LWRS
LIGHT WATER REACTOR SUSTAINABILITY

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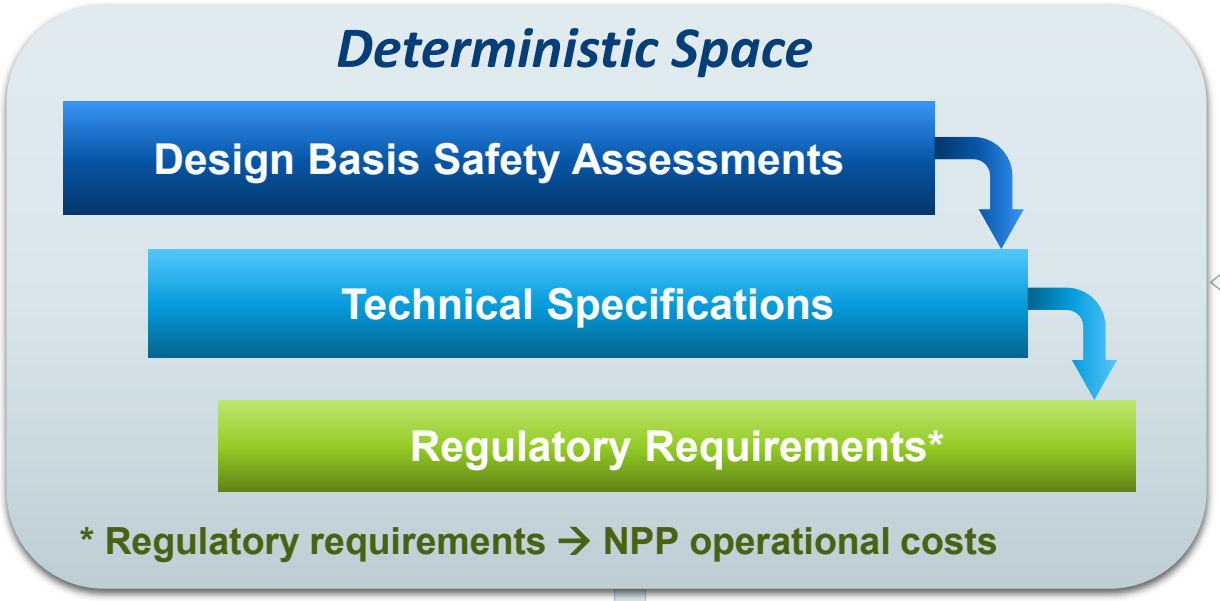
Benefits of Adoption of RIPB Approaches for Operating Reactors' Licensing and Standards

ANS RP3C Community of Practice Presentation

Current State of Operating Reactors' Transformation



Impacts:

- Decision-Making Dictated by Regulatory Imperatives
- Applications Rely Heavily on NRC Approved PRA
  - RI Technical Specifications (4B, 5B)
  - 10 CFR 50.69

Transition to Probabilistic Space:

- Stylized Bounding scenarios
- Intentional conservatisms

Associated difficulties:

- Prescriptive solutions to plant performance monitoring
- Not all plant performance aspects are addressed by PRA (i.e., "risk" does not translate to CDF in scrutable ways – **lacks transparency**)
- Risk metrics based on legacy data not on real-time observations

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Beyond Risk-Informed: Expanded Tool-Box for Risk Informed and Performance-Based (RIPB) Ideas

- RIPB Approach Means
  - **Risk-informed**: identify important things
  - **Performance-based**: flexible strategies for monitoring performance of the important things
- SRM-SECY-98-144, White Paper on Risk-Informed and Performance-Based Regulation, 1999:

  "…a risk-informed, performance-based regulation 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**,*

  *(2) establish **objective criteria** for evaluating **performance**,*

  *(3) develop measurable or calculable **parameters for monitoring** system and **licensee performance**,*

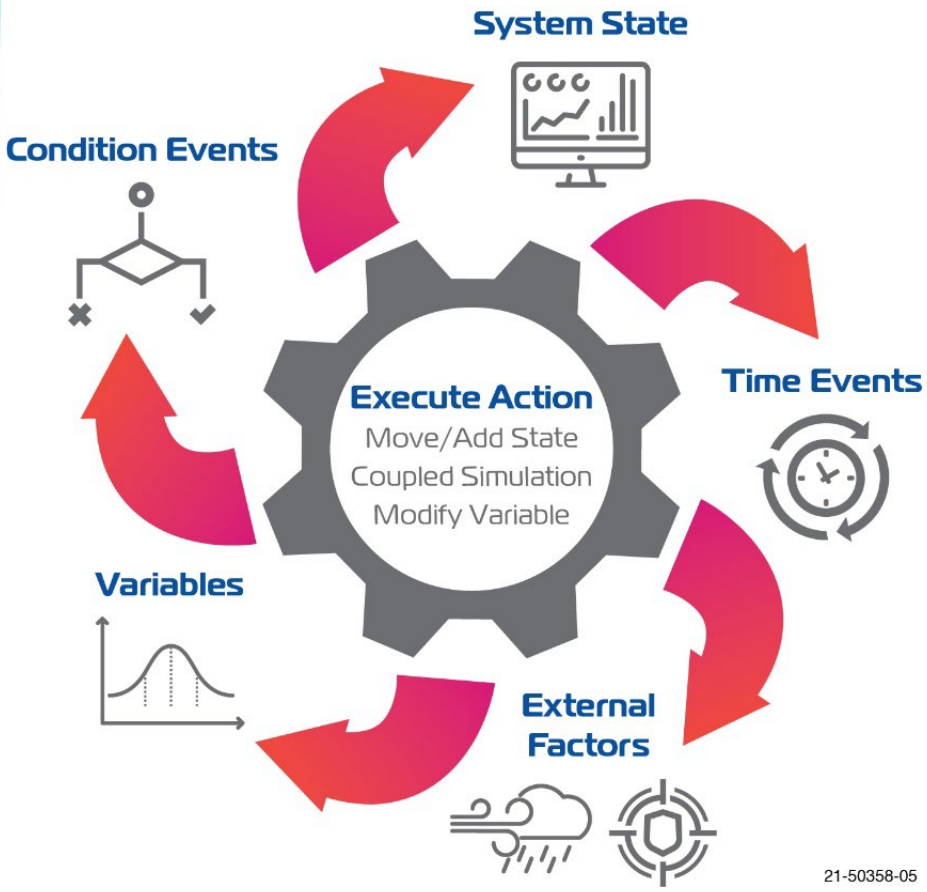
  *(4) provide **flexibility** to determine how to meet the established performance criteria in a way that **will encourage and reward improved outcomes**, and*

  (5) focus on the results as the primary basis for regulatory decision-making."
- Not mentioned often, but certainly is not forgotten
  - NRC Staff position for Risk-Informing CCFs in DI&C: *"Any use of risk-informed approaches will be expected to be consistent with the Safety Goal Policy Statement, PRA Policy Statement, and SRM **SECY- 98-0144**"*

Specific Benefits from Performance-Based (PB) Ideas

- The performance-based approach is grounded on the idea that **real-time observations** can be used to validate accomplishment of the defined objectives for a system performance (as opposed to sole reliance on prescriptive rules for system manufacturing and performance)
- Either for design or licensing activities, flexibility in the PB approach arises from:
  - Margin between an operational state and a limit state of the system representing acceptance criteria
  - A performance objective is characterized by requirements associated with minimum accepted margin for design or licensing purposes
  - Requirements management for system performance, expressed in terms of margin, include consideration of safety as well as other needs such as economics and investment protection.
- Regulatory framework can employ PB approaches, in addition to risk-informed approaches, to reduce intrusive inspection strategies by verifying licensee monitoring of accepted margins

RIPB Practices Incorporated into Transformation



Scenario

- Proceed through event scenarios from the perspective of margins between best-estimate conditions to unacceptable limit states

Consequence

- Apply decision analysis to estimate likelihood that the limit states will not be breached

Performance Metrics

- Identify **objective performance criteria**
- Evaluate plant performance with respect to established qualitative and quantitative criteria.

Safety Margins Based on Observable Parameters

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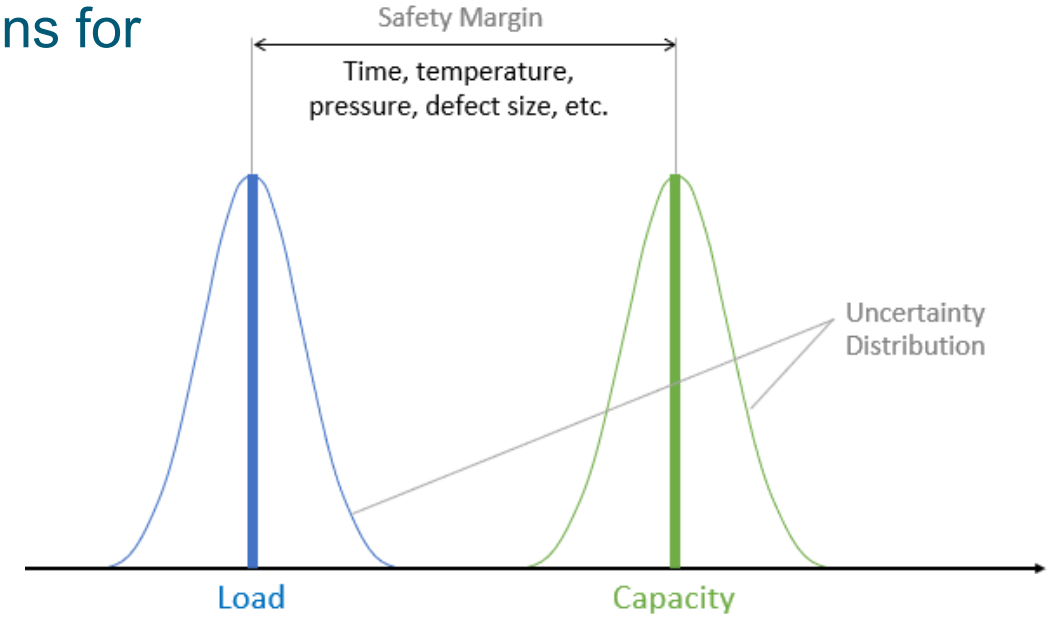
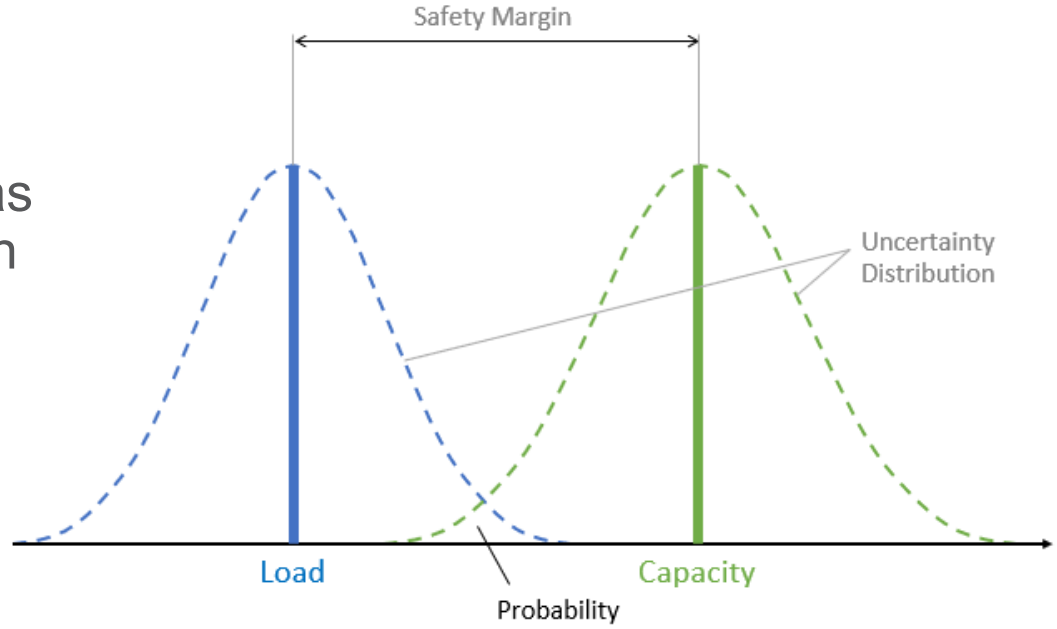
Safety Margins For Performance Objectives

NOT a new concept, we have used safety margins for decades in many industries / applications

- Concrete performance
  - Crack size as metric to evaluate degradation of margin
- Metal performance
  - Remaining wall thickness as a metric for available service margin
- Component Health
  - Remaining useful life (time) as a proxy for acceptable margin
- 10 CFR 54 Time-Limited Aging
  - Acceptable level of margin in capability of SSC

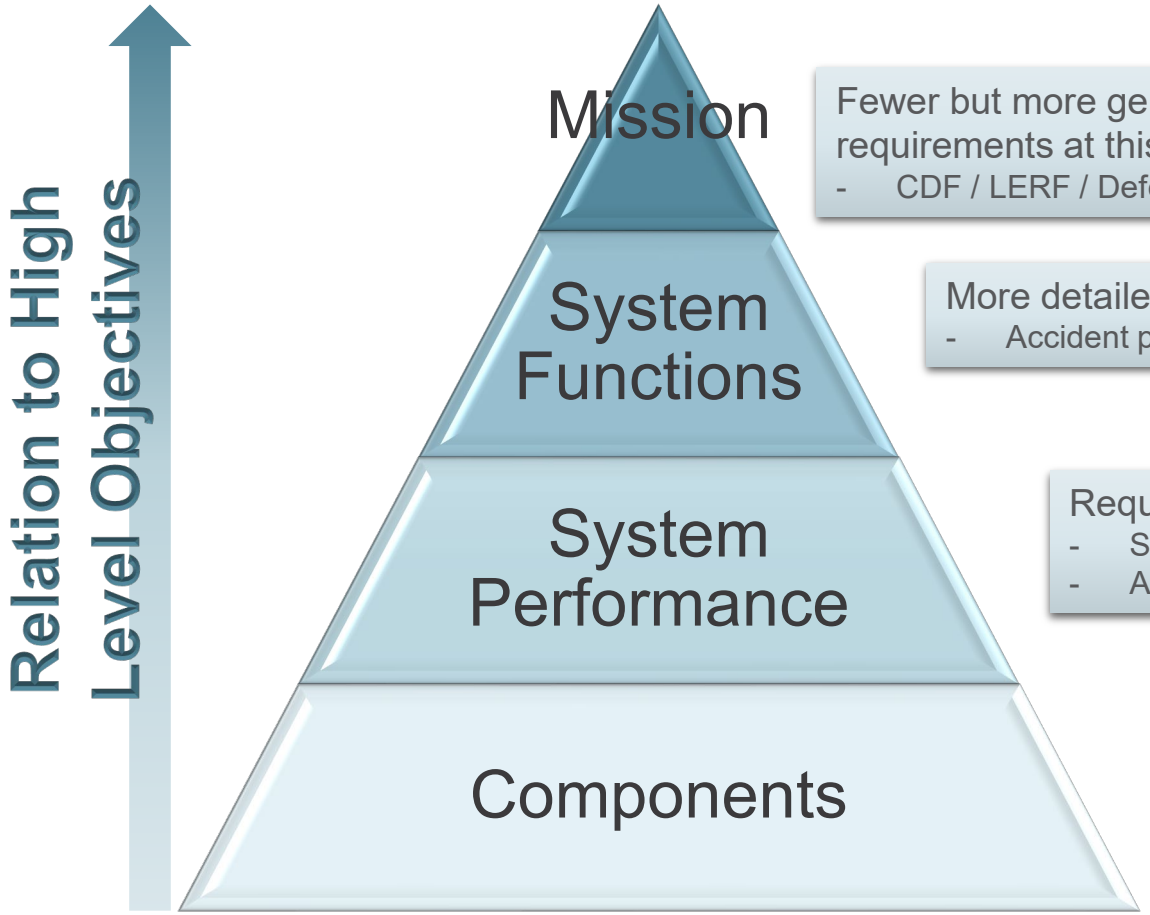




Performance-Based Approach: What does it mean?

- Traditional way:
  - Safe performance of a section of piping is assured by prescribing details of dimensions, materials, heat-treatment, etc. for the piece of pipe.
- Performance-Based approach:
  - Establish **objective criteria** for evaluating conditions of XYZ pipe
  - Develop measurable or calculable **parameters for monitoring** XYZ pipe performance
  - Determine **how to meet** the established performance criteria
  - Licensee controls **how to meet** criteria
  - Licensee enjoys reward of **meeting criteria** more efficiently
- Benefits:
  - Provides flexibility to determine **how to meet** the established performance criteria in a way that will encourage and reward improved outcomes
  - Focus on the results as the primary basis for regulatory decision-making
  - Licensee has more control over results with NRC oversight being secondary

Reimagining Requirements Management



Fewer but more general requirements at this level
- CDF / LERF / Defense-In-Depth

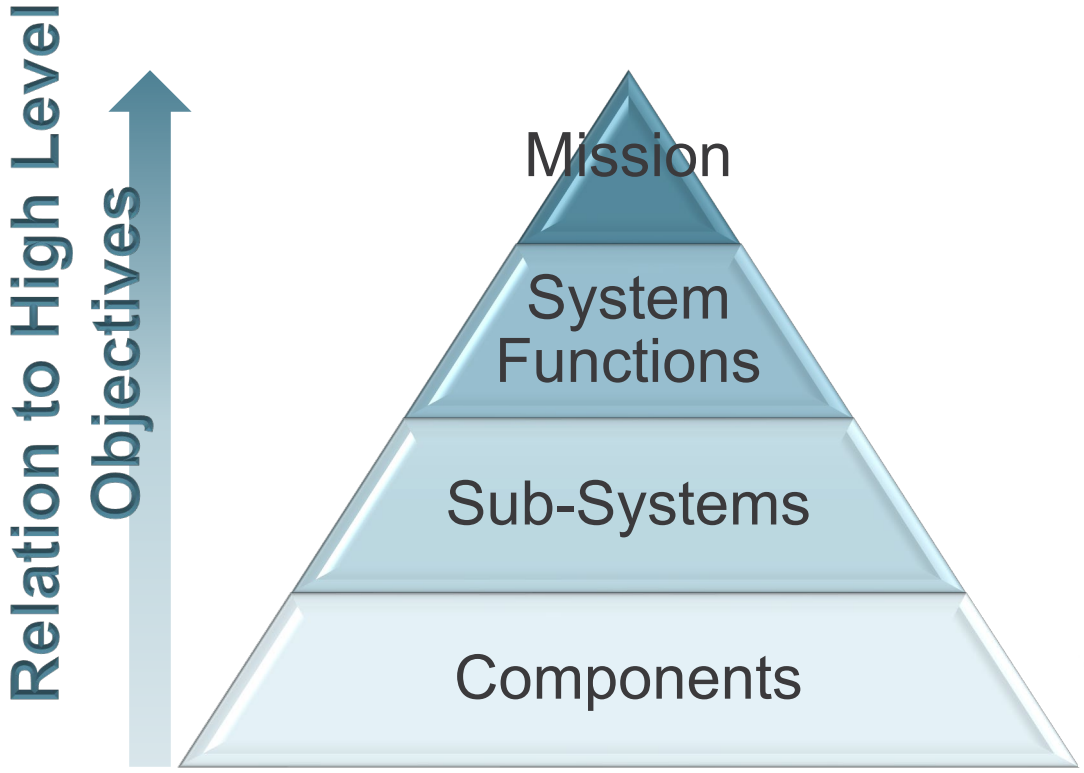
More detailed requirements at this level
- Accident progression given system functions

Requirements address fitness for purpose
- System success criteria
- Accident progression given system performance

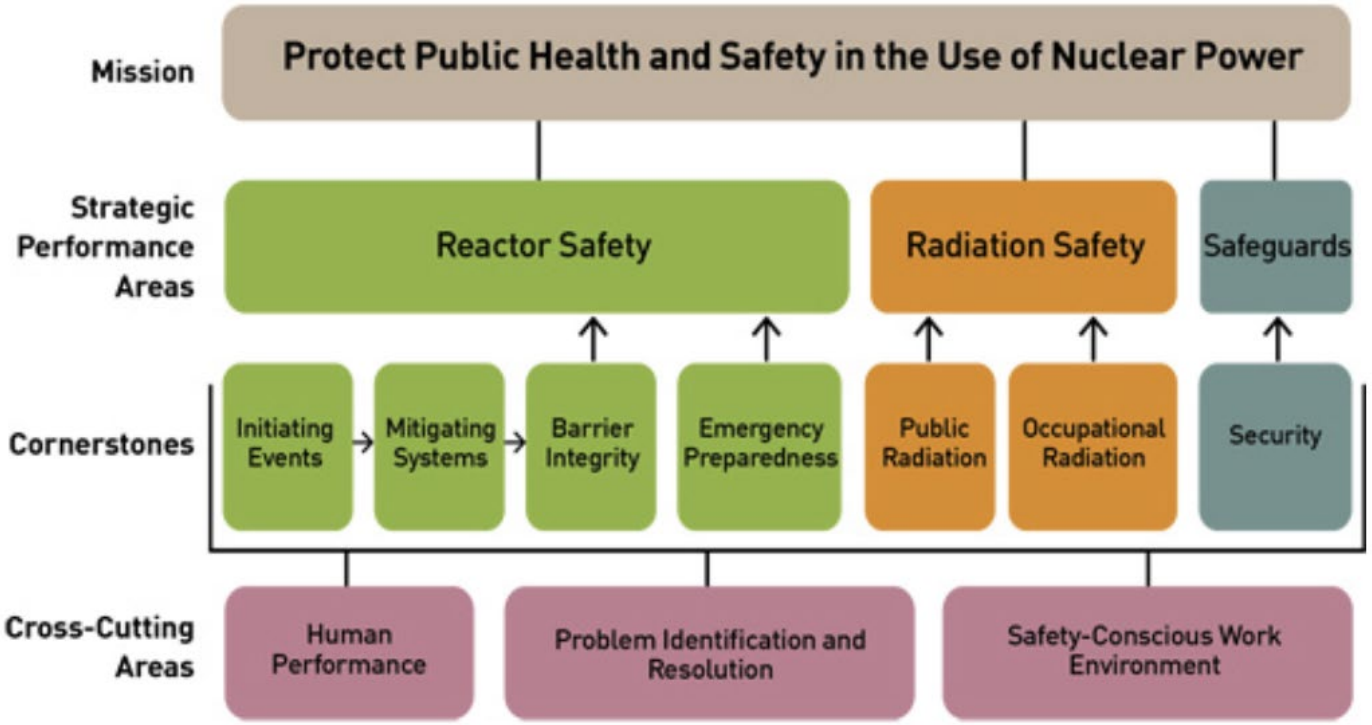
Requirements become prescriptive for components
- Imposed by codes and standards (ASME, IEEE, etc.)
- Reliability / Availability (e.g., MSPI, MRule)

Typical System Hierarchy

Example of Reimagined Requirements Management

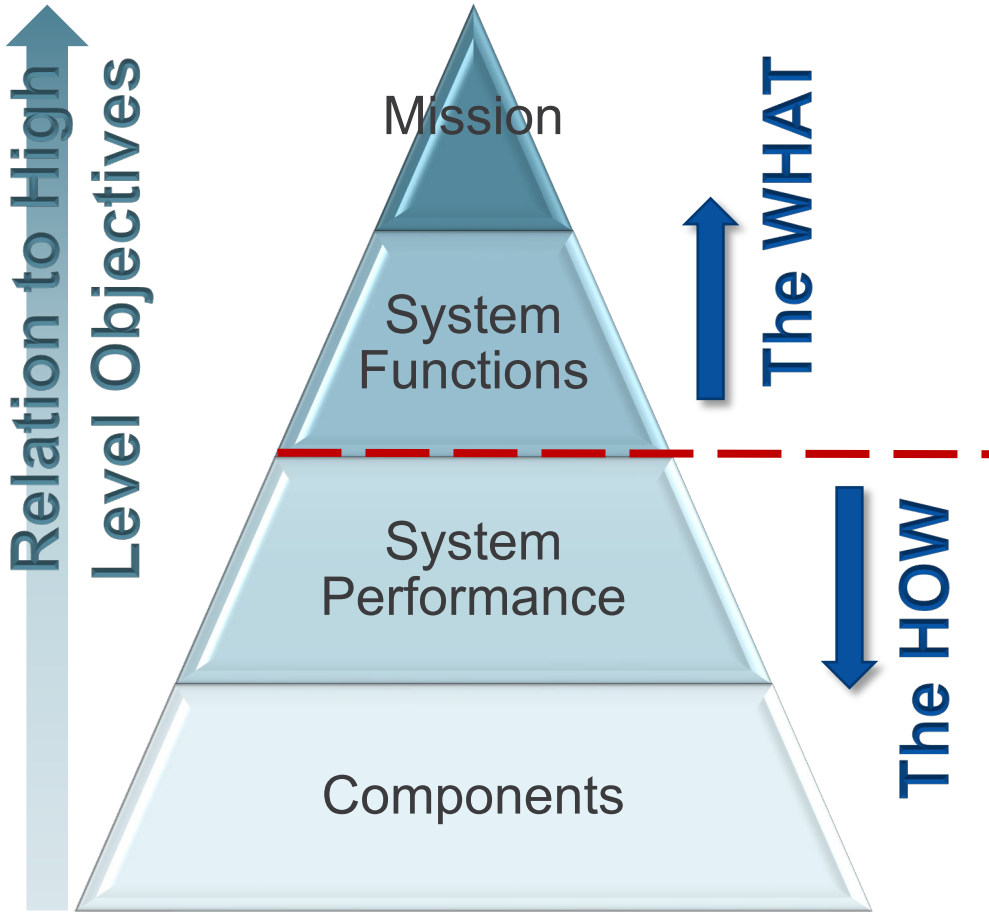


Typical System Hierarchy

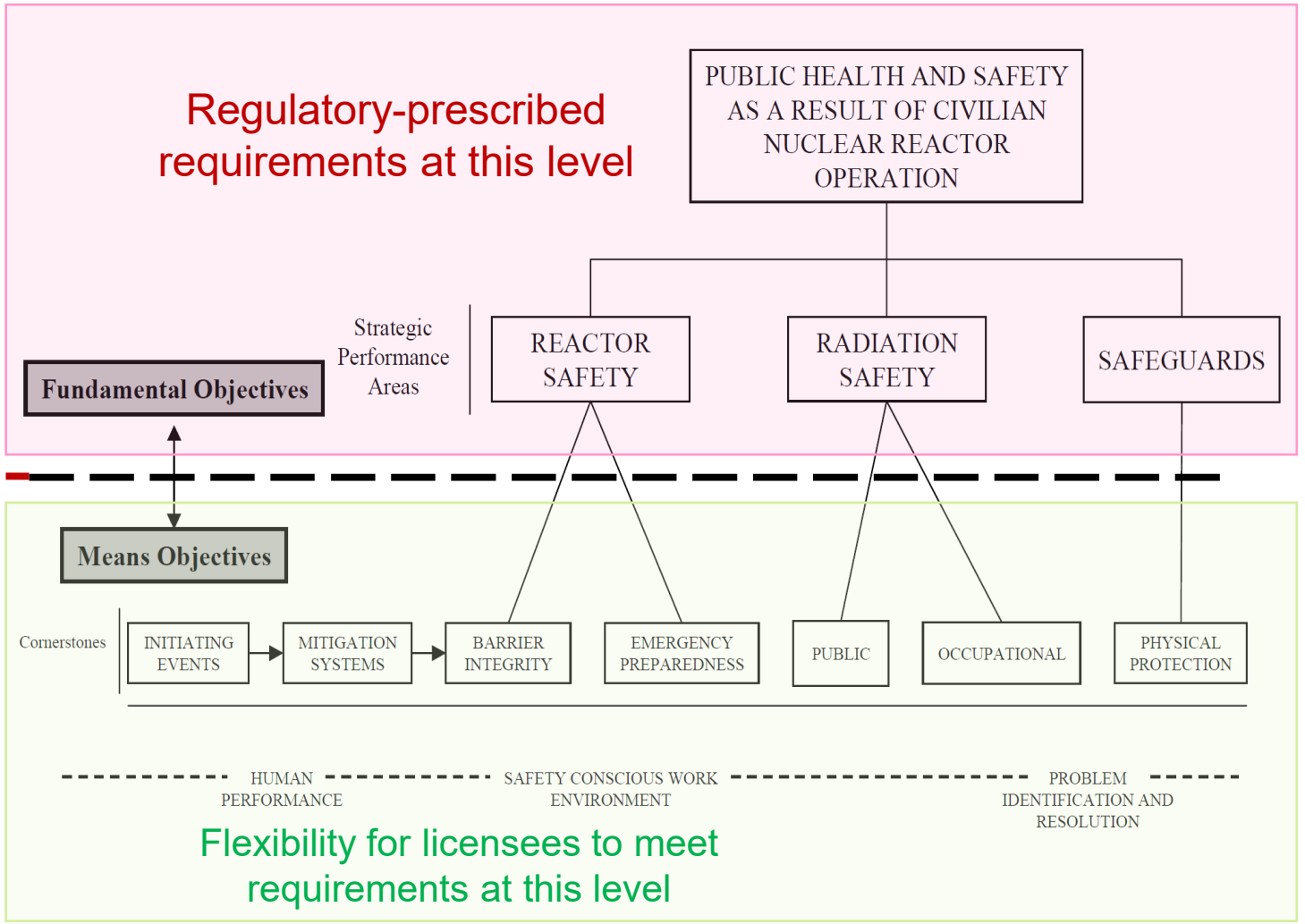


NRC Reactor Oversight Framework
https://www.nrc.gov/reactors/operating/oversight/rop-description.html

Reimagining Requirements Management (continued)



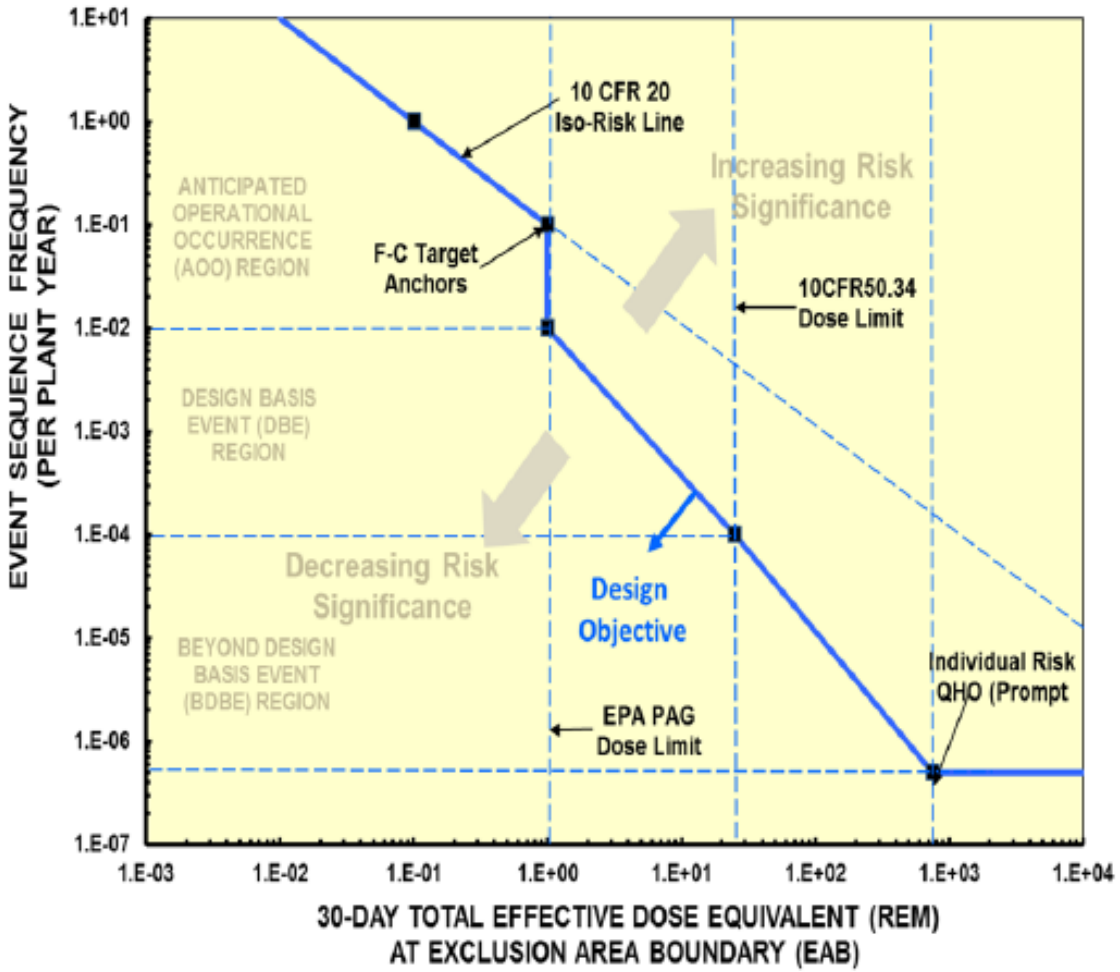
Typical System Hierarchy



Reactor Oversight Process Objectives Hierarchy

LMP Framework – Could be Adapted to Operating LWRs

- Use of phenomenological modeling and simulations
  - Could reduce reliance on assumptions and uncertainties
- Redefine DBAs for LWRs: use F-C curve vs the list in Chapter 15
  - E.g., Large Break LOCA would not be a DBA
  - Employ framework of ANSI/ANS-2.26 to support seismic LBEs
- Could allow use of safety margins expressed in metrics other than "risk"
  - Time as a parameter for physical and operator response
  - Modelling of defect size
  - Margin to acceptable radiation dose



NEI 18-04: Figure 3-1. Frequency-Consequence Target

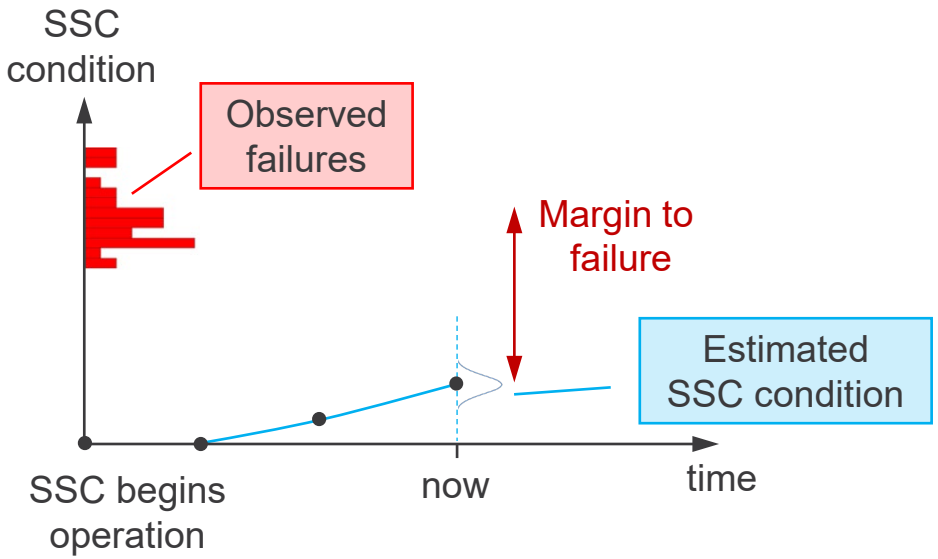
Beneficial to transition form ΔCDF-only margin to physics-based margins

Cost Saving Opportunities Examples

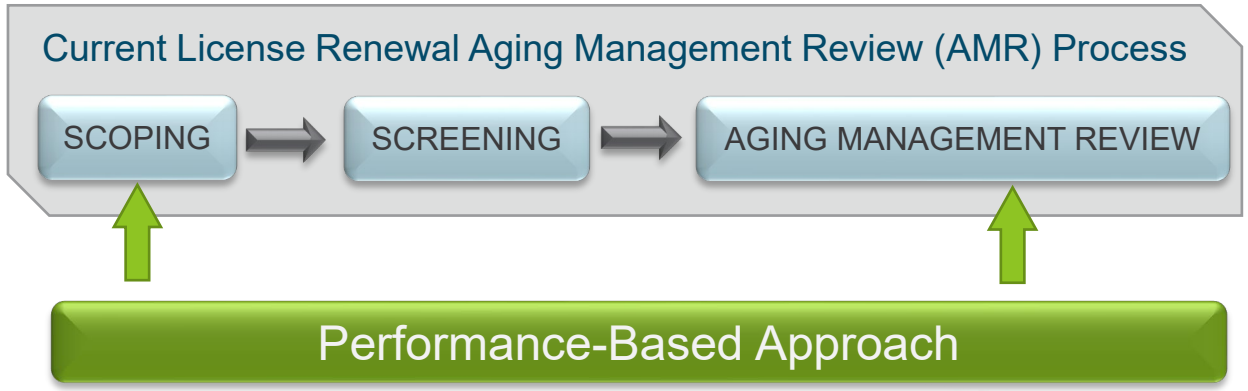
- Equipment Maintenance
  - Change reliability metric from:

    Instead of *"probability of failure = 2.56E-4"*

    use "*remaining useful life is 70 months*"
  - Switch from "risk" to "margin" where margins can be defined in measurable and **observable** terms such as flow rate, temperature, viscosity, leak rate, etc.
  - Benefits:
    - Clear communication of equipment health
    - Direct support of decision-making done by systems engineers and plant managers
    - Allows prioritization and optimization of maintenance activities and schedules



- Subsequent License Renewal (SLR)
  - SSCs "in scope" for SLR can be selected based on their need to fulfill system top-level functions instead of using a prescribed list of SSCs
  - Aging Management Review and subsequent aging management plans (AMPs) can be setup to use SSC-specific performance metric (e.g., crack size) instead of prescribing frequency of inspections
  - Benefits: flexibility in plant operations and cost savings



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Other Cost Saving Opportunities

- **Risk-Informed, Performance-Based Design for LWRs**
  - ANSI/ANS-30.3-2022, Light Water Reactor Risk-Informed, Performance- Based Design, July 2022
  - Performance-based options to NUREG-0800, Chapter 15 for margins assurance in DBE scenarios
  - Performance-based options to Appendix A to Part 50 “General Design Criteria for Nuclear Power Plants”
  - Benefits: fewer safety-related SSCs, flexibility in SSC performance assurance → cost savings
- **Equipment Qualification**
  - Move from NQA-1* requirements (prescriptive) to performance-based options for equipment manufacturing, testing, and maintenance
  - Benefits: significant cost reduction in SSC procurement and maintenance
- **Specification Management**
  - Transition from the currently-used prescriptive specifications for SSC performance to systems-based approach where required performance is specified only at a functional level allowing flexibility at the component level to meet functional requirements
  - Benefits: flexibility of how functional level requirements can be achieved allowing optimization of design solutions, adjustments based on availability of components which drive cost savings and better system designs

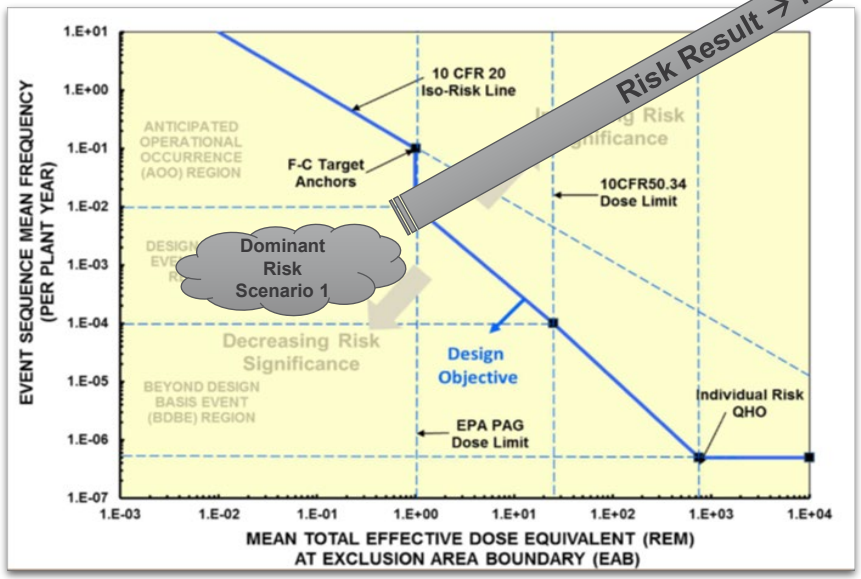
* ASME Quality Assurance Requirements for Nuclear Facility Applications

Bringing the Focus to Specific ANS and Other Standards

Reliability and Integrity Management (RIM) Program

RIPB Approach to Aging Management (ASME Section XI, Division 2)

- **Reliability Targets**
  - Plant-level targets are informed by expected SSCs performance
  - SSC reliability targets are set to ensure the plant-level target is not exceeded



Risk Result → Risk Target

Risk Target = Scenario Frequency & Consequence (Dose)

Hazard Initiating Event | Plant Reliability | Release | Mitigation of Release

Scenario Representing Risk Target

Reliability Target

Reliability Target

Frequency of Enabling Condition

Probability Condition Leads to Initiating Event

Systems

Reliability of System or Function A X Reliability of System or Function B X Reliability of System or Function C

Subsystems

R(A.1) X + R(A.2) R(B.1) R(C.1) X + R(C.2) X + R(C.3)

Components

R(A.1.1) R(A.1.2) R(A.1.3) R(A.2.1) R(A.2.2) R(B.1.1) R(C.1.1) ... R(C.3.1)

Etc.

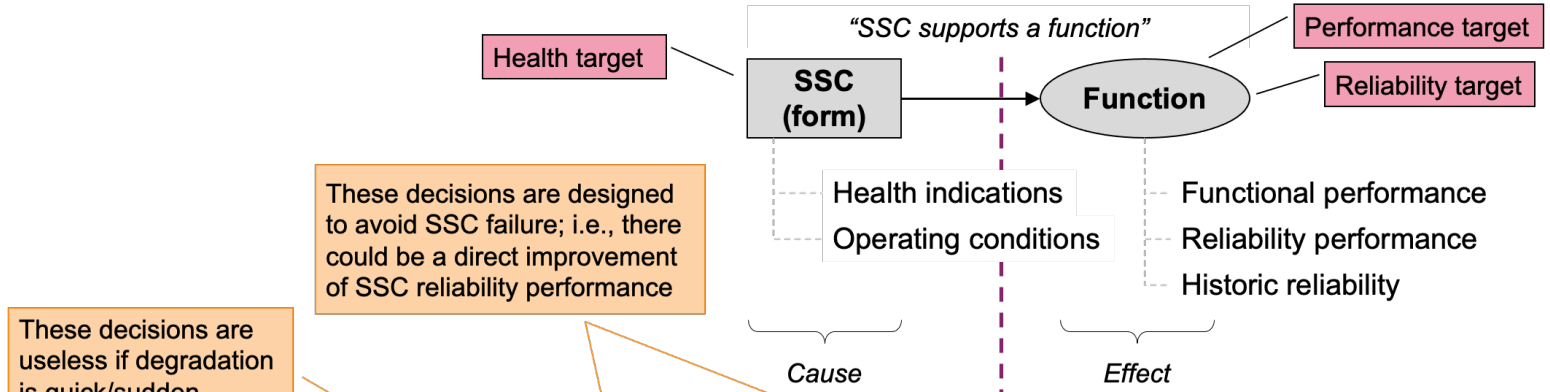
3 components in a system

2 components in a system

1 component in a system

Reliability and Integrity Management (RIM) Program
RIPB Approach to Aging Management (ASME Section XI, Division 2)

- **RIM Strategies (monitoring of equipment performance)**
  - Numeric reliability (e.g., 2.5E-6) is not observable and reliability value is “post-mortem”
  - RIM goal is to prevent failures (i.e., no drastic changes in reliability targets) → need a performance target (e.g., leak rate)
  - RIPB approach is the solution → a bridge between observable performance and resulting reliability



Players	Decisions (cause node)	Decisions (effect node)
System engineers	• Monitor SSC health • Restore SSC form if health indications are approaching limiting conditions	• Monitor SSC performances • Restore SSC function if functional performance is approaching limiting conditions • Set preventive maintenance actions • Restore SSC function if failed • Validate/check reliability targets
PRA analysts		• Update reliability data • Update PRA models • Establish reliability targets

Risk and Performance Metrics

ANS-2.26

"Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design"

ANS-2.26 is a standard for determining the Limit States of components that could impact the seismic safety of nuclear facilities.

- The Limit States are selected to ensure the desired safety performance in an earthquake.

a) criteria for selecting the seismic design category (SDC) for nuclear facility structures, systems, and components (SSCs) to achieve seismic safety and

b) criteria and guidelines for selecting Limit States for these SSCs to govern their seismic design.

What ANS-2.26 Does

ANS-2.26:
Assign a "Seismic Design Category (SDC):"

Given the potential consequences of failure, assign a performance criterion: specifically, a *failure probability criterion*.

The other standards then tell you how to go about engineering satisfaction of this criterion.

Figure from Appendix A:

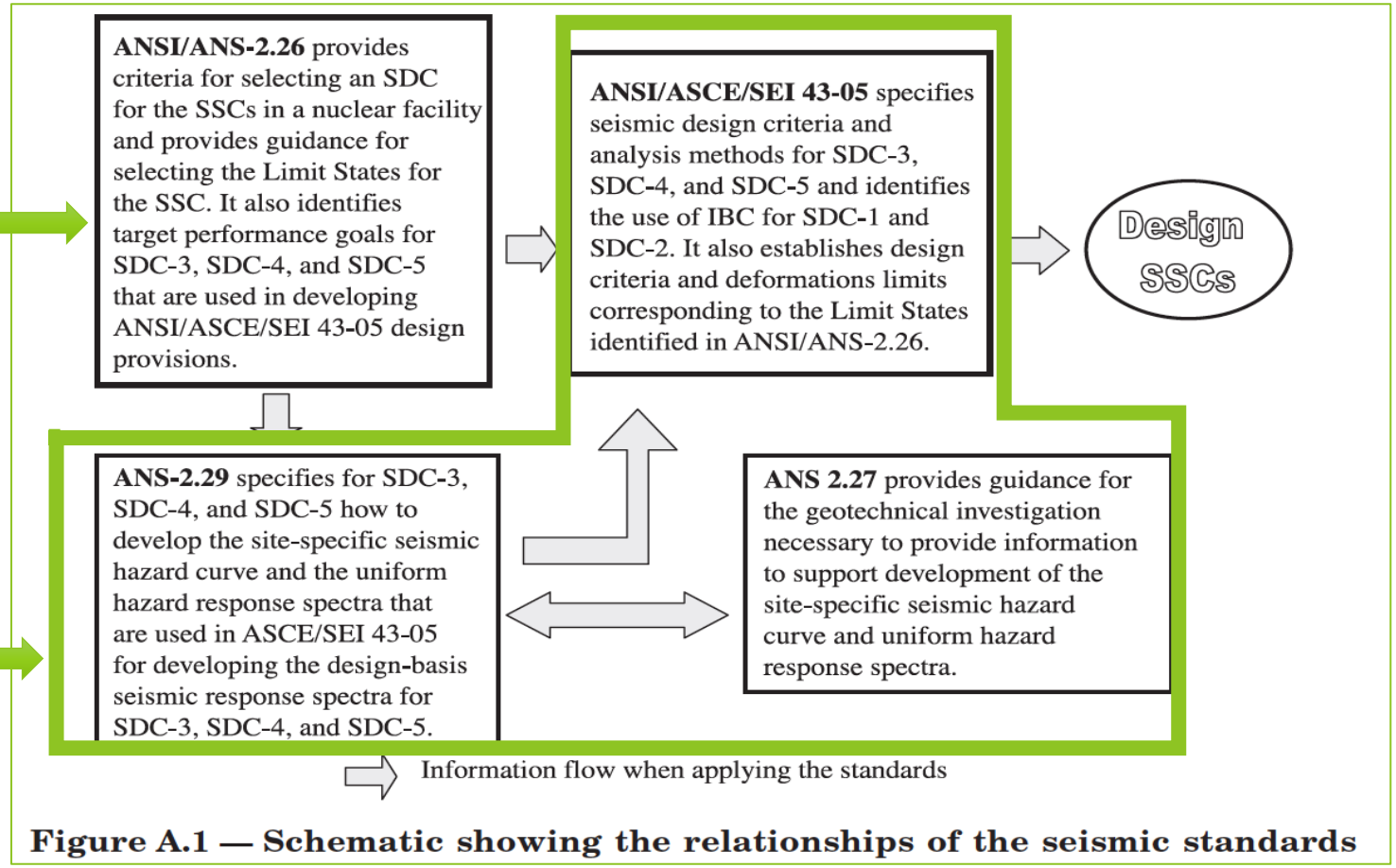


Figure A.1 — Schematic showing the relationships of the seismic standards

ANSI/ANS-30.3-2022
Light Water Reactor Risk-Informed, Performance-Based Design

This standard provides requirements for the incorporation of risk-informed, performance-based principles and methods into the nuclear safety design of new commercial light water reactors.

- This standard establishes a minimum set of requirements for the designer to appropriately combine deterministic, probabilistic, and performance-based methods during design and continuing into operations.
- ANS-30.3 requires that the user 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
- ANS-30.3 employs requirements management for establishing requirements, evaluate options, identify acceptable options, and track integration of requirements into the reactor product.
- ANS-30.3 offers 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.

ANSI/ANS-3.5.1-202x

Nuclear Power Plant Simulators for Use in Simulation-Assisted Engineering and Non-Operator Training

Graded Approach to Requirements Management

- Requirements are established based on the “Use Type”, which considers specific objectives for a simulator
  - Use Type1 - Operator Training and Examination Simulator
  - Use Type 2 - Modified operator training and examination simulator
  - Use Type 3 - Engineering simulator
  - Use Type 4 - Physical plant hardware connected to a simulator
  - Use Type 5 - Non-Operator training
  - Use Type 6 - Use of part-task, classroom, and limited-scope simulators
- Standard addresses activities for which a simulator was not initially designed
- Enables use of modified simulators, and other types of simulators

SUMMARY

- Regulatory practices associated with safety assessments on operating reactors have remained deterministic and prescriptive even though the Commission directed that changes be made to such practices in SRM-SECY-98-144, “White Paper on Risk-Informed and Performance-Based Regulation”
- While industry has pushed for modernization in the use of risk information, little attention has been given to the benefits of performance-based approaches even though NRC published guidance in 2002 with the issuance of NUREG/BR-0303, “Guidance on Performance-Based Regulation”
- Recently, there has been widespread recognition of the benefits of considering performance-based tools to complement the well-developed methods on risk insights.
- The key element in this recognition has been that risk and safety margins can work together to improve cost effectiveness of safety activities related to 10 CFR Part 54
- These observations apply equally to existing and new consensus standards also.

Sustaining National Nuclear Assets

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