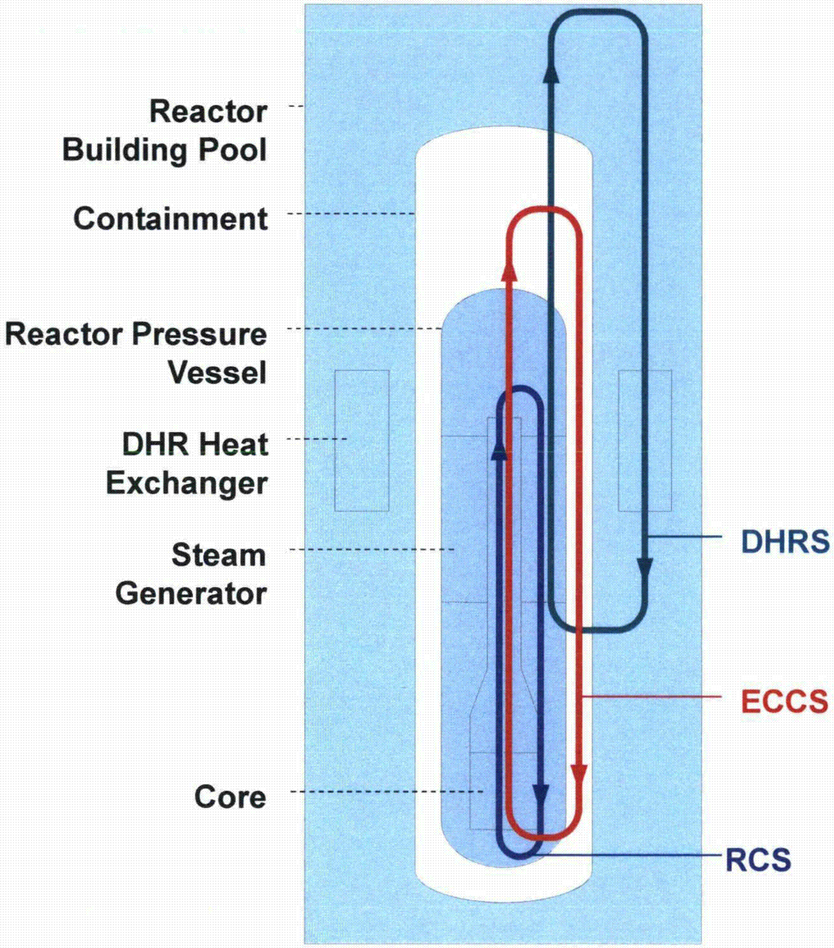
Reactor Building



Reactor Building

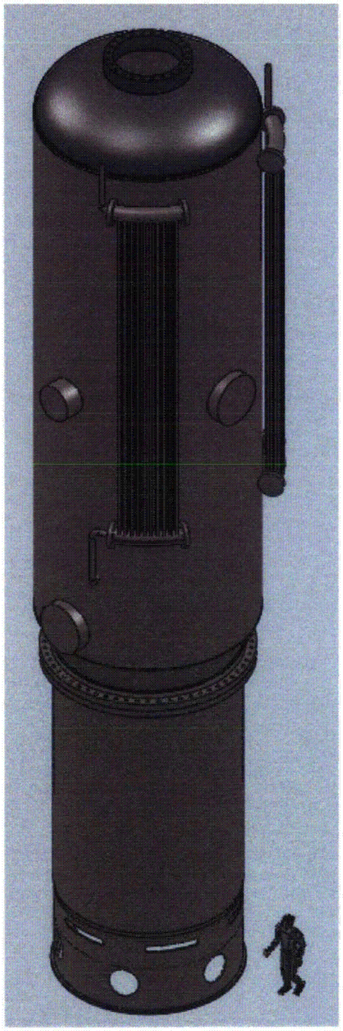


Reactor Module Heat Removal Systems

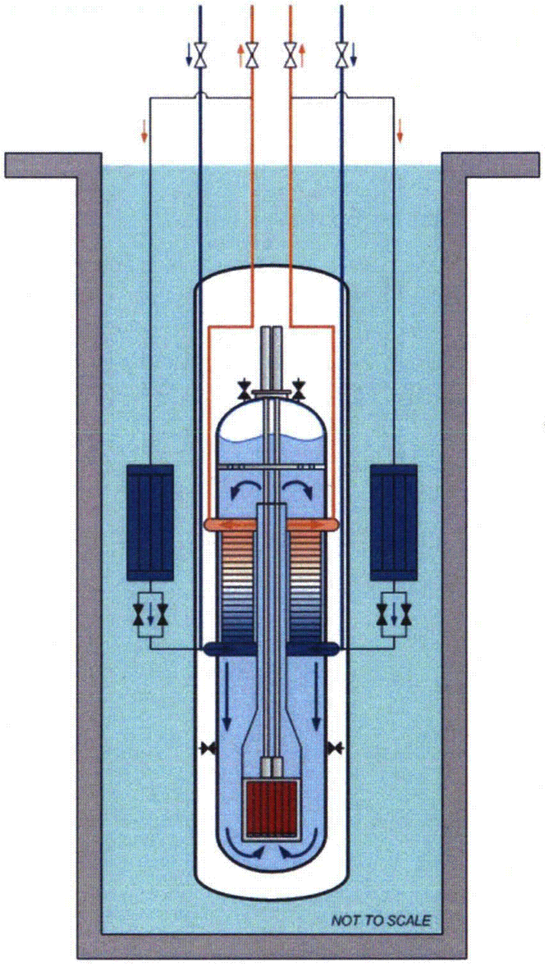


- **Natural circulation in the reactor coolant system (RCS)**
- **Natural circulation in the decay heat removal system (DHRS)**
- **Natural circulation in the emergency core cooling system (ECCS)**

Decay Heat Removal System



- Main steam and main feedwater isolated
- Decay heat removal (DHR) isolation valves opened
- Decay heat passively removed via the steam generators and DHR heat exchangers to the reactor pool



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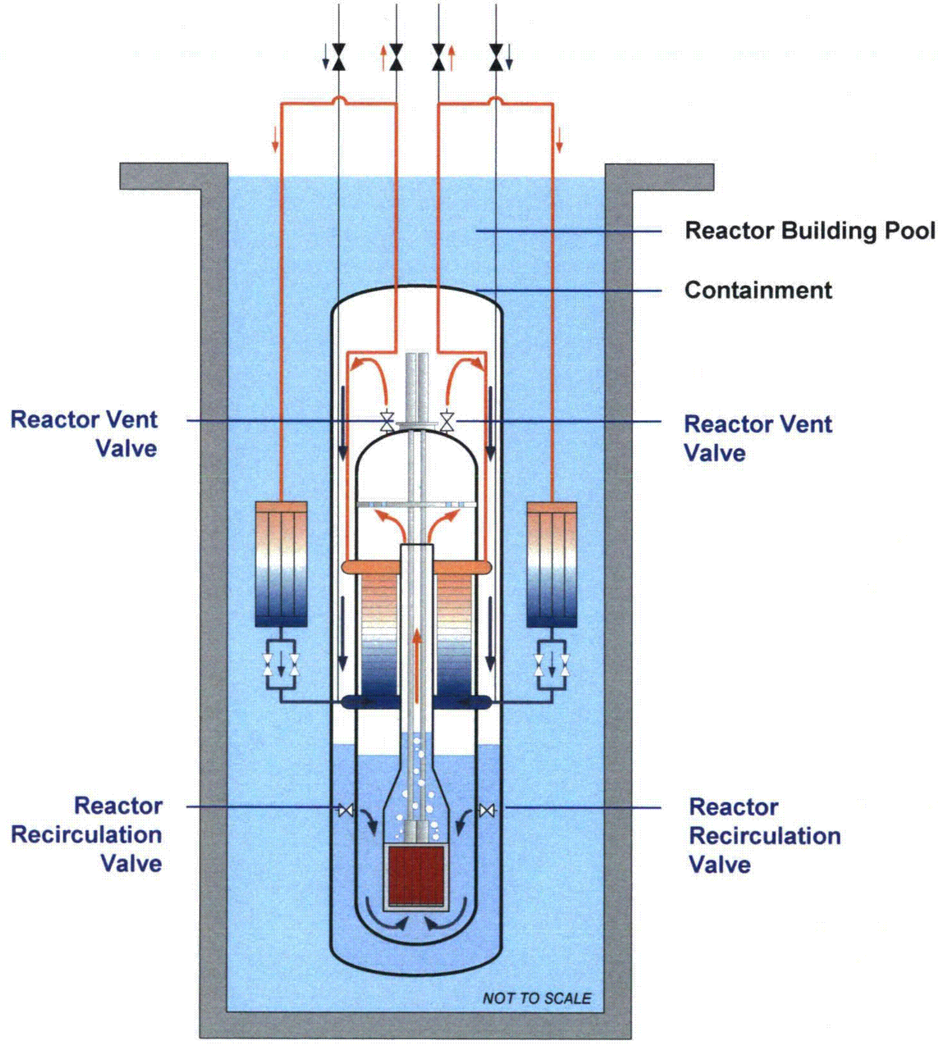
Containment Heat Removal System

- Removes residual heat and limits containment pressure by:
  - steam condensation.
  - convective heat transfer.
  - heat conduction.
  - sump recirculation.
- Reactor vessel steam vented through reactor vent valves (flow limiter)
- Steam condenses on containment
- Condensate collects in lower containment region
- Reactor recirculation valves open to provide recirculation path through the core
- Provide cooling for all 12 modules through pool water followed by indefinite period of air cooling



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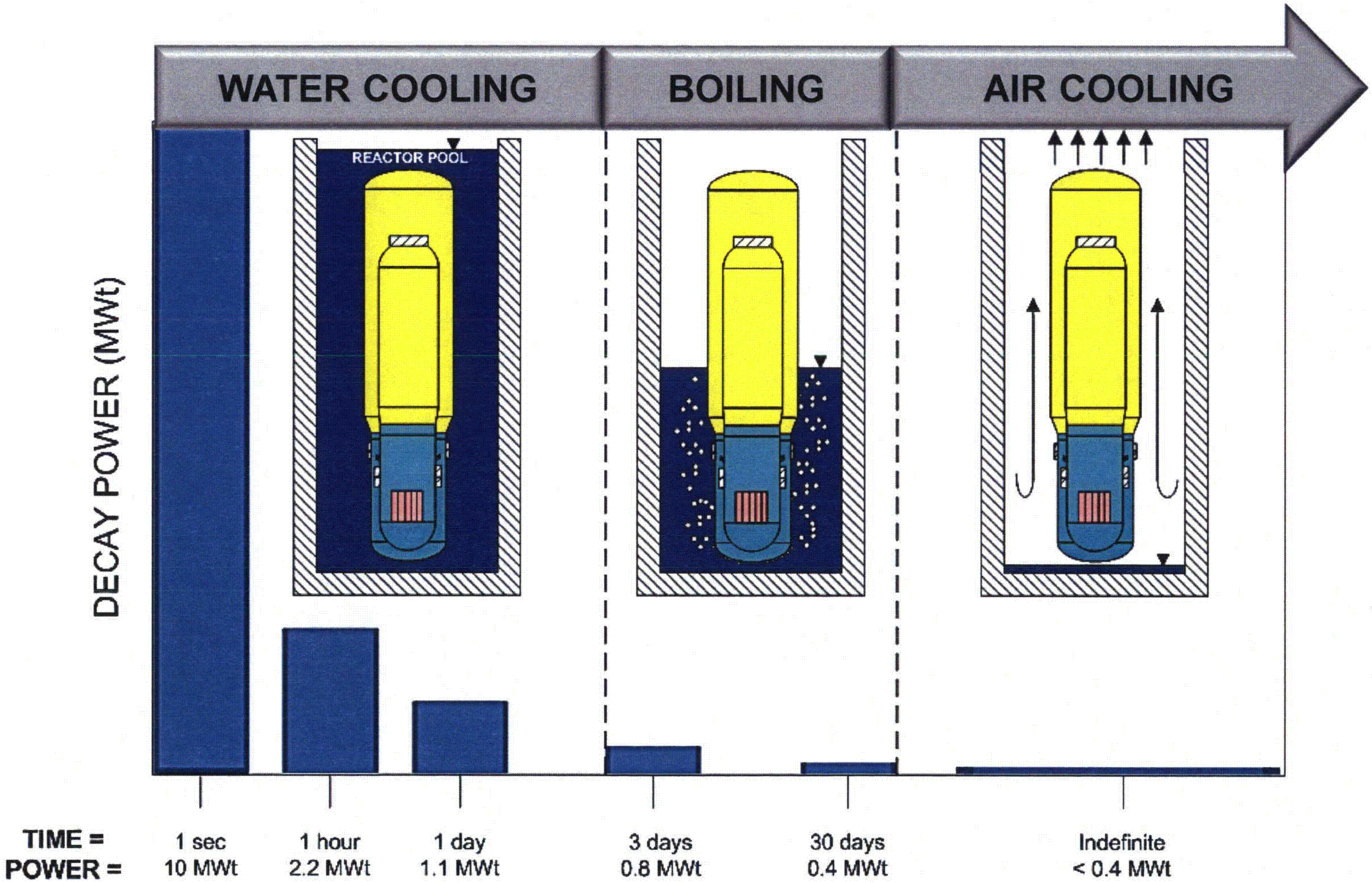
Stable, Long-Term Passive Cooling

- Containment and fuel cooled indefinitely for all 12 modules without pumps or power.



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Development of RIPB Regulations

- Report to Congress
- Staff requirement memorandum
- NUREG-2150
- Near Term Task Force

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Development of RIPB Regulation

Next generation nuclear power (NGNP) licensing strategy describes a risk-informed approach objective agreed to by the NRC and DOE (2008).

"Among the attributes that could assist in establishing the acceptability or licensability of a proposed advanced reactor design, and therefore should be considered in advanced designs, are… **[d]esigns that incorporate the defense-in-depth philosophy by maintaining multiple barriers against radiation release, and by reducing the potential for, and consequences of, severe accidents.**"

"Advanced reactor designers are encouraged as part of their design submittals to **propose specific review criteria or novel regulatory approaches which NRC might apply to their designs**."

Report to Congress Regulation of Advanced Reactors,
(FR Vol. 73, No. 199, pg. 60612-60616, October 14, 2008)

- Provided incentive and foundation for RIPB approach presented by NuScale in June 2010

Development of RIPB Regulation

Staff requirements memorandum (SRM), COMGBJ-10-0004/COMGEA-10-0001, August 2010.

- Directs NRC staff development of a framework, implementation strategy
  - more fully **integrate the use of risk insights into pre-application activities**
  - review of small modular reactor (SMR) applications
  - develop **risk-informed licensing review plans** for each of the SMR reviews
  - develop a new risk-informed regulatory structure, building on insights from integral pressurized water reactor (iPWR) reviews
- Provides direction to develop the pre-application process, NRC to issue a Design-Specific Review Standard

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Development of RIPB Regulation

"… the concept of defense in depth has served the NRC and the regulated industries well and continues to be valuable today. However, it is not used consistently, and **there is no guidance on how much defense-in-depth is sufficient**.

The RMTF recognizes the importance of translating the concept of risk management into more operational terms. **The task force proposes doing this by integrating the traditional concept of defense in depth and the methods of risk assessment.** Traditional analysis techniques are combined with risk assessment methods to define appropriate personnel training and qualifications, barriers and controls, including ensuring that the risks from the failure of these protections are acceptably low. This combination brings forth the systems analysis approach and provides a way to decide how much defense in depth is sufficient. The decision of what are acceptably low risks is not necessarily based on quantitative probabilistic metrics."

–NUREG 2150. A Proposed Risk Management Regulatory Framework, *Feb 2012*

Near Term Task Force Recommendation 1

"Option 1 - Continue with existing regulatory processes (status quo) making occasional improvements in a non-integrated manner."

"Option 2 - Coordinated effort to refine/improve portions of existing regulatory processes as approved by the commission."

"Option 3 - Develop revised regulatory framework."

"There does not appear to be a consensus regarding criteria for determining the adequacy of defense-in-depth."

- Commission paper due to EDO mid-February 2013

Near Term Task Force Recommendation 1

Concerns and Observations

- SMRs are treated outside proposed rule but in parallel with other staff initiatives on regulatory framework.
- Risk – future process of selecting the regulatory option may impose higher regulatory burden/requirements on the SMRs and discount innovations already in place .
  - NuScale design concept: integrated operation of multiple modules.
  - Passively safe nuclear fuel and containment cooling systems do not require onsite power, offsite power, or diesel generators for safety.

NTTF Topics for Discussion

- Implications of Near Term Task Force (NTTF)
  - Options of the task force applicable to the NuScale design?
  - Benefits and disadvantages of options?
  - Future impacts on DSRS decisions?

NuScale PRA Approach

- PRA Objectives
- Risk-informed design elements
- Risk assessment development overview

NuScale PRA Objectives

- Demonstrate that the NuScale reactor design is safe
- Achieve diversity, and independence with sufficient defense-in-depth and safety margins by using active equipment, passive safety features, plant architectures, and expected operational practices
- Accomplish with RIPB approach
  - Tool for decision making in selecting among alternative design features, operational strategies, design options and special treatment
  - Evaluate potential design improvements for risk-significant scenarios in terms of core damage, containment failure, or large releases
  - Human error prevention analyses tool for risk-significant human errors
  - Evaluate tolerances to severe accidents initiated by either internal or external events
  - Defense against unforeseen risk-significant failures
  - Evaluate uncertainties to better understand safety margins

NuScale PRA Objectives

- The PRA will include SSCs, human actions, and common cause failure considerations
- Follow existing regulations and guidance
  - Regulatory Guide 1.200
  - Internal Events – ASME/ANS RA-Sa-2009
  - External Events – NUREG-CR-6850, ANS-58.23-2007, ANS-58.21-2007
  - Lower power and shutdown – ANS-58.22-200x
- No proposed changes to guidance
- Consider multi-module risk

Risk-Informed Design Elements

- Top-level risk-informed design requirements
- SSC screening criteria and risk metrics
- Graded evaluations
  - More risk significant systems get greater attention
- Categorization and treatment of SCCs based on risk significance (e.g., SR, non-SR with special treatment, non-SR)
- Interdisciplinary reviews
- Trade studies that consider risk insights
- Integrating security into the design process
- Identify critical and risk-important operator actions as input to the human factors engineering
- PRA-based seismic margin assessment (SMA)
- Probabilistic treatment of uncertainties

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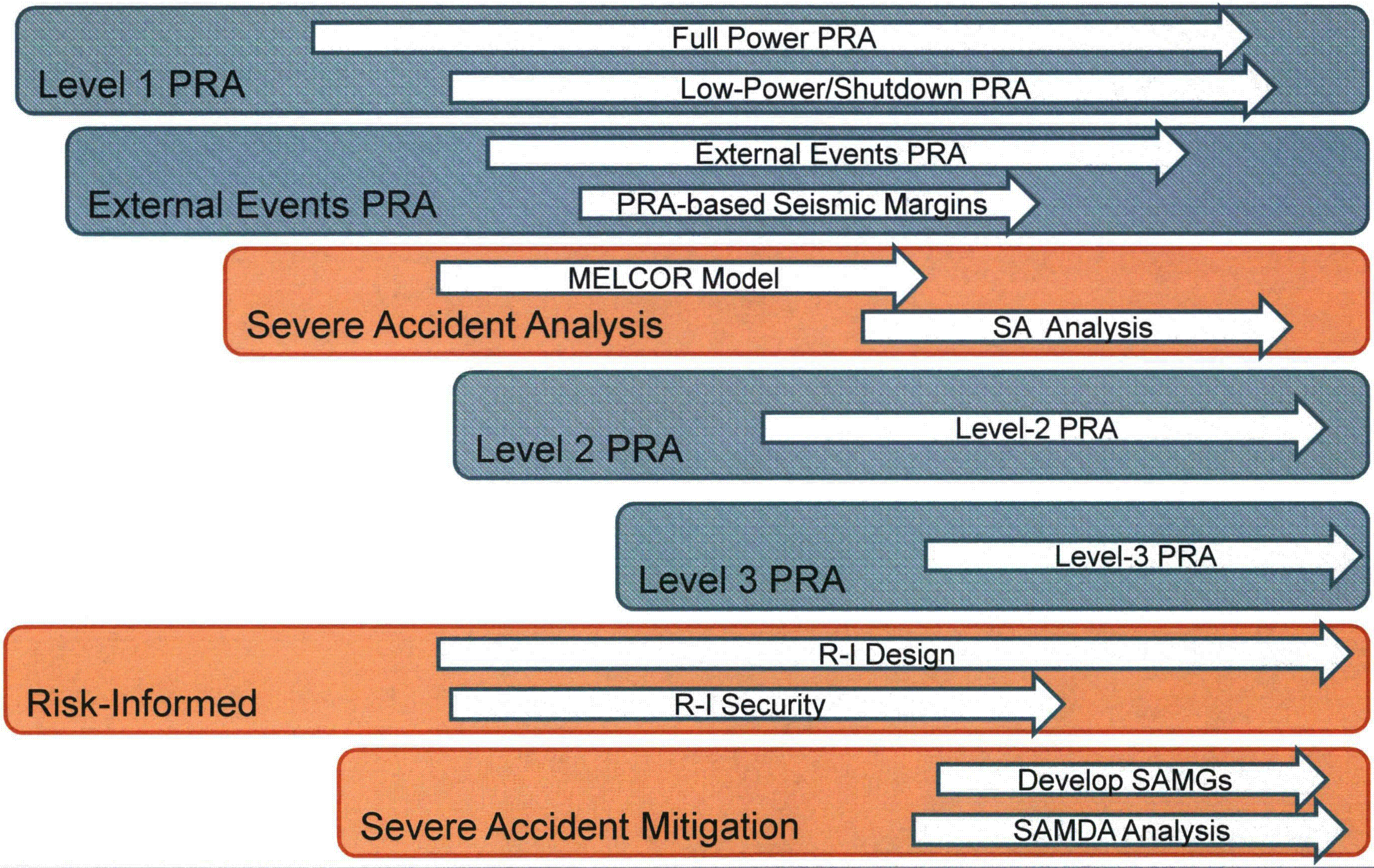
Risk Assessment Development Overview



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NuScale RIPB Licensing Approach

- Definition of risk-informed approach
- Risk-informed application
- NuScale DID framework
- NuScale DSRS development

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Definition of Risk-Informed Approach

"A 'risk-informed' approach enhances the traditional approach by:

(a) allowing explicit consideration of a broader set of potential challenges to safety,

(b) providing a logical means for prioritizing these challenges based on risk significance, operating experience, and/or engineering judgment,

(c) facilitating consideration of a broader set of resources to defend against these challenges,

(d) explicitly identifying and quantifying sources of uncertainty in the analysis, and

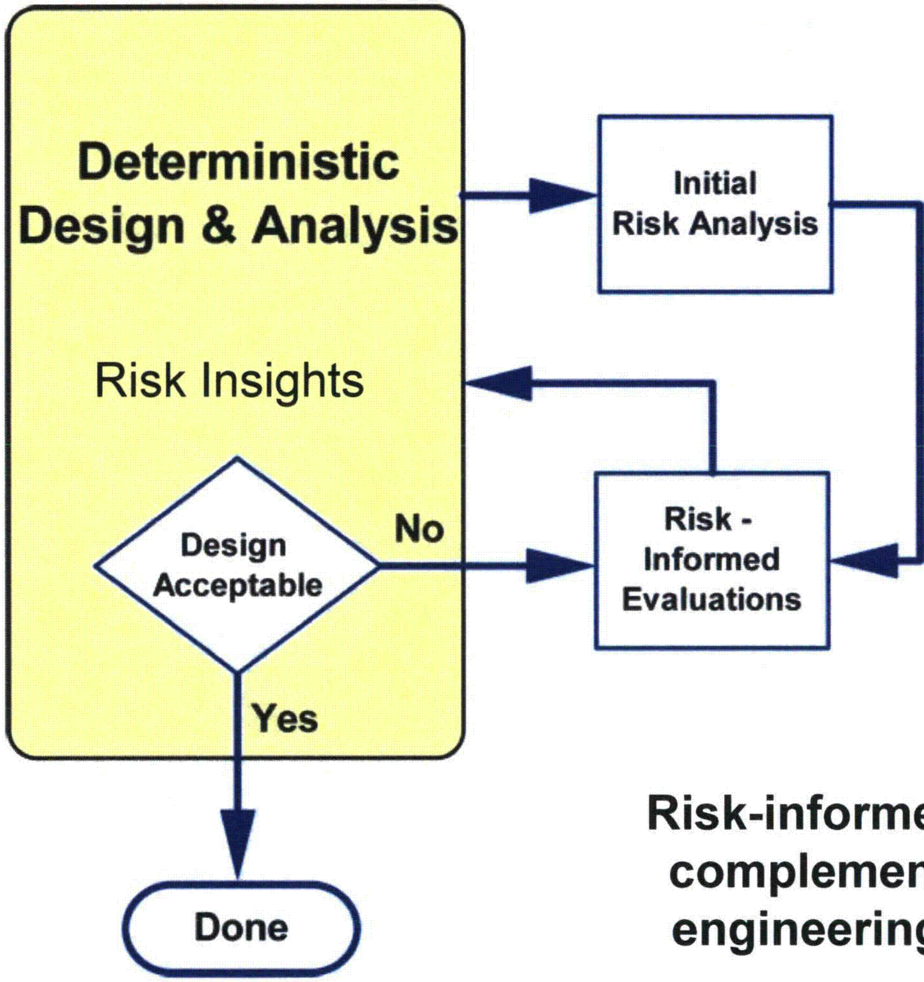
(e) leading to better decision-making by providing a means to test the sensitivity of the results to key assumptions.

Where appropriate, a **risk-informed regulatory approach can also be used to reduce unnecessary conservatism in deterministic approaches, or can be used to identify areas with insufficient conservatism and provide the bases for additional requirements or regulatory actions**."
(SECY-98-144/NUREG-2122)

Definition of Risk-Informed Approach

- Impacts multiple design and programmatic issues
- Tailored for advanced passive designs with unique technology and design approaches that include
  - Smaller power level, reactor modules
  - Passive reactor cooling during normal operation and off-normal events
  - Enhanced DID capabilities
  - Shared systems
  - Multi-reactor operation
- Creates a robust and stable evaluation framework for future design and operational changes for impacts on safety and DID

Risk-Informed Application — Model



Risk-informed processes complement traditional engineering processes

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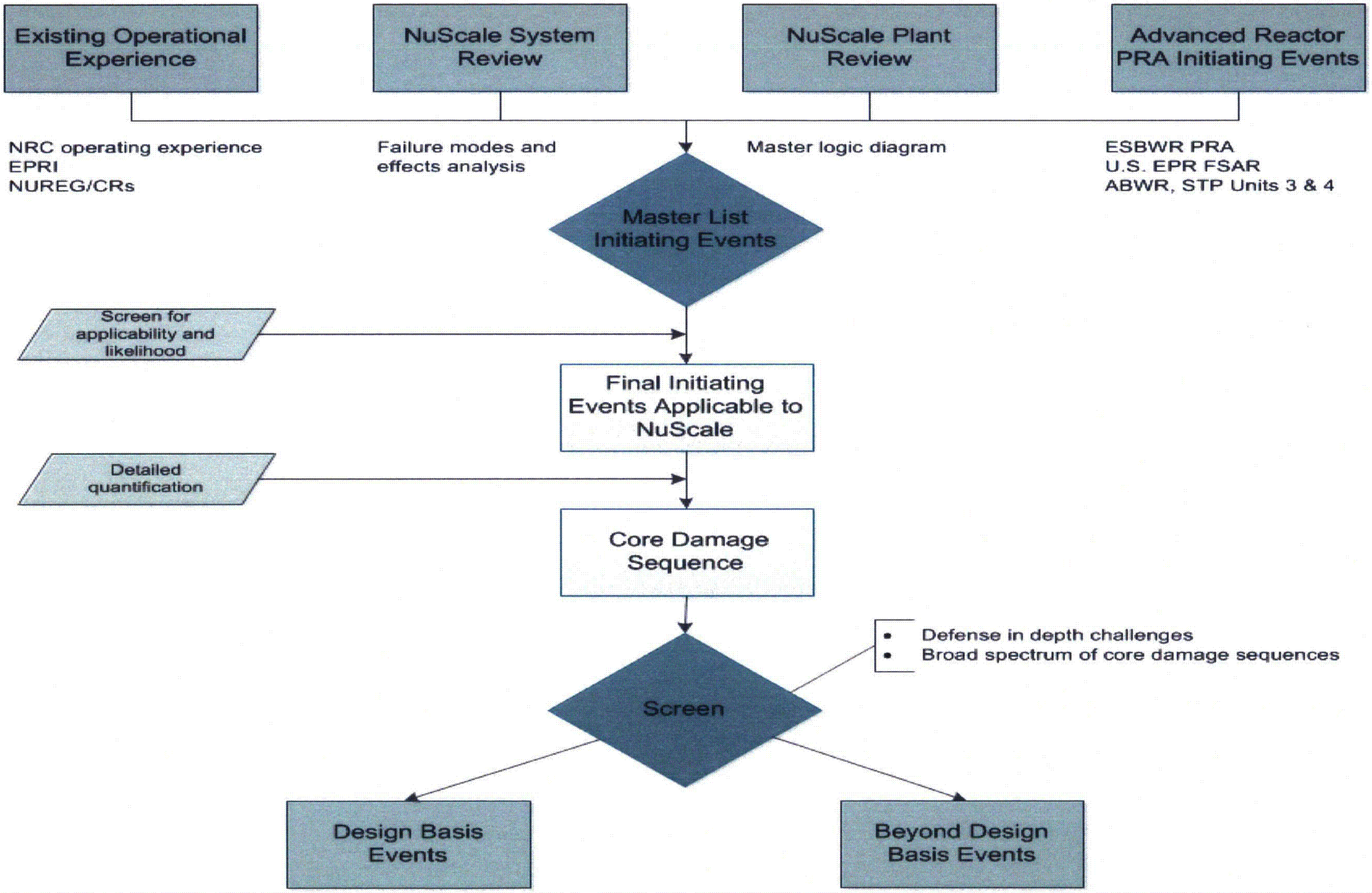
Risk-Informed Application — LBE Selection



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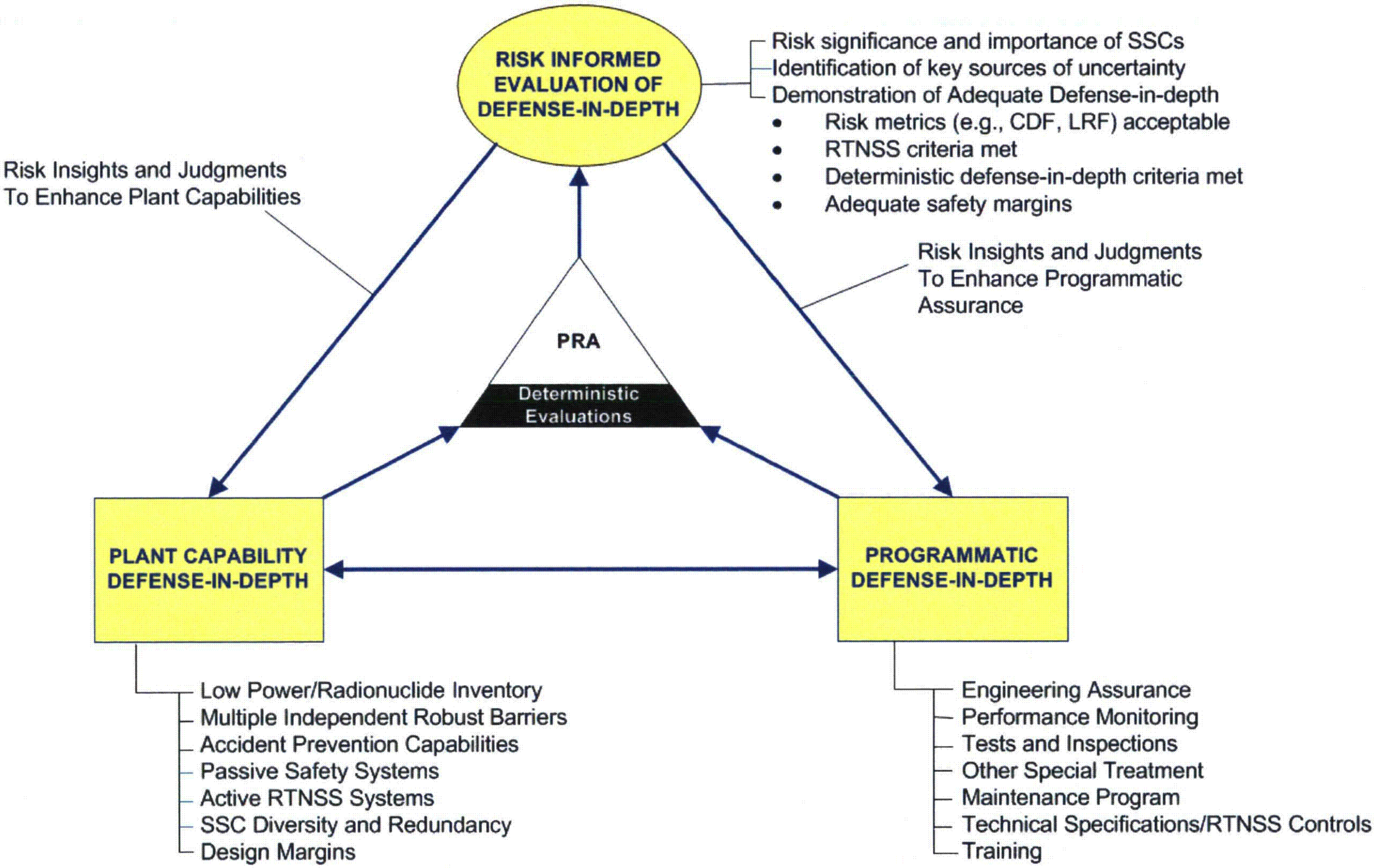
NuScale DID Framework



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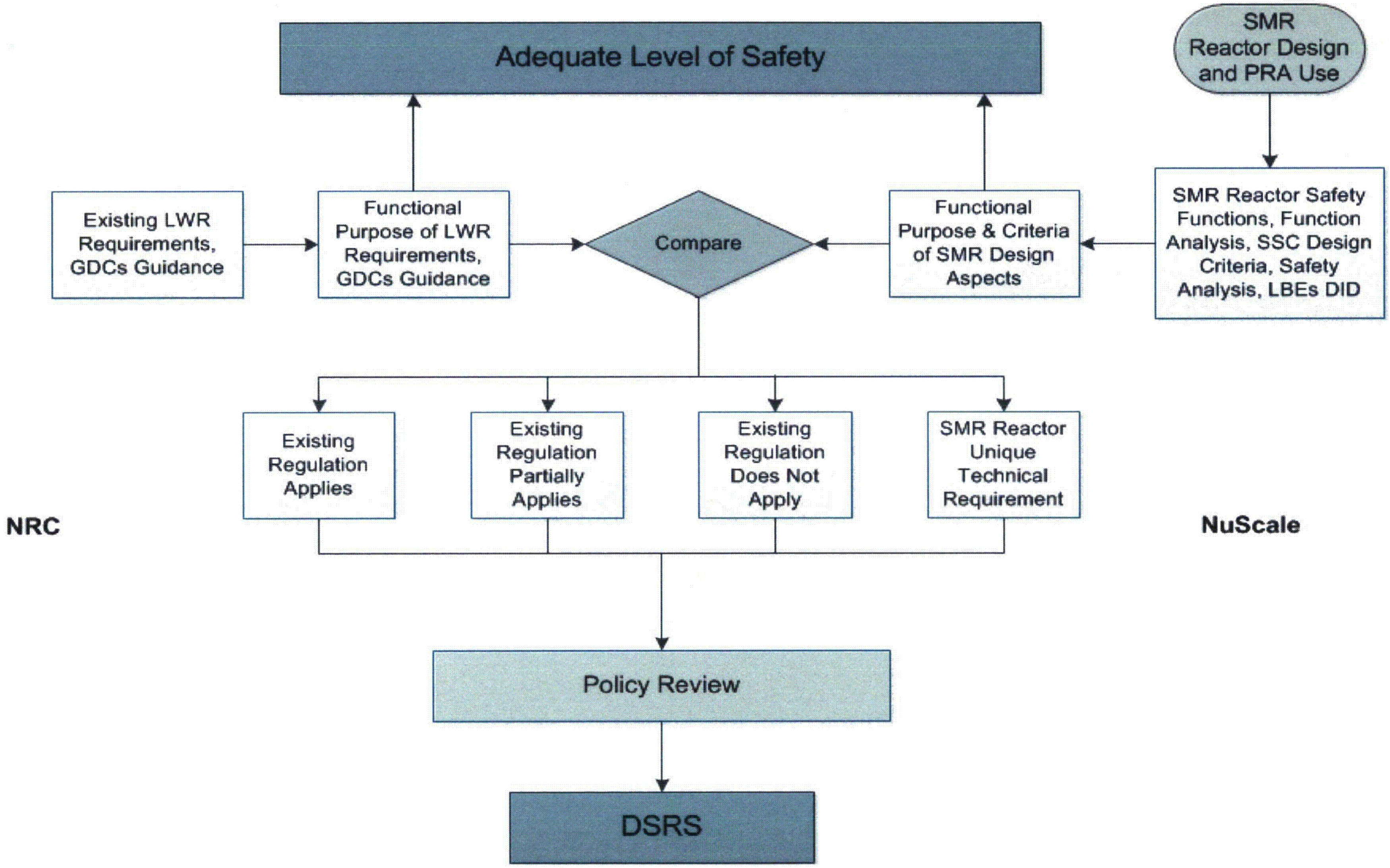
NuScale DSRS Development

Objective

- NRC to develop DSRS that supports the review of the NuScale plant including
  - unique technology and design features.
  - RIPB design and licensing approach.
- Anticipate draft Chapter SRP 19.3/RTNSS and Chapter 19 DSRS will provide suitable guidance for
  - SSC capabilities and reliabilities for DID.
  - evaluation of DID adequacy.

Convergence of NuScale and NRC Approaches



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Impact of RIPB Approach

- Licensing Approach
  - Chapter 1
- Design
  - Chapters 3-10
- Implementation
  - Chapter 19 PRA
  - Chapter 3 SSC classifications and codes and standards
  - Tier 1 inspections, tests, analyses, and acceptance criteria
- Analysis or Programmatic
  - Chapter 15 design-basis events
  - Chapter 17 reliability assessment program

Feedback and Next Steps

- Two-pronged approach: ***Design and RIPB description***
  - A series of interactions for design familiarity so that differences of NuScale design and corresponding licensing implications become clearer.
  - Continued focused and detailed discussion of NuScale plan for RIPB licensing elements (e.g., licensing basis events (LBEs), SSC classification, DID)
- Development of DSRS that factors in impacts of both unique areas