Licensing Modernization Project-
A Systems Engineering Approach to RIPB Design Safety and Licensing

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Disclaimer

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Introduction and Welcome

- Ed Wallace – President, GNBC Associates, Inc
  - 50+ years in the nuclear industry
    - Nuclear Navy
    - Utilities – GPU Nuclear, TVA, Exelon
    - Developers – PBMR, NuScale Power
    - Consulting Clients – WEC, KEPCO, TransAtomic, Southern
  - Academic Background
    - BS – US Naval Academy
    - Naval Nuclear Power School and Prototype Training
    - Graduate Studies - Stevens Institute
    - MBA – University of Tennessee – Chattanooga
  - ANS Member – 2004 - present
    - ANS 53.1 WG – 2004-2010
    - Standards Board 2013- 2019
    - RP3C 2013-present (Vice Chair – 2013-2019)

NEVER CONFUSE SAFETY AND LICENSING!

LMP is about RIPB safety design   TICAP is about licensing

LMP Overview

- Purpose: provide an overview of LMP outcomes, content, context and some potential applications
- Major Outcomes
  - NEI 18-04 r1 " Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development
  - Southern Company supporting reports on:
    - PRA Approach
    - LBE Selection
    - SSC Classification and Special Treatment
    - Defense-in-Depth Adequacy Evaluation
    - LMP Lessons Learned, Best Practices, and Frequently Asked Questions
  - Endorsement in NRC RG 1.233 r0 "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors"

LMP Purpose

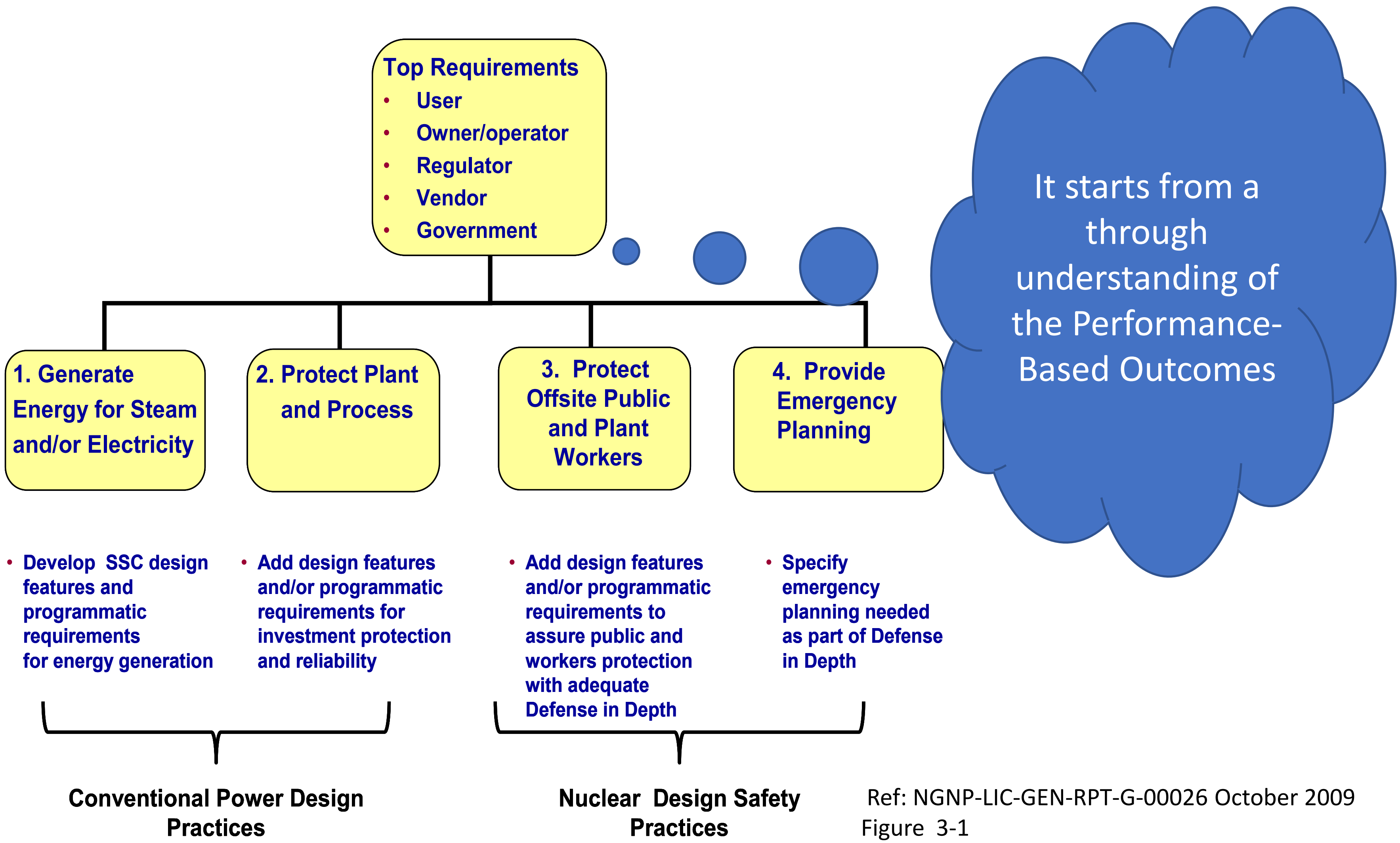
From NEI 18-04 (LMP Guideline):

- …The scope of this document is focused on establishing guidance for advanced (i.e., non-LWR) designs so license applicants can develop inputs that can be used to comply with applicable regulatory requirements, …

Based on regulatory application requirements and their implementation guidance, an applicant must answer the following questions:

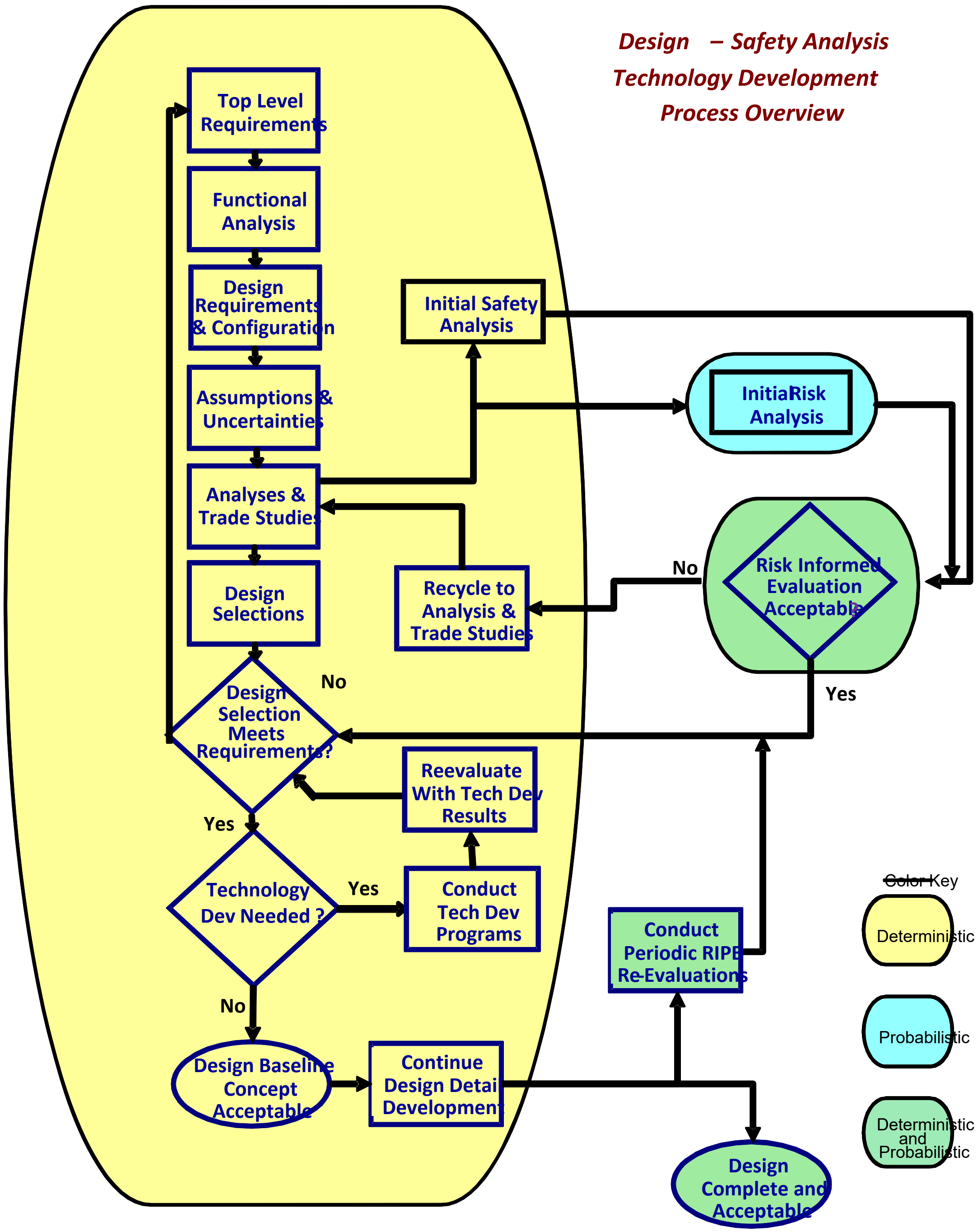
- What are the plant initiating events, event sequences, and accidents that are associated with the design?
- How does the proposed design and its SSCs respond to initiating events and event sequences?
- What are the margins provided by the facility's response, as it relates to prevention and mitigation of radiological releases within prescribed limits for the protection of public health and safety?
- Is the philosophy of DID adequately reflected in the design and operation of the facility?

Systems Engineering Design Approach



Ref: NGNP-LIC-GEN-RPT-G-00026 October 2009
Figure 3-1

LMP As an Additional Consideration in Design



An important LMP objective is to build this into the design, not bolt it on.

Ref: NGNP-LIC-GEN-RPT-G-00026 October 2009
Figure 3-2

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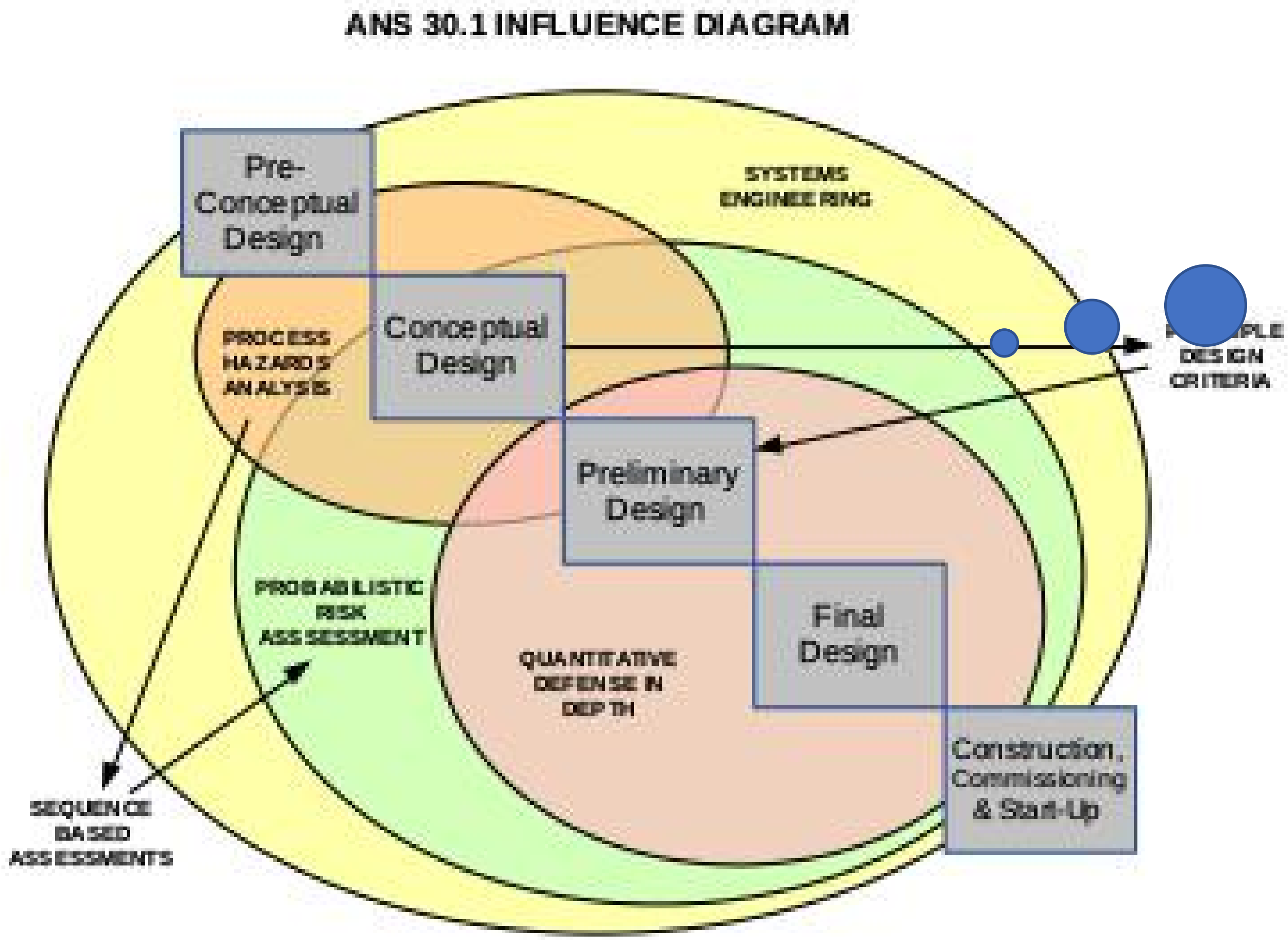
Systems Engineering Applications in Practice



SE practices create the structure to build RIPB safety into designs. LMP assumed this would occur.

Figure Courtesy of Ralph Hill

Notional Phasing of RIBP Evolution in Design (MHTGR Example)

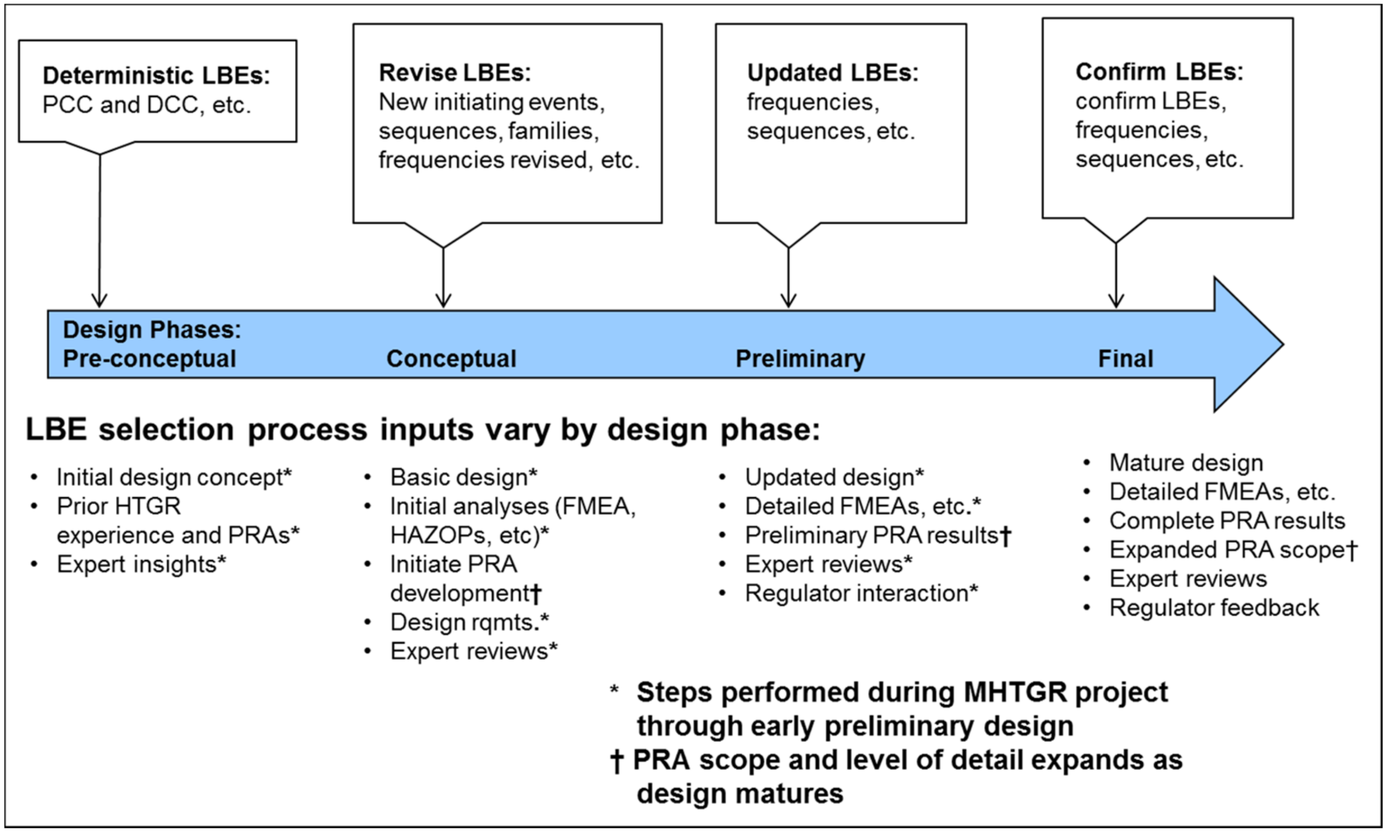


Figure 3-3. Evolution of Design, PRA, and LBE Development for the MHTGR[42]

LMP supporting document: Southern Company Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Probabilistic Risk Assessment Approach SC-29980-101 Rev 1 March 2020

RIPB Systems Engineering Elements (Partial)

DESIGN DEVELOPMENT STAGE					
R&D					
		CONTRACT TECHNICAL REQUIREMENTS			
Pre-Conceptual Design					
	Plant Functional & Performance Rqmnts				
		Plant Hazard Identification			
			Plant Risk Evaluation		
				Plant F-C Curve	
					Plant Safety Functi
		FUNCTIONAL BASELINE			Binning?
Conceptual Design					
	SS Functional & Performance Rqmnts				
SS = System/Structure		SS Hazard Identification			
			SS Risk Evaluation →	SS Safety Strategy & Safety Functions →	SS Safety Fu Allocati
			↑	SS Target Reliability	↓
			↑	←	SS Safety Classsific
		ALLOCATED BASELINE			Binning?
Detailed Design					
	Product Functional & Performance Rqmnts				
		Product Hazard Identification			
			Product Hazard Evaluation		
				Prodiuct Target Reliability	
					Product Safety Classsification
		PRODUCT BASELINE			Binning?

Categorize Functions

Classify SSCs

Building it into a Design Control Process is a Developer Responsibility! (Standards can help too!)

Table Courtesy of Ralph Hill

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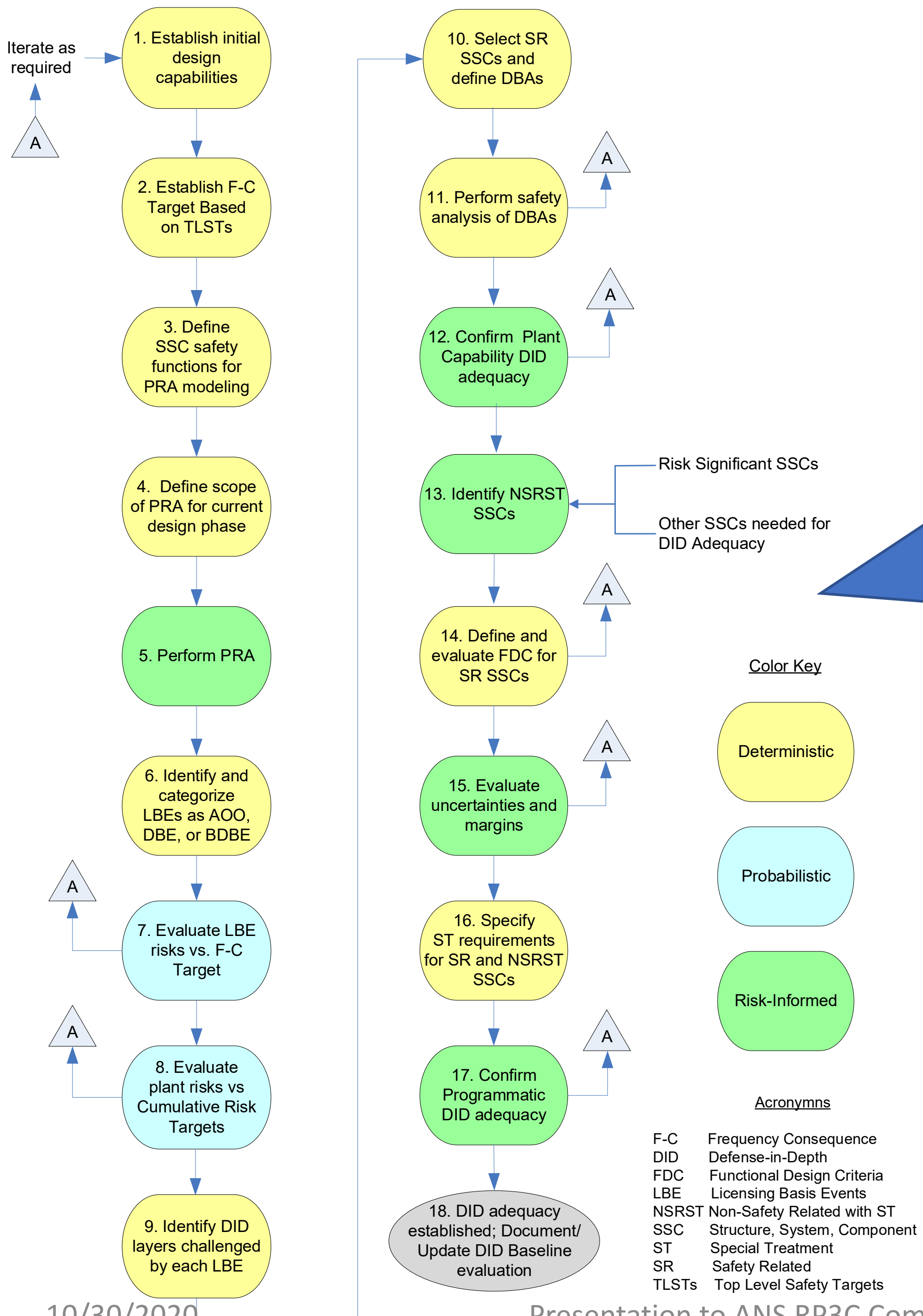
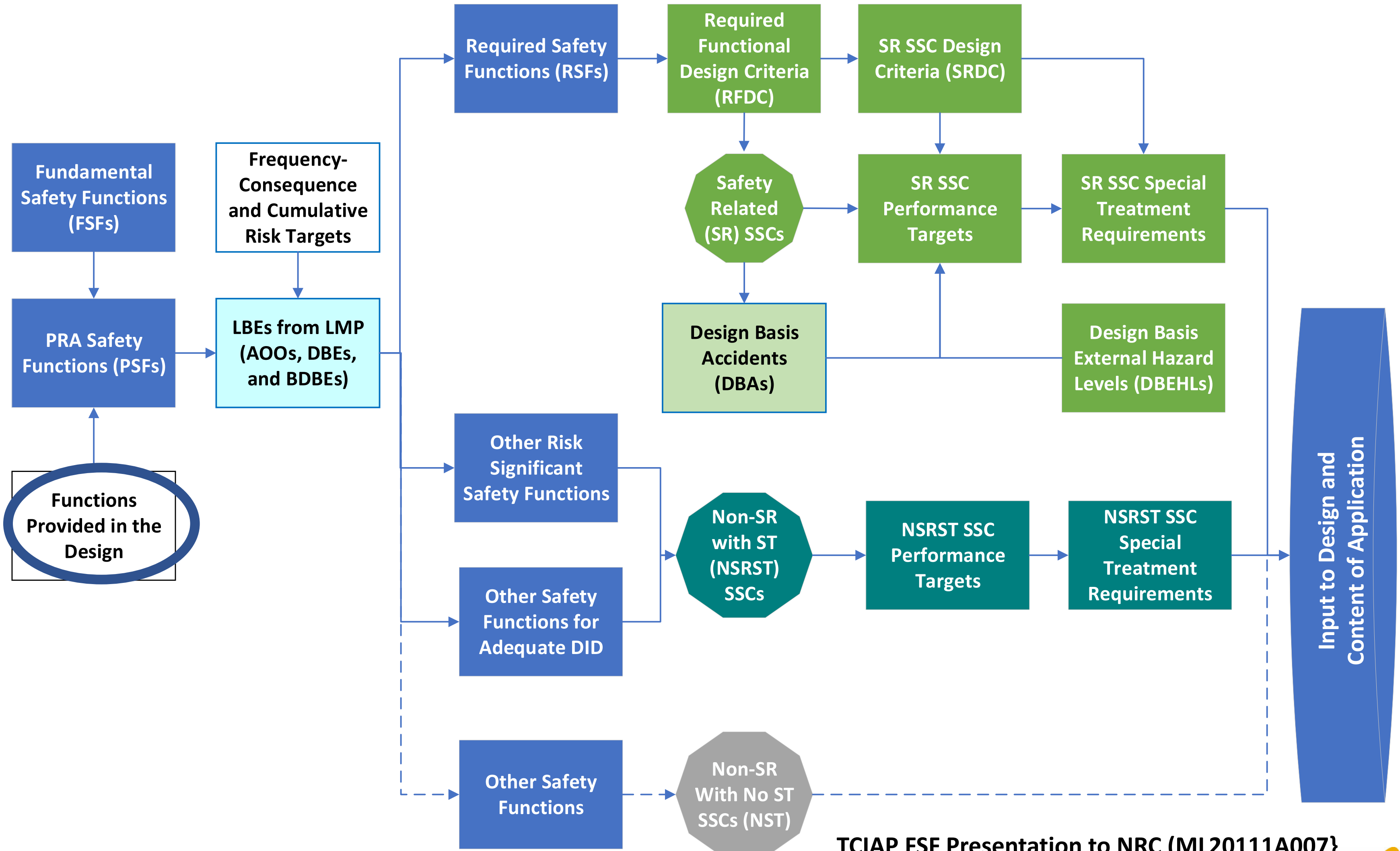
LMP Methodology Overview



- These are tasks that must be addressed for a complete RIPB design development.
- The include traditional deterministic actions, PRA, and integrated RIPB decisions
- The task order is up to the design control process owner
- The process is iterative within design phases and across design phases

NEI 18-04: Figure 5-4. Integrated Process for Incorporation and Evaluation of Defense-in-Depth

Fundamental Safety Function Satisfaction Using LMP Products

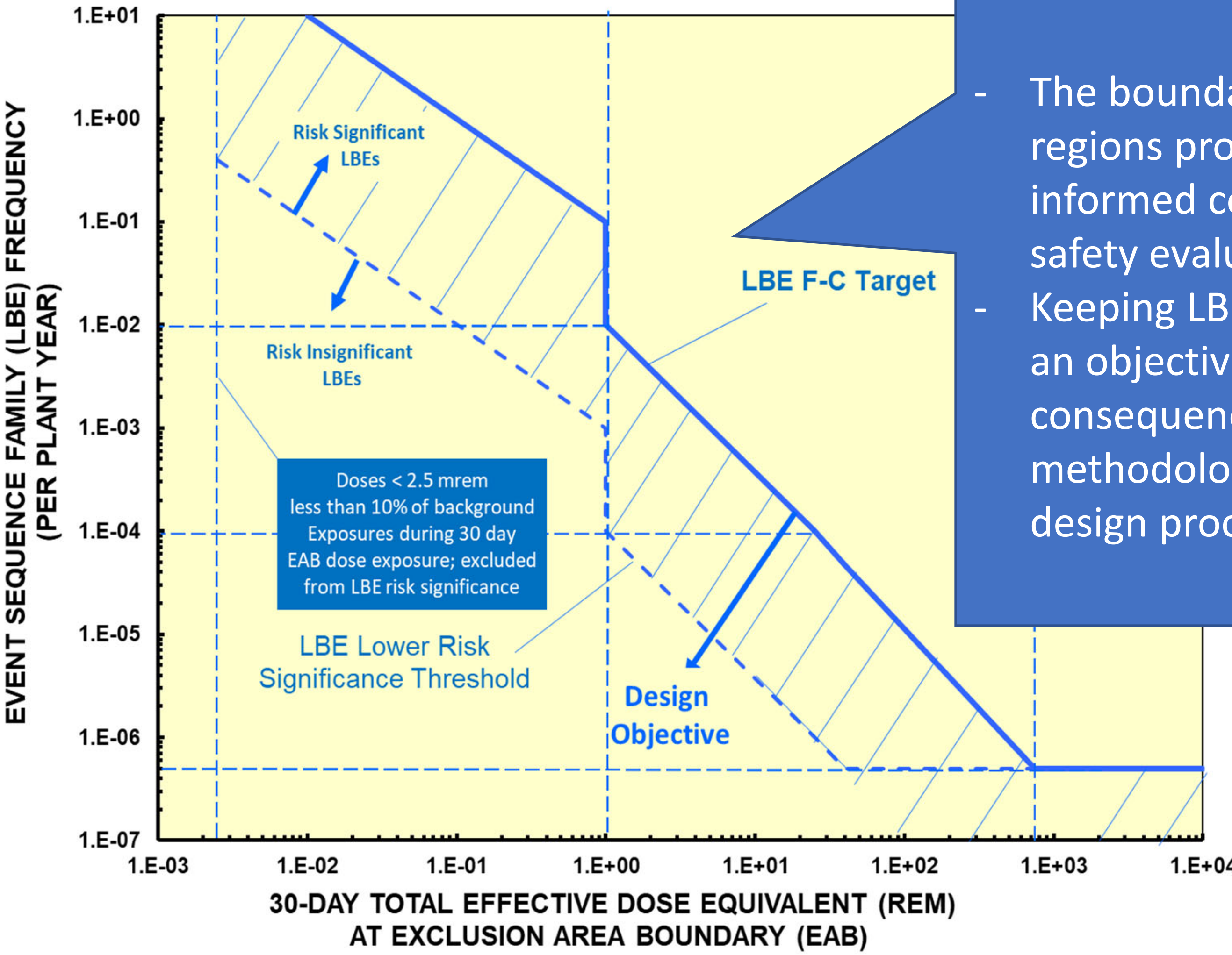


TCIAP FSF Presentation to NRC (ML20111A007}

Licensing Basis Events (LBEs)

- LBEs are defined by event sequence families from design specific PRA
- Purpose is to evaluate risk significance of individual LBEs and SSCs and to help define the RSFs; not a regulatory acceptance criterion
- Derived from the NGNP F-C Target and frequency bins for AOOs, DBEs, and BDBEs
  - Modified to ensure risk target does not increase with decreasing frequency
- F-C Target anchor points based on:
  - 10 CFR 20 annual dose limits used to define iso-risk contour in AOO region
  - Avoidance of offsite protective actions for lower frequency AOOs
  - 10 CFR 50.34 dose limit for lowest frequency DBEs
  - Consequences based on 30day TEDE dose at EAB
  - EAB dose target for BDBEs ensures meeting QHO for prompt fatality
- LBEs compared to F-C target based on mean, and upper (95%tile) and lower (5%tile) bound estimates of LBE frequency and dose
- Separate cumulative risk targets used to ensure that 10 CFR 20 and QHO met for the total risk over all the LBEs

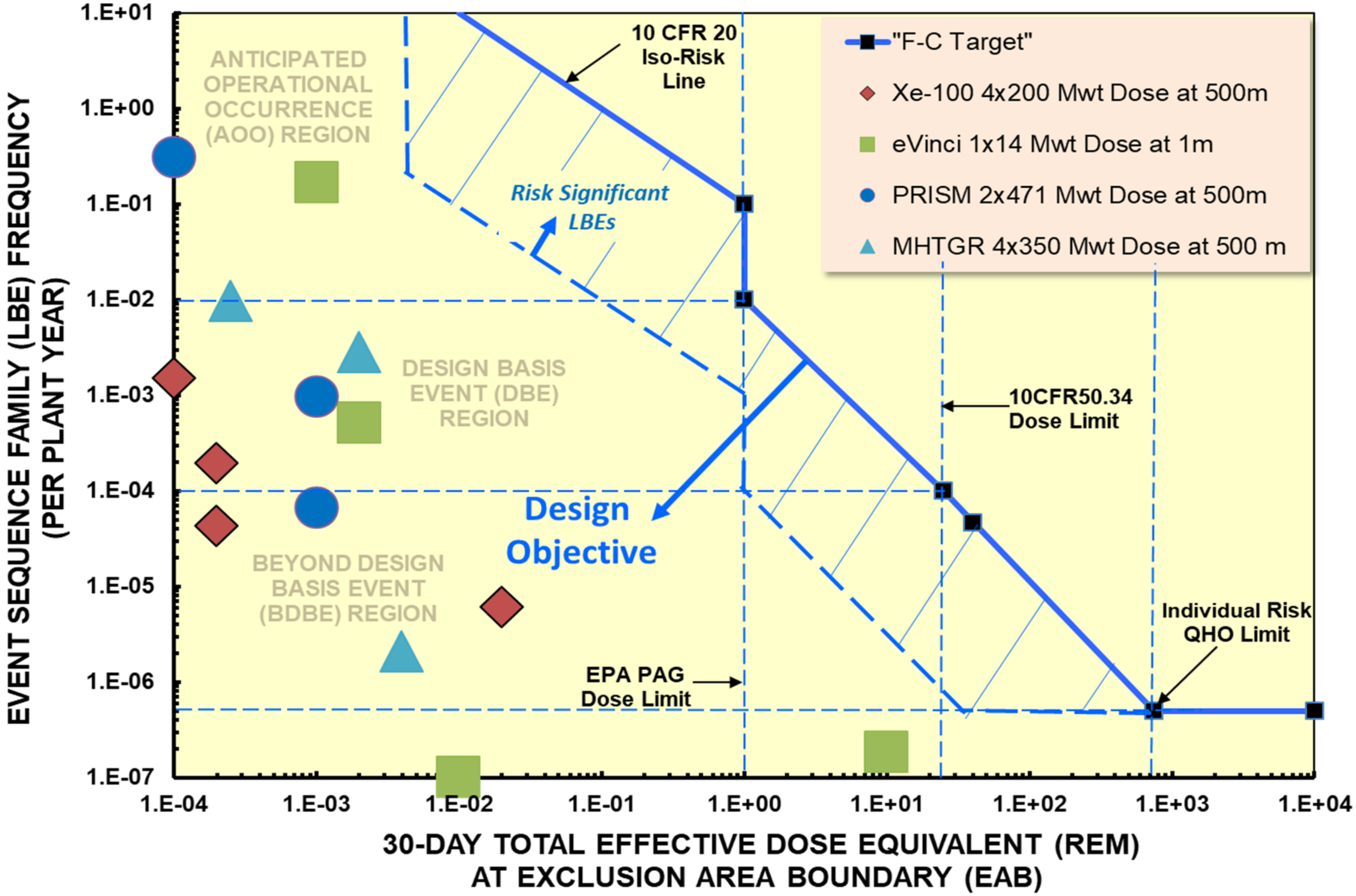
F-C Target w/ Risk-Significance Criteria



- The boundary lines and regions provide the risk-informed context for design safety evaluation
- Keeping LBE risk low should be an objective and natural consequence of using the LMP methodology early in the design process

NEI 18-04: Figure 5-4. Integrated Process for Incorporation and Evaluation of Defense-in-Depth

Example of LBEs in an F-C Context



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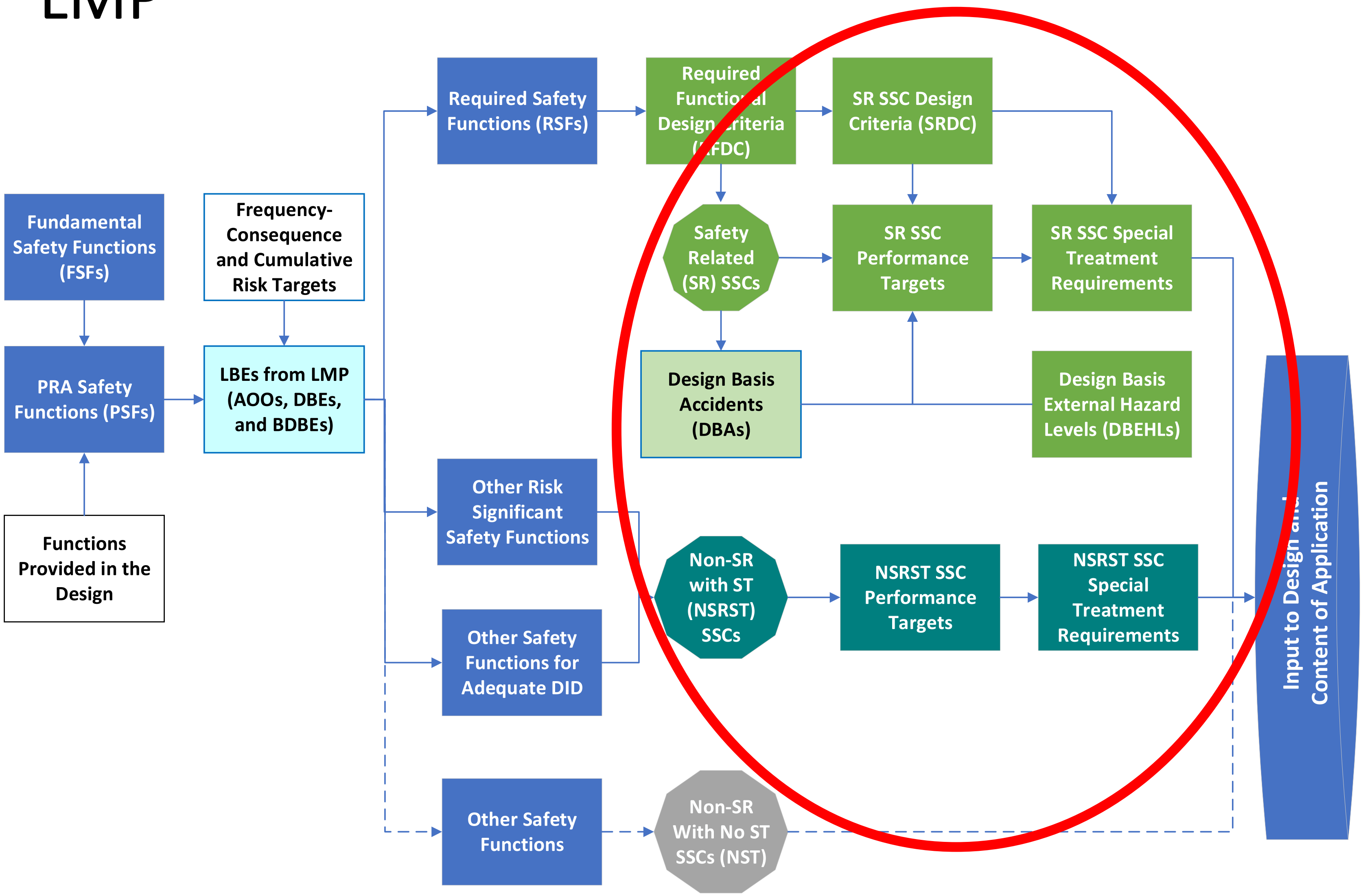
SSC Classification and Special Treatment in LMP

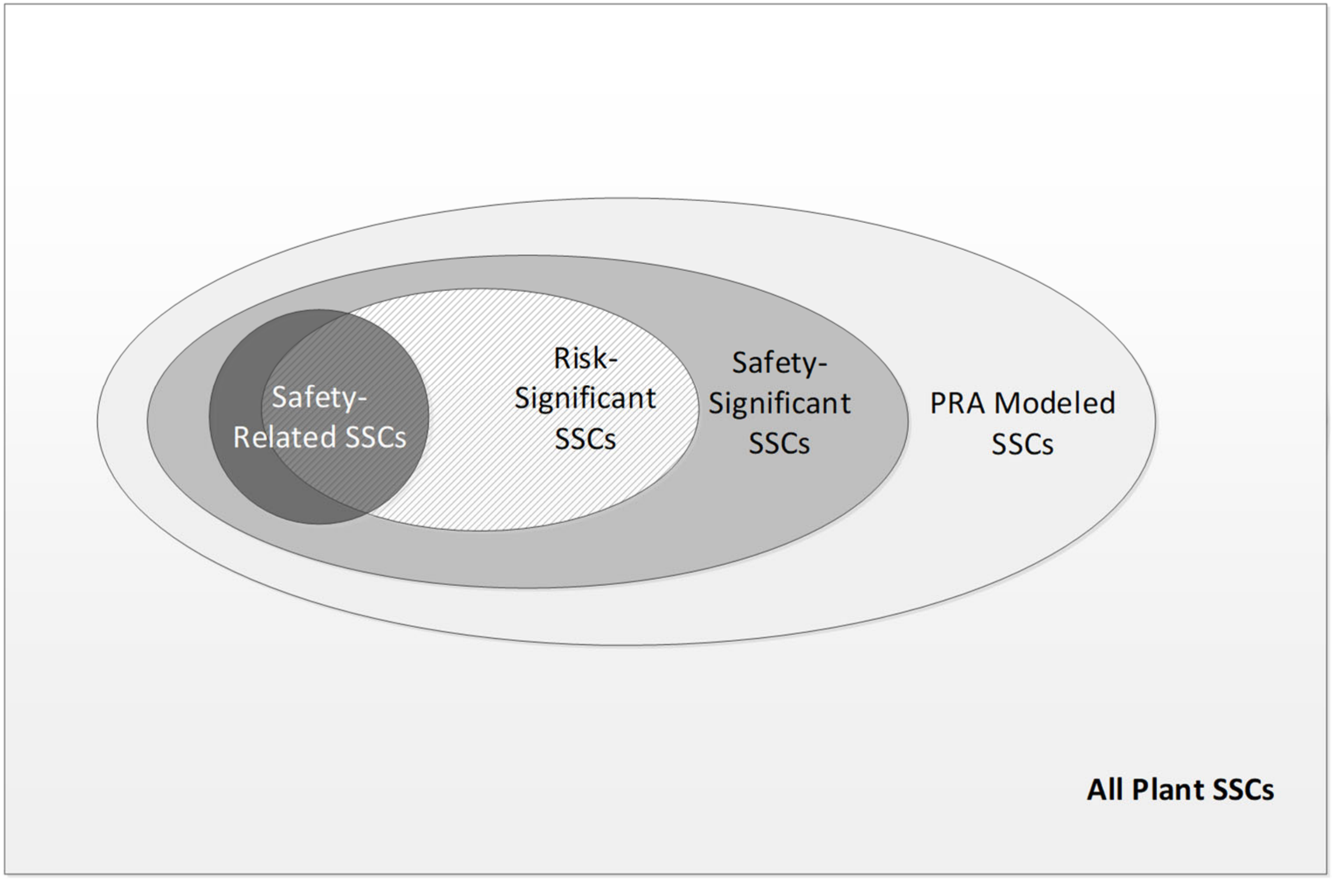


TCIAP FSF Presentation to NRC (ML20111A007}

SSC Classification and Risk Significance

- A prevention or mitigation function of the SSC is necessary to meet the design objective of keeping all LBEs within the F-C target.
  - **The LBE is considered within the F-C target when a point defined by the upper 95%-tile uncertainty of the LBE frequency and dose estimates are within the F-C target.**
- The SSC makes a significant contribution to one of the cumulative risk metrics used for evaluating the risk significance of LBEs.
  - A significant contribution to each cumulative risk metric limit is satisfied when total frequency of all LBEs with failure of the SSC exceeds 1% of the cumulative risk metric limit. The cumulative risk metrics and limits include:
    - The total frequency of exceeding of a site boundary dose of 100 mrem <1/plant-year (10 CFR 20)
    - The average individual risk of early fatality within 1 mile of the Exclusion Area Boundary (EAB) < 5×10^{-7}/ plant-year (QHO)
    - The average individual risk of latent cancer fatalities within 10 miles of the EAB shall not exceed 2×10^{-6}/plant-year (QHO)

SSC Classification Universe



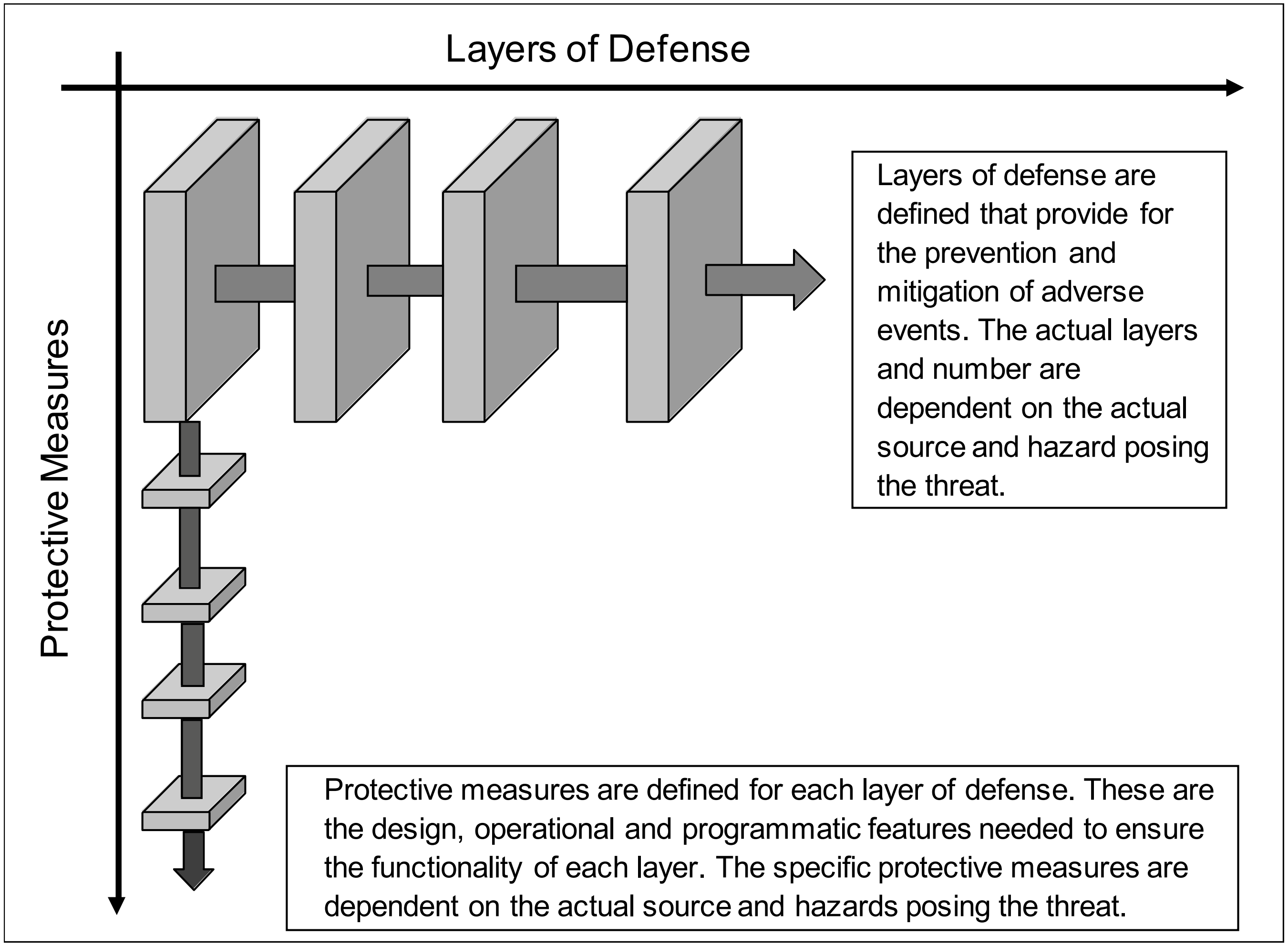
NEI 18-04 Figure 4-2. Definition of Risk-Significant and Safety-Significant SSCs

Derivation of Special Treatment Requirements

- SR SSCs
  - Required Functional Design Criteria (RFDC) derived from Required Safety Functions (RSFs); may be used with ARDCs in formulating principle design criteria
  - Component level Safety Related Design Criteria (SRDC) developed from RSFs
- SR and NSRST SSCs
  - SSC reliability and capability performance targets
  - Focus on prevention and mitigation functions identified in LBEs
  - Integrated decision-making process to derive additional specific special treatment requirements, if any
  - Reflects concepts from 10 CFR 50.69 and NEI-00-04 from existing reactors from a "forward fit" perspective
  - Reflects Commission's expectations for risk-informed and performance- based regulation from SRM to SECY 98-0144

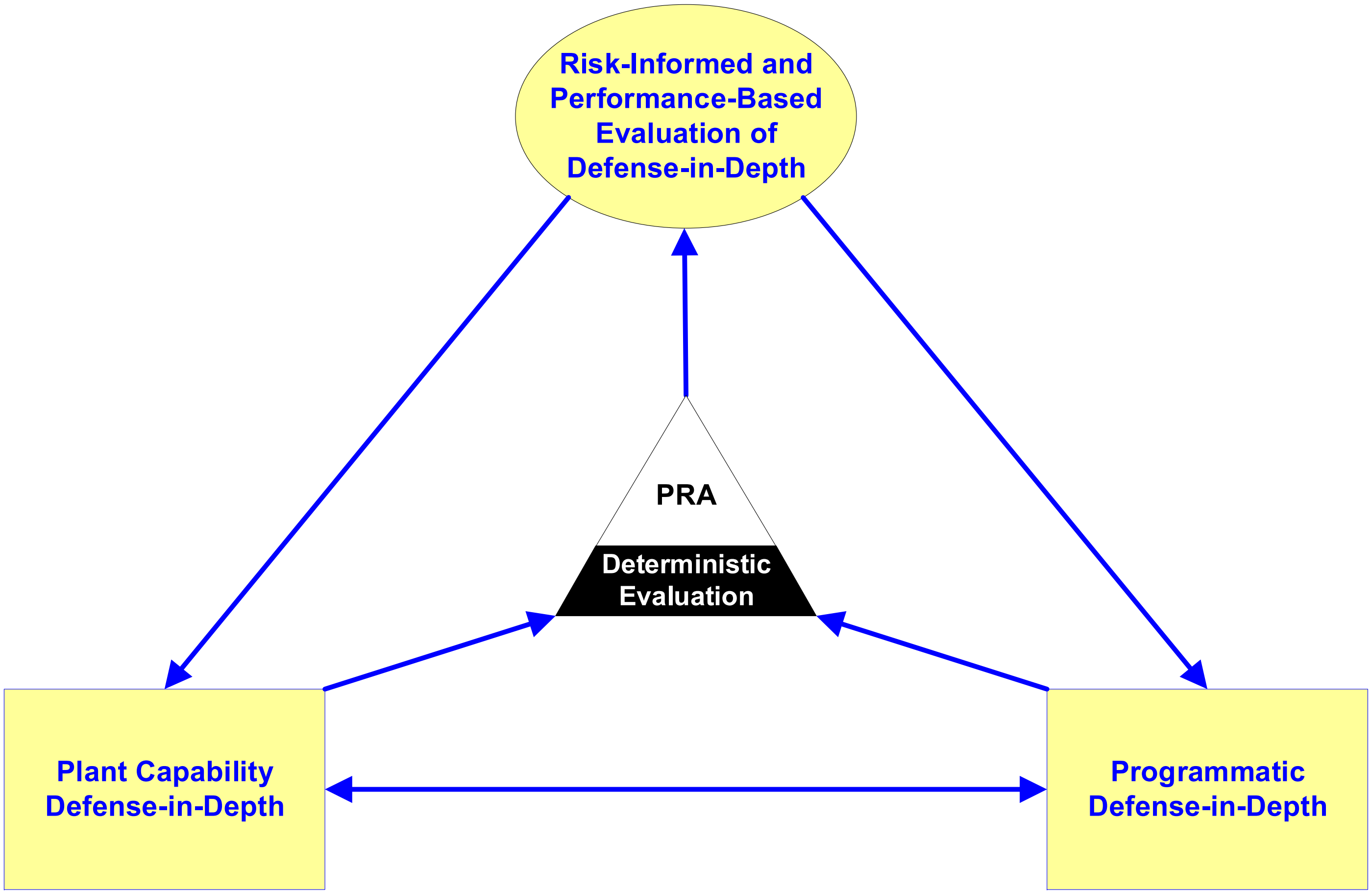
See NEI18-04 Section 4 and 5

NRC NUREG KM-009 DID Concept



NEI 18-04 Figure 5-1. U.S. Nuclear Regulatory Commission's Defense-in-Depth Concept

LMP Defense-in-Depth Framework



NEI 18-04 Figure 5-2 Framework for Establishing DID Adequacy (simplified)

LMP DID Adequacy Evaluation Objectives

- Establish alignment with accepted definitions of the DID philosophy and describe how multiple layers of defense are deployed to establish DID adequacy
- Describe how the concept of protective strategies of DID are used to evaluate DID attributes incorporated into the plant capabilities that support each layer of defense.
- Identify the importance of defenses against common cause failures and need to minimize dependencies among the layers of defense
- Identify any single features that are over relied on and take appropriate compensatory actions
- Summarize the programmatic attributes of DID to provide adequate assurance that the DID plant capabilities in the design are realized when the plant is constructed and commissioned and are maintained during the plant design life cycle
- Discuss the roles of programmatic DID attributes to compensate for uncertainties, human errors, and hardware failures
- Provide a DID Baseline of information for evaluating changes to the design or operations that could impair DID adequacy conclusions

Plant Capability DID Attributes

Attribute	Evaluation Focus
Initiating Event and Event Sequence Completeness	PRA Documentation of Initiating Event Selection and Event Sequence Modeling Insights from reactor operating experience, system engineering evaluations, expert judgment
Layers of Defense	Multiple Layers of Defense Extent of Layer Functional Independence Functional Barriers Physical Barriers
Functional Reliability	Inherent Reactor Features that contribute to performing PRA Safety Functions Passive and Active SSCs performing PRA Safety Functions Redundant Functional Capabilities Diverse Functional Capabilities
Prevention and Mitigation Balance	SSCs performing prevention functions SSCs performing mitigation functions No Single Layer / Feature Exclusively Relied Upon

NEI 18-04 Table 5-3. Plant Capability Defense-In-Depth Attributes

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Programmatic DID Attributes

Attribute	Evaluation Focus
Quality / Reliability	Performance targets for SSC reliability and capability
	Design, manufacturing, construction, O&M features, or special treatment sufficient to meet performance targets
Compensation for Uncertainties	Compensation for human errors
	Compensation for mechanical errors
	Compensation for unknowns (performance variability)
	Compensation for unknowns (knowledge uncertainty)
Offsite Response	Emergency response capability

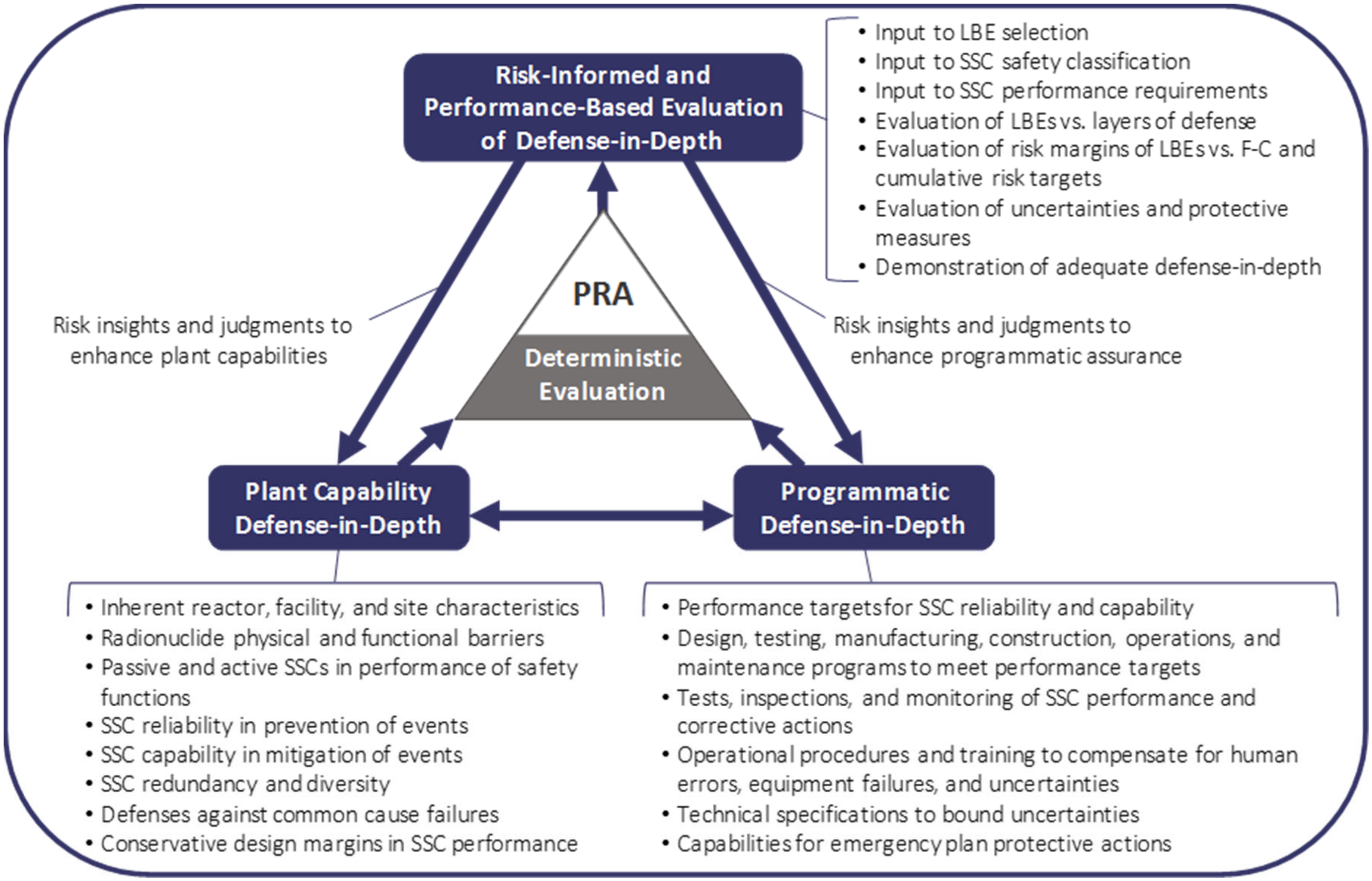
NEI 18-04 Table 5-5. Programmatic DID Attributes

Integrated DID Adequacy Decision Attributes

Attribute	Evaluation Focus
Use of Risk Triplet Beyond PRA	What can go wrong? How likely is it? What are the consequences?
Knowledge Level	Plant Simulation and Modeling of LBEs State of Knowledge Margin to Performance-Based Targets and Limits
Uncertainty Management	Magnitude and Sources of Uncertainties
Action Refinement	Implementation Practicality and Effectiveness Cost/Risk/Benefit Considerations

NEI 18-04 Table 5-8. Risk-Informed and Performance-Based Decision-Making Attributes

Detailed Integrated DID Framework



NEI 18-04 Figure 5-2. Framework for Establishing DID Adequacy

A Note on Terminology Lessons Learned

- LMP took particular efforts to define new terms with new meanings such as:
  - Licensing Basis Events (LBE)
  - Safety Significant (SS)
  - Required Safety Function (RSF)
  - Safety Related Design Criteria (SRDC)
  - Design Basis External Hazards Levels (DBEHL)
  - Non-Safety Related with Special Treatment (NSRST)
- These are all defined specifically in the Glossary of NEI 18-04
- LMP also avoided certain terms that have been used historically and they are intentionally avoided in this RIPB methodology such as:
  - Single Failure Criteria
  - Important to Safety
  - Regulatory Treatment of Non-Safety Systems
  - "Credited"
  - 10CFR50.69 "RISC" Categories
- These terms carry a great deal of regulatory baggage that is, in part, what the LMP modifies, enabling the affirmative safety case to be the safety focus.
- Future standards activities focused on RI or PB incorporation should adopt these newer terms or build on them to assist with terminology convergence

Key References:

1. NEI 18-04 Revision 1 “ Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development , August 2019 (also as ADAMS ML19241A472)
2. NRC Regulatory Guide 1.233 Revision 0, Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors, 06/2020, (also ML20091L698. This contains a long list of additional references as well)
3. Southern Company, Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Probabilistic Risk Assessment Approach SC-29980-101 Rev 1, March 2020
4. Southern Company, Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Selection and Evaluation of Licensing Basis Events, SC-29980-100 Rev 1, March 2020
5. Southern Company, Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Safety Classification and Performance Criteria for Structures, Systems, and Components SC-29980-102 Rev1, March 2020
6. Southern Company, Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Risk-Informed and Performance-Based Evaluation of Defense-in-Depth Adequacy, SC-29980-103 Rev1, March 2020
7. Southern Company, Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Final Project Report, SC-29980-105 Rev1, March 2020
8. Southern Company Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: LMP Lessons Learned, Best Practices, and Frequently Asked Questions, SC-29980-106 Rev0, March 2020

Overview-LMP Lessons Learned, Best Practices, and Frequently Asked Questions (Ref 8)

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Thank You!

Any further questions?