Technology-Inclusive Implications of ANS-30.3, “LWR Risk-Informed, Performance-Based Design”

ANS RP3C Community Of Practice Presentation:

By

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Outline

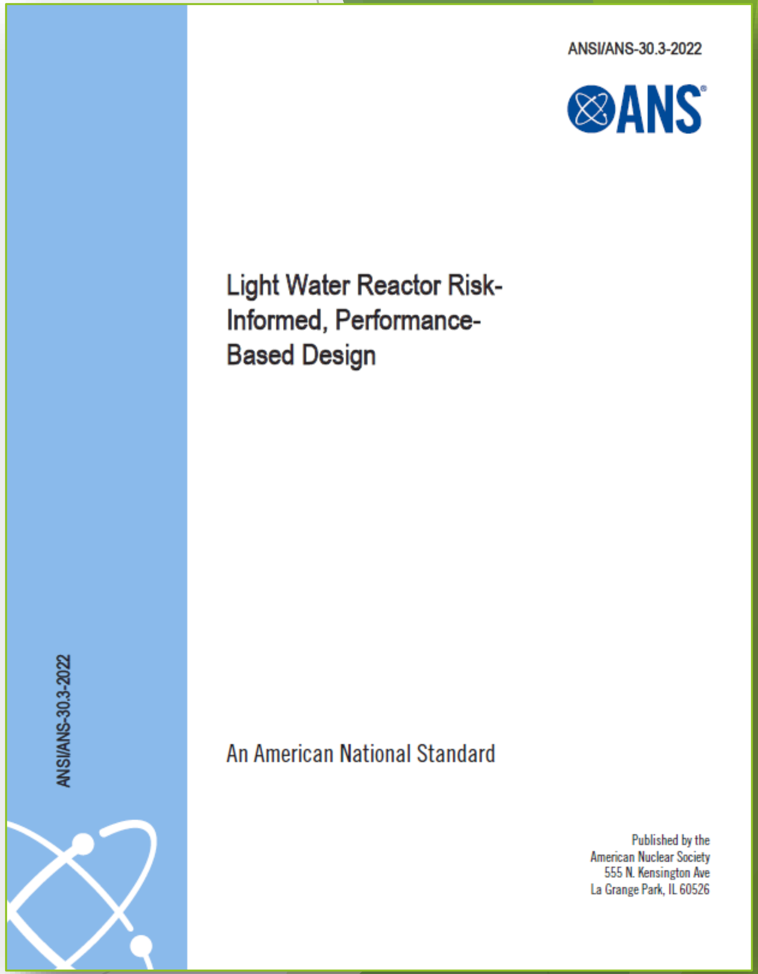
- Introduction to ANS-30.3 as a Case-Specific application of technology-inclusive risk-informed and performance-based (TI RIPB) principles
- Concepts related to a decision-making framework using an objectives hierarchy and risk management
- A notional construct for a 10 CFR Part 52 license application using ANS-30.3 toward certifying a molten-fuel molten-salt reactor (MF-MSR) design
- Summary emphasizing the value of ANS-30.3 as a voluntary consensus standard (VCS).

ANS-30.3, LWR Risk-Informed Performance-Based Design

- Provides requirements for the incorporation of risk-informed, performance-based (RIPB) principles and methods into the nuclear safety design of new commercial light water reactors (LWRs)
- Establishes a minimum set of requirements for the designer to follow with respect to in-scope items to appropriately combine deterministic, probabilistic, and performance-based methods during design development

<u>**SCOPE**</u>

4. Definition of safety requirements
5. Licensing-basis event (LBE) selection
6. Design-basis safety analysis
7. Probabilistic risk assessments (PRAs)
8. Severe accident analysis
9. Classification and categorization of structures, systems, and components (SSCs)
10. Systematic defense-in-depth (DID) evaluations
11. Performance-based decision analysis



How ANS-30.3 Contributes to Project Success

Application of ANS-30.3

- Establish decision analysis process to: Identify technical alternatives; Identify and evaluate alternative courses of action; Record preferences, decision rationale, and assumptions. (Section 11, "Performance-Based Decision-Making")
- Implement other sections toward achieving nuclear licensing success

Project Level Decisions: Covers unique technologies, Plant level design features and Site characteristics

Plant Level Design Features: Nuclear steam supply systems; Secondary side systems; Support systems; etc.

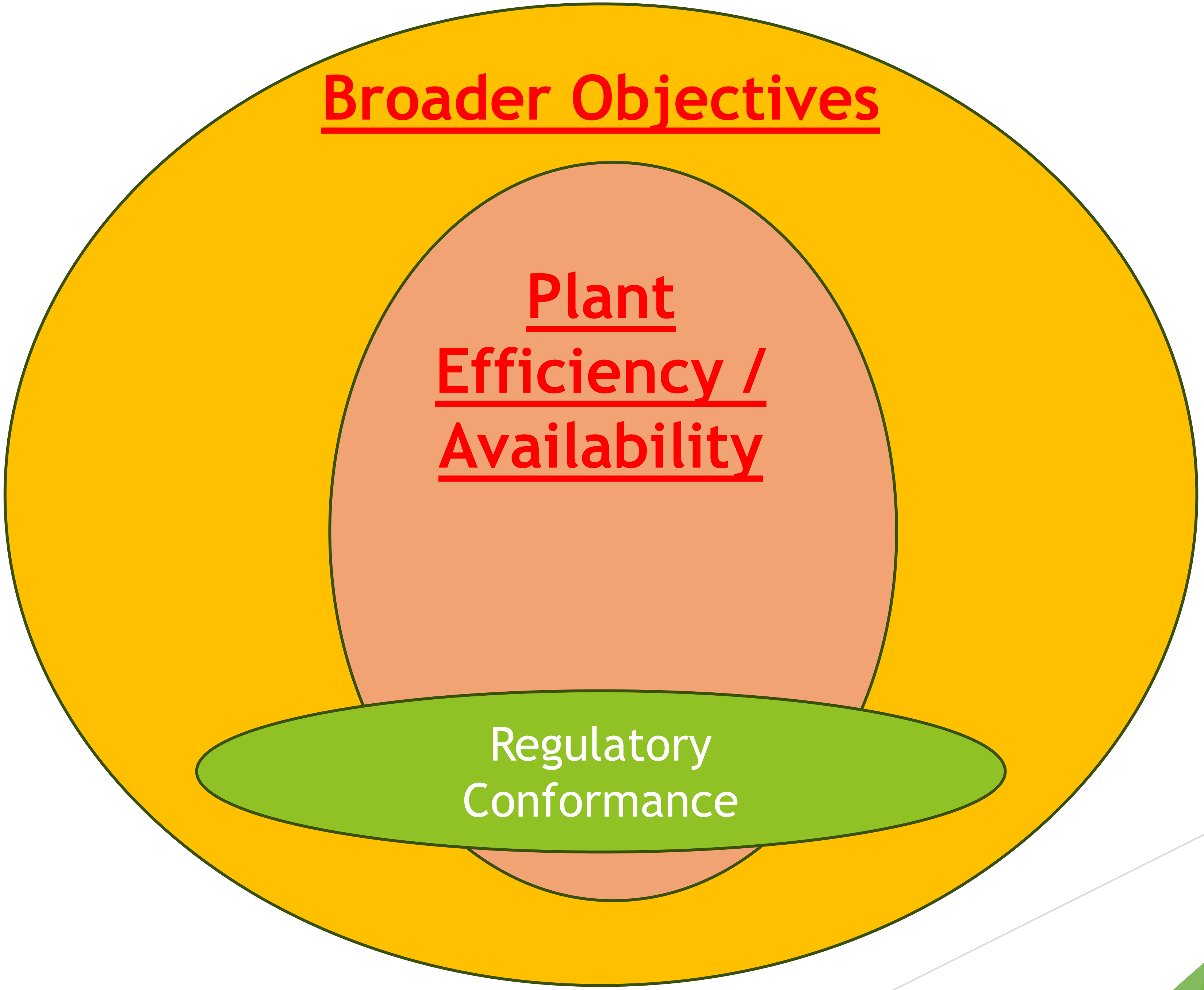
Project Success: Optimal decisions using systems-engineering best-practices considering project life cycle

Reactor Product Success: Optimize specification of requirements covering diverse performance objectives including safety, economics, environment, etc.

Nuclear Licensing Success: Conform with performance objectives of regulatory requirements provided in the regulatory framework of the applicable jurisdiction using RIPB methods

Structure and Processes In ANS-30.3

- The minimum set of requirements is based on a hierarchical arrangement of requirements each of which represents accomplishment of a specific performance objective (called "objectives driven").
- This objectives driven structure is described under Section 11, "Performance-based Decision Analysis"; it is to be used by the designer in all other sections
- A distinction is made between the safety design of a reactor product and the overall set of design activities that necessarily includes economic, environmental, and other considerations.
- A further distinction is made between the processes associated with safety design and licensing of the product, but the standard does not cover all the licensing matters that may arise.


Broader Objectives
Plant Efficiency / Availability
Regulatory Conformance

Current US LWR Licensing Process Has Plenty of Flexibility

- Current US reactor licensees achieve operational success with conventional approaches
- RIPB approaches can offer economic benefits for power uprates, license renewal, or life extension
- Maximum benefits may be available to non-LWR applicants using regulatory modernization

Applicable Regulatory Framework: 10CFR 50;52;53?

- Format and Content Guidance
  - RG- 1.70; 1.206; 1.233; 1.253
- Technical Requirements
  - 10 CFR Parts: 20; 50; 51; 54; 100
- Administrative Requirements
  - 10 CFR Parts: 2; 21; 52; 110; 170; 171
- Technical Guidance
  - NUREG-0800; ARCAP; TICAP
  - RG-1.1 through 1.253

Important Elements of Current State-of-Practice

- Define safety requirements
- Select LBEs
- Document design-basis safety analysis
- Document PRA
- Document severe accident analysis
- Classify and categorize SSCs
- Evaluate DID systematically

These are necessary but not exhaustive for reactor product licensing success

"Technology-Inclusive" Outcome Objectives for Licensing

From 10 CFR Part 50, Appendix A, "Introduction":

"The General Design Criteria are also considered to be generally applicable to other types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for such other units."

From SRM-SECY-98-144, "RIPB Approach":

"A RIPB approach to safety decision-making combines the "risk-informed" and "performance-based" elements. Stated succinctly, RIPB safety is an approach in which risk insights, engineering analysis and judgment including the principle of defense-in-depth and the incorporation of safety margins, and performance history are used to
(1) focus attention on the most important activities to achieve the desired results,
(2) establish objective criteria for evaluating performance,
(3) develop measurable or calculable parameters for monitoring system and licensee performance,
(4) provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes, and
(5) focus on the results as the primary basis for decision-making."

From SECY-18-0096, "Functional Containment Criteria for Non-LWRs":

"…a methodology that would be used by non-LWR designers to define functional containment performance criteria in a manner that is technology inclusive, risk informed, and performance based."

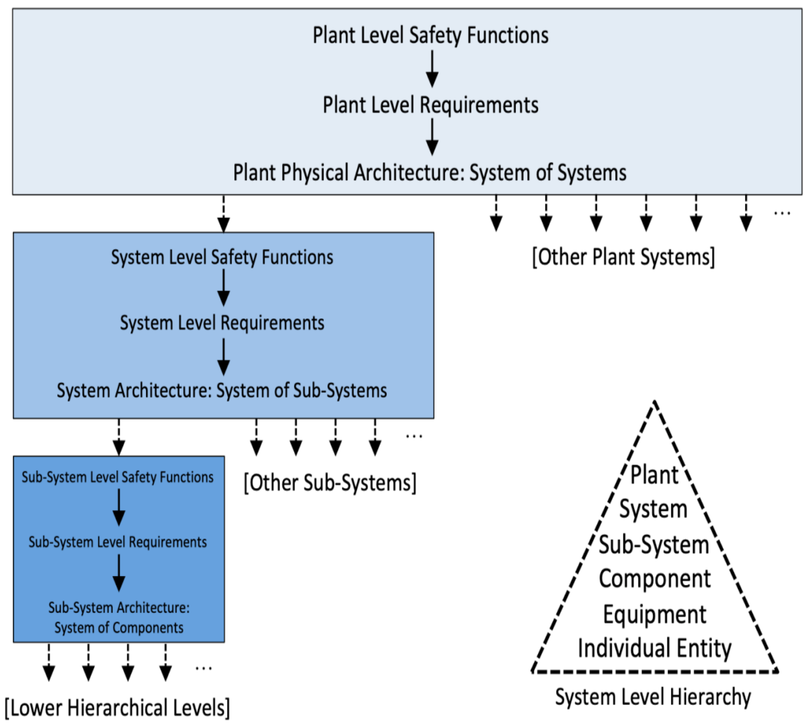
Functional Containment is Technology-Inclusive

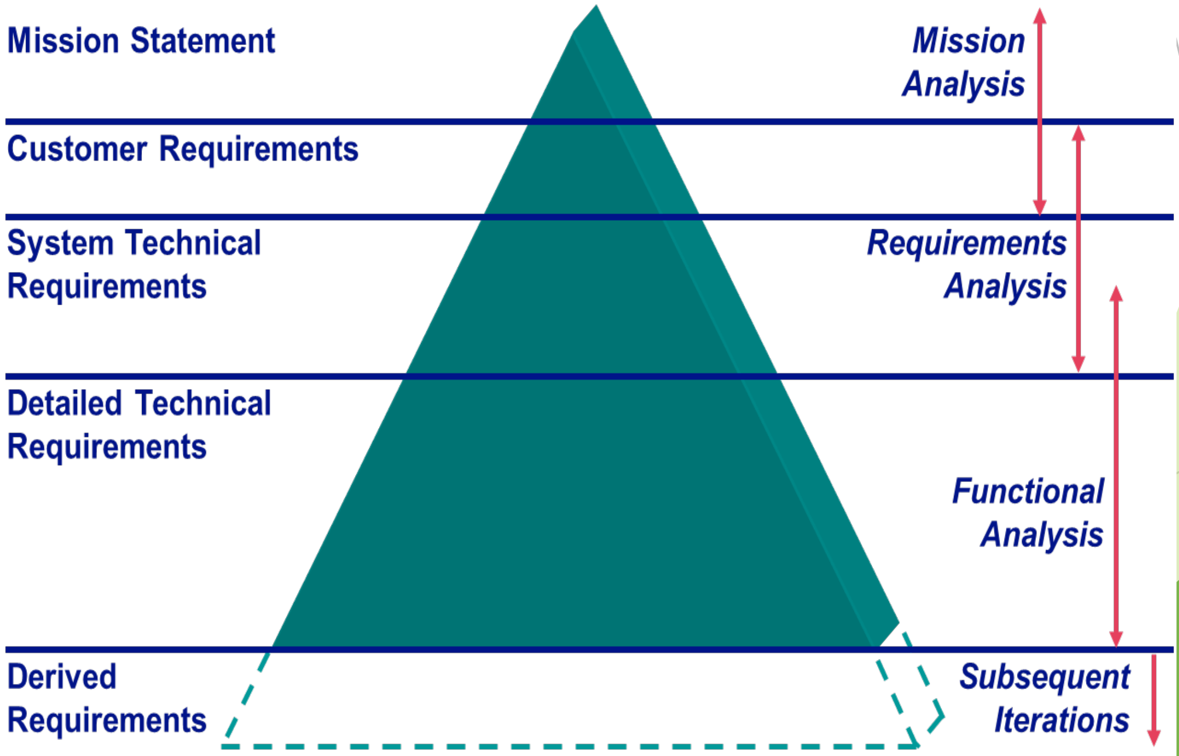
- **Justification for alternative containment performance criteria based on SRM-SECY-98-144**
- **ANS-30.3 provides generalized basis for alternatives for all design criteria**

Requirements Management Using an Objectives Hierarchy

Requirements management is the process of documenting, analyzing, tracking, and verifying requirements throughout the system development lifecycle.

The purpose of an objectives driven structure for a reactor product is to specify one set of requirements for every objective within a structured set of objectives

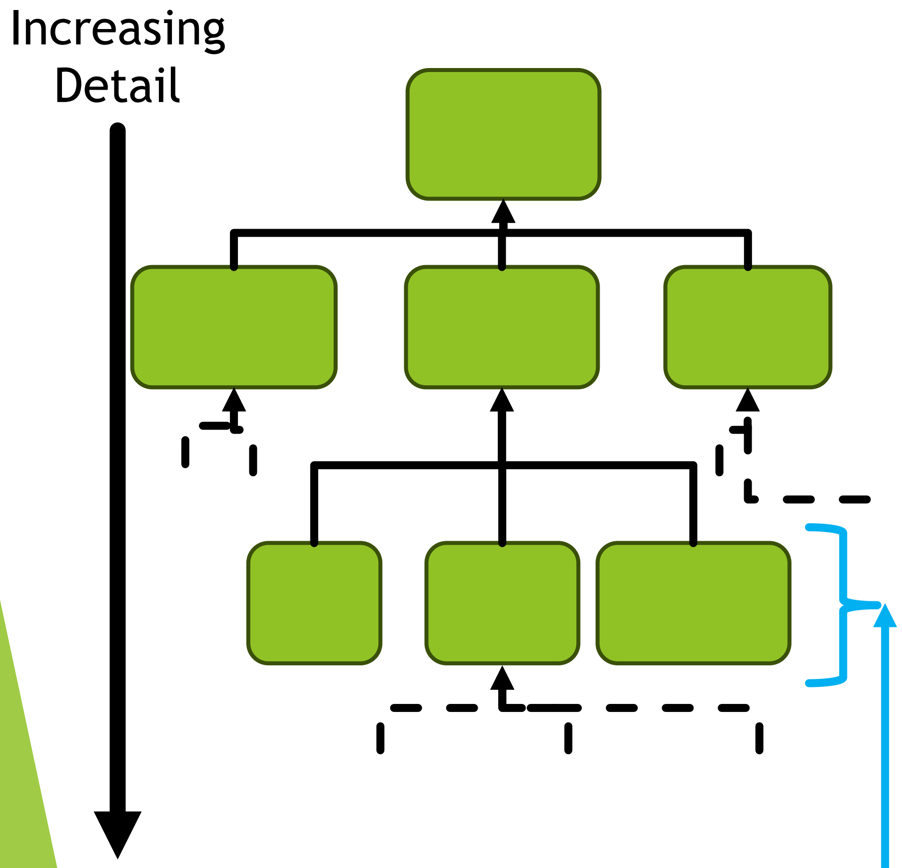




The Decision-Making Framework in ANS-30.3

Making Choices Taking Into Account Information at Multiple Levels of Detail

Framework = Representation of relationships and dependencies among specified elements



- **<u>Requirement</u> to establish a formal decision analysis process.**
  Without a formal RIPB decision analysis process, decisions made over the evolution of a design may become ambiguous, conflicting, or inefficient.
- **<u>Requirement</u> to employ requirements management** for establishing requirements, evaluate options, identify acceptable options, and track integration of requirements into the reactor product.
- Describes a decision-making structure within which requirements associated with the processes described meet specified acceptance criteria and thereby achieve the standard's outcome objectives in a formal way.
  A substantial part of the value of ANS-30.3 as a voluntary consensus standard is on account of this formal decision-making structure.

Satisfaction of the objectives at this level implies satisfaction of the objective at the level above

Relationship Between Requirement, Criterion, and Performance Objective

A **Requirement** is the basic element for the interface and interaction between the designer and the rest of the project relative to fulfilling the functional purposes of the project.

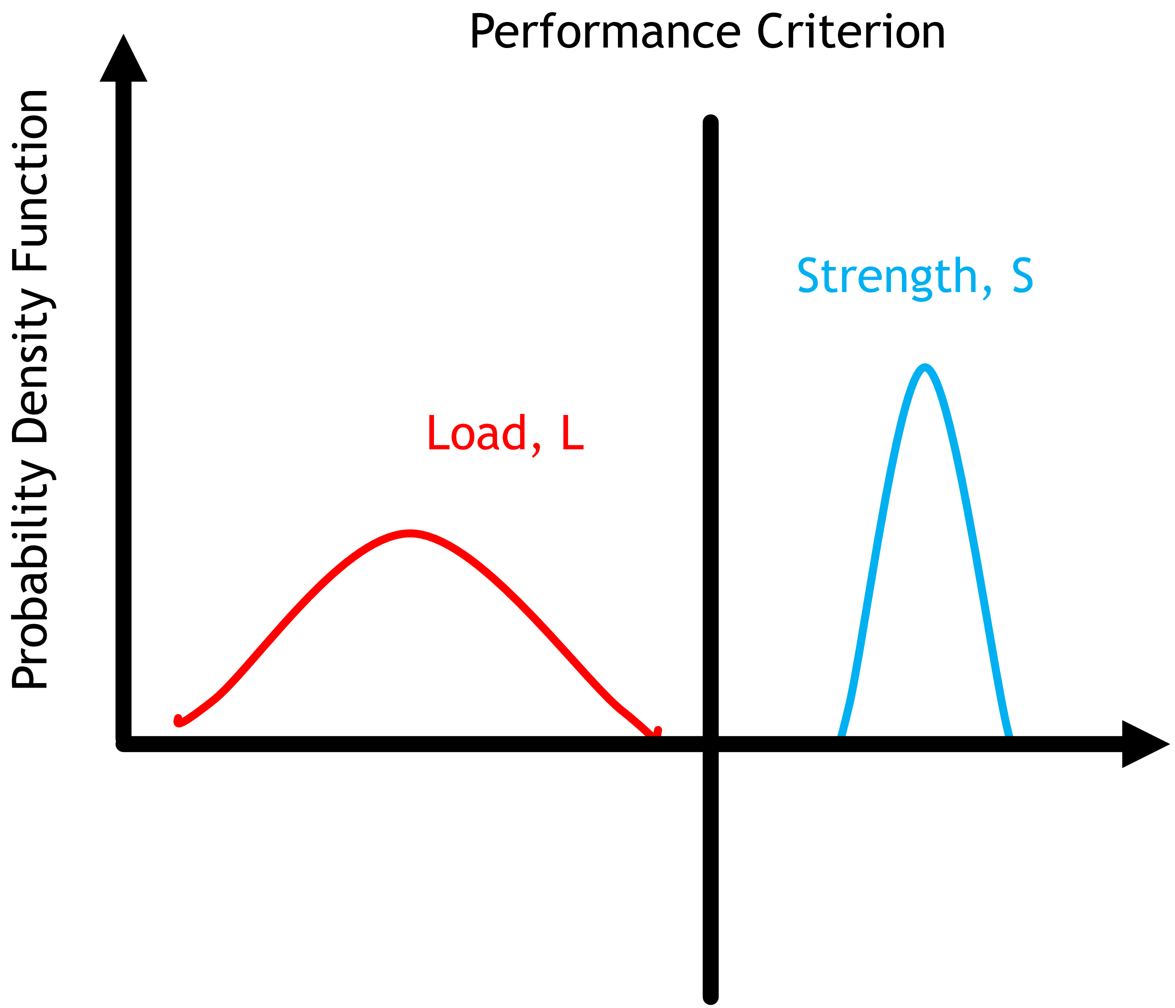
For example, a high-level requirement could be to demonstrate feasibility of employing a nuclear heat source to replace a coal-powered heat source.

A low-level design-process requirement could be that as a baseline, at the conceptual design phase, all components are presumed to be off-the-shelf items (and if this does not imply adequate performance, some components will need to be upgraded)

A **Criterion** is the level of one or a set of parameters that establishes the limit state of acceptance for a given system.

A **Performance Objective** is a set of activities that defines success at accomplishing a purpose

Setting Criteria Using Concept of Safety Margin



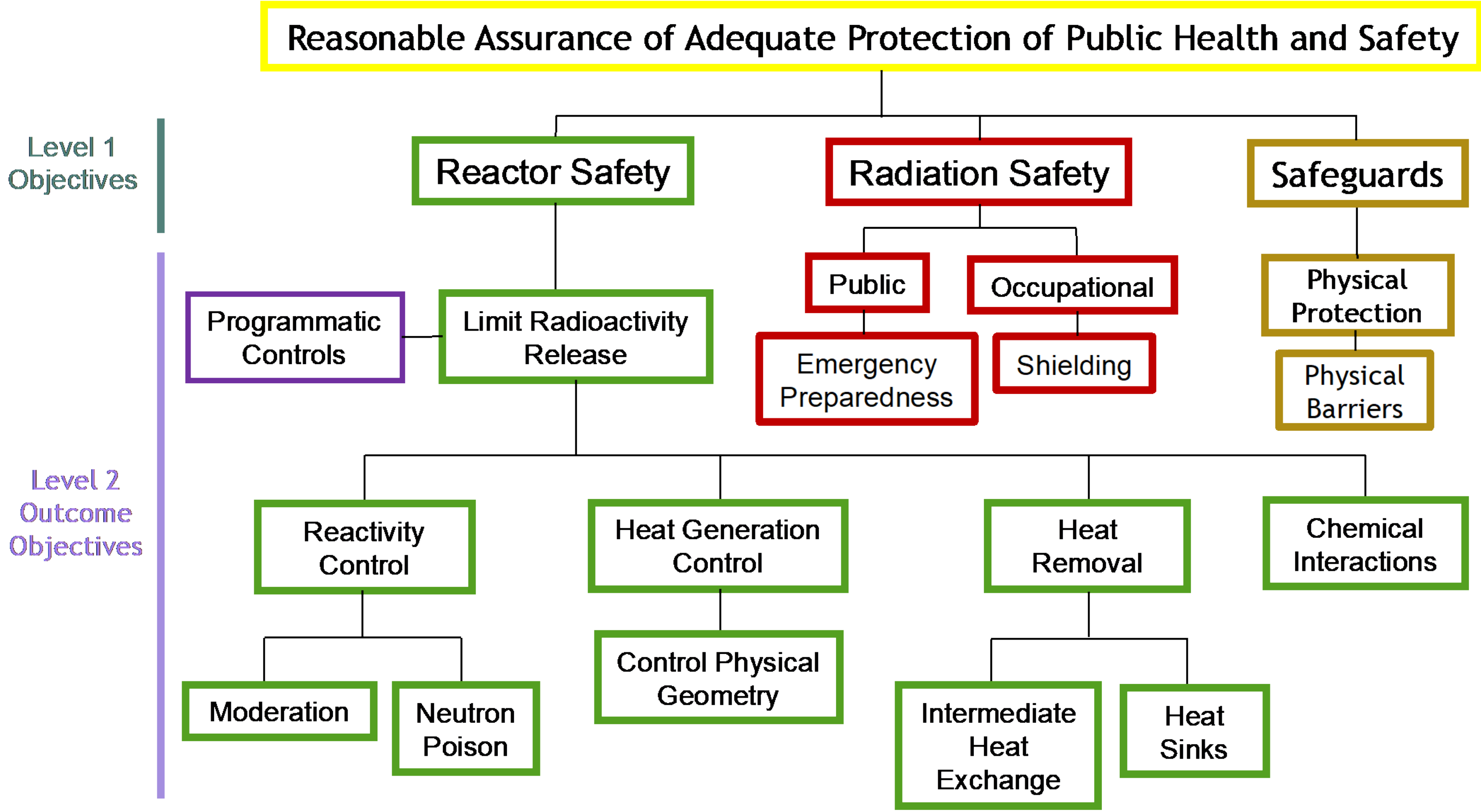
Blue PDF
Representation of system attributes that enable it to meet performance objective

Red PDF
Representation of operating or transient state system attributes

Safety Margin is the difference between criterion and a state point

ANS-30.3 offers a method to evaluate the set point for a criterion to estimate likelihood of being right or wrong on margin estimate

Notional Objectives Hierarchy for a Molten Salt Reactor



Notional Application of ANS-30.3 to Licensing a Molten-Fuel Molten-Salt Reactor (MF-MSR)

The notion envisions an application under 10 CFR Part 52 for a design certification application (DCA) using deterministic and performance-based approaches

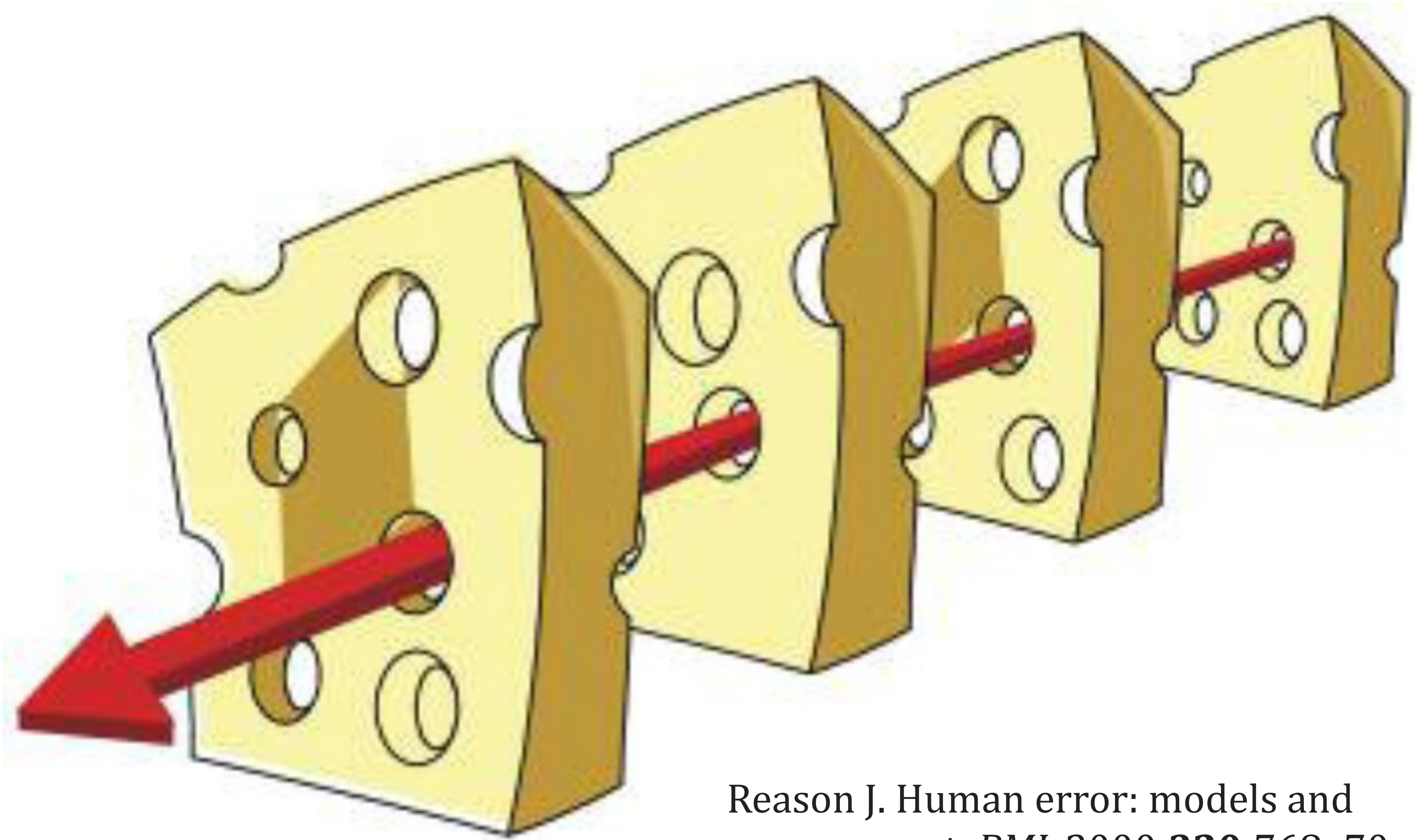
Part 52 envisions a rulemaking based on NRC staff review of a SAR that describes a safety case in the DCA claiming to meet 10 CFR Part 52.47. Specifically, the safety case proposes principal design criteria (PDC) with their relationship to the design bases.

The proposed PDC and design bases could employ the process elements in Sections 4, 5, and 6 to specify the requirements associated with a set of design basis events postulated as the limiting challenges that SSCs need to meet.

The notional application needs to recognize that challenges posed by scenarios beyond the design basis should be considered; these could be addressed using Sections 8, 9, and 10 as evaluation of DID.

Section 7 could be used as a basis for confirmation that a fit-for-purpose PRA shows appropriate risk management in the design.

Defense in Depth



Reason J. Human error: models and management. *BMJ.* 2000;**320**:768–70.

Value Proposition of ANS-30.3 as a Voluntary Consensus Standard

- ANSI/ANS-30.3 is well positioned to offer many of the bases needed to build the safety case to prepare a non-LWR license application using a VCS in the same way that standards developed by other standards developing organizations are used
- ANS-30.3 provides for an architecture of a decision-making framework that enables input of information on performance objectives to be incorporated into a structure such that various levels of detail can be formally considered while proposing alternative means for accomplishing them.
- One or more decision-making structures may be used to serve as “scaffolding” that formally tracks requirements among the various processes described to reach logically defensible decisions.
- ANS-30.3 offers methods to take account of physical and temporal margins by assessing the likelihood of making right or wrong decisions relative to set points of observable criteria.
- If on-going NRC review leads to endorsement, ANS-30.3 would be a notable accomplishment relative to NEIMA as well as federal direction in OMB Circular A-119 to strive for performance-based requirements.