HTGR Technology Course for the Nuclear Regulatory Commission

May 24 – 27, 2010

Module 4

HTGR Licensing

Ed Wallace

Pebble Bed Modular Reactors (Pty) Ltd.

Idaho National Laboratory

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Outline

- Licensing and pre-licensing history
- Specific regulatory topics
- NGNP licensing approach
- Industry perspective on HTGR safety and licensing
- Recent international licensing activities

US HTGR Licensing and Pre-licensing History

US Program	Licensing Period	Organization	Stage
Peach Bottom-1	1958-1966	PECO	OL Issued Decommissioned
Ft. St. Vrain (Prismatic)	1966-1972	PS Colo.	OL Issued Decommissioned
Summit (Prismatic)	1972-1975	GA	CP-LWA Submitted
MHTGR (Prismatic)	**1986-1995**	**DOE/GA**	**Pre-App Review**
Exelon DC (Pebble)	**2001-2002**	**Exelon**	**Pre-App Review**
PBMR DC (Pebble)	**2006-current**	**PBMR (Pty.) Ltd**	**Pre-App Review**
NGNP (Prismatic/Pebble)	**2009-current**	**DOE**	**Pre-App Review**

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Non-US HTGR Licensing and Pre-licensing History

International	Licensing Period	Country /Organization	Stage
Dragon	1959-1964	UK /OECD/NEA	OL Issued Decommissioned
HTTR (Prismatic)	1985-1998	Japan	OL Issued
AVR (Pebble)	1959-1967	Germany /FJZ	OL Issued Decommissioned
THTR (Pebble)	1979-1983	Germany	OL Issued Decommissioned
HTR Modul (Pebble)	**1987-1990**	**Germany /Siemens**	**Pre-App Review**
HTR-10 (Pebble)	1994-1995	China / CNNC	OL Issued
PBMR-400 (Pebble)	1999-current	South Africa /PBMR (Pty) Ltd.	CP App Review

Important NRC Framework Precedents

Commission Policy Statements	Year Issued
• Severe Accident	• 1985
• Advanced Reactors	• 1986
• Safety Goals	• 1986
• Use of Probabilistic Risk Assessment	• 1995

NRC Regulations	
• 10CFR Part52	• 1989

Severe Reactor Accidents Regarding Future Designs and Existing Plants

"At the present stage of development, a number of positive uses of PRA's have been demonstrated, especially in identifying: (1) Those contributors to severe accident risk that are clearly dominant and hence need to be examined for cost-effective risk reduction measures and (2) those accident sequences that are clearly insignificant risk contributors and can therefore be prudently dismissed."

(50 FR 32138, August 8, 1985)

Regulation of Advanced Reactors

"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."

(FR Vol. 73, No. 199, pg. 60612-60616, October 14, 2008)

Safety Goals for the Operation of Nuclear Power Plants

"A key element in formulating a qualitative safety goal whose achievement is measured by quantitative health effects objectives is to understand both the strengths and limitations of the techniques by which one judges whether the qualitative safety goal has been met."

"…through the use of quantitative [risk]*techniques, important uncertainties have been and continue to be brought into better focus and may even be reduced compared to those that would remain with sole reliance on deterministic decision making. To the extent practicable, the Commission intends to ensure that the quantitative techniques used for regulatory decisionmaking take into account the potential uncertainties that exist so that an estimate can be made on the confidence level to be ascribed to the quantitative results."*

"Depending on the decision needs, the probabilistic results should also be reasonably balanced and supported through use of deterministic arguments. This is a key part in the process of determining the degree of regulatory conservatism that may be warranted for a particular decision."

(FR Vol. 51, No. 160, pg. 30028-30023, August 21, 1986)

Use of PRA Methods in Nuclear Regulatory Activities

"The Commission believes that the use of PRA in regulatory activities should be increased to the extent supported by the state-of-the-art PRA methods and data in a manner that complements the NRC deterministic approach."

"[T]he expanded use of PRA technology will continue to support the NRC's defense-in-depth philosophy by allowing quantification of the levels of protection and by helping to identify and address weaknesses or overly conservative regulatory requirements applicable to the nuclear industry. Defense-in-depth is a philosophy used by NRC to provide redundancy for facilities with 'active' safety systems, e.g., a commercial nuclear power (sic), as well as the philosophy of a multiple-barrier approach against fission product releases."

(FR, Vol. 60, No. 158, pg. 42622-42629, August 16, 1995)

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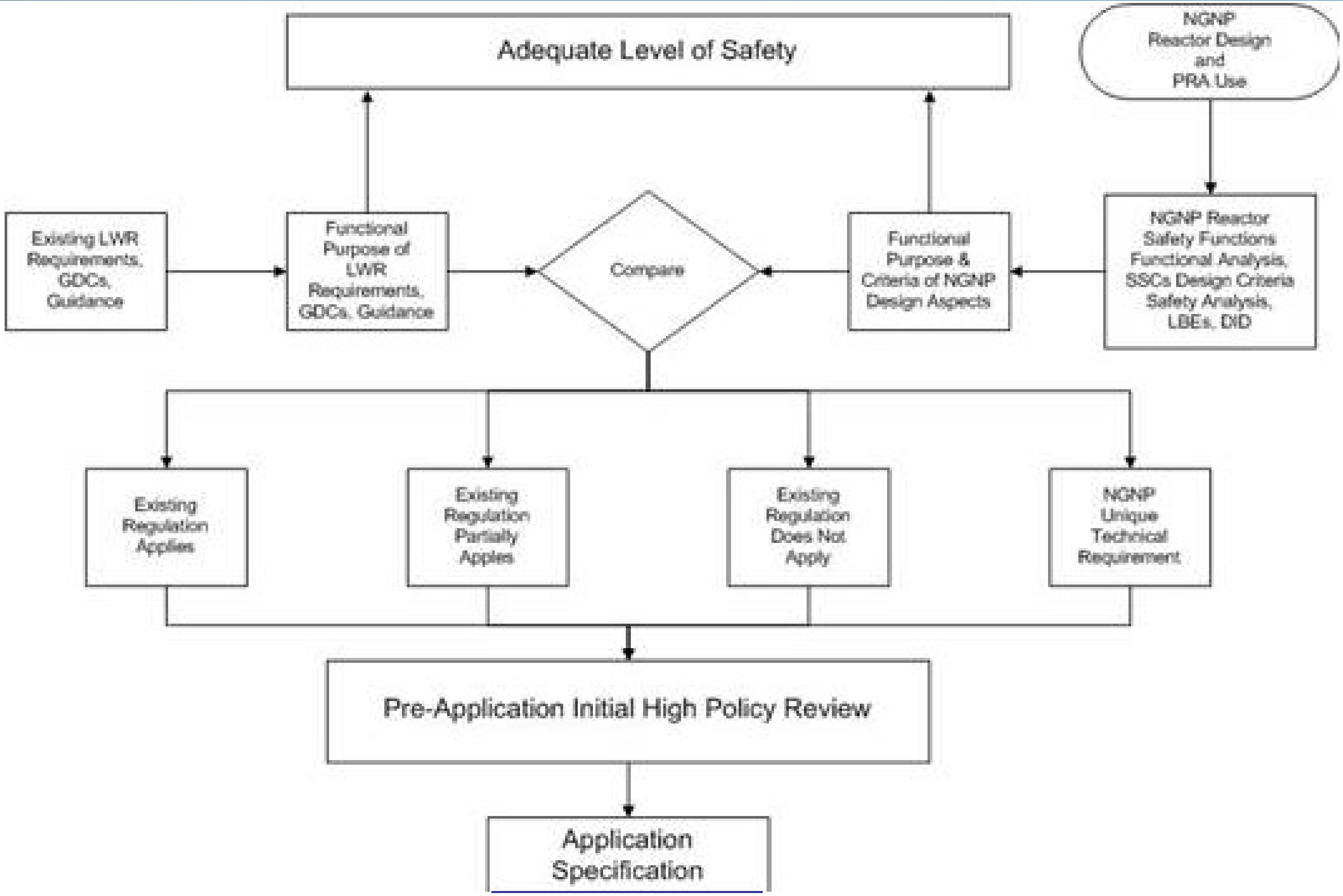
Specific Regulatory Topics

- Regulatory gap analysis
- Use of probabilistic risk information
- Use of mechanistic source terms
- Containment functional performance requirements

Regulatory Gap Analysis

- **NRC Staff draft Preapplication Safety Evaluation Report (PSER) of the MHTGR (NUREG 1338) summarizes technical issues and regulatory gaps to be closed for successful HTGR licensing in 1998**
- **Proposed approach to close gaps described by Exelon in 2001**
  - Identifies range of "applicability" conditions
  - Utilizes design specific details and risk techniques to inform evaluation
  - Creates basis for "Not Applicable" determinations
  - Provides an exemption basis
  - Identifies a basis for policy development where needed
  - Feeds into HTGR-specific Application Specification
- **NRC staff evaluated proposed approach in 2002**
- **NGNP Licensing Strategy Report to Congress in 2008**

Regulatory Gap Analysis Process



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Risk-Informed Approach

- NRC PRA Policy Statement motivates risk-informed approach to HTGR licensing
- Complements traditional deterministic design approach and defense-in-depth philosophy to increase use of risk insights in design and licensing decisions to the extent supported by state-of-the-art PRA
- NGNP Licensing Strategy Report to Congress describes a risk-informed approach agreed to by NRC and DOE for NGNP Licensing (2008)
- MHTGR PSID and Exelon & PBMR (Pty) Ltd. pre-applications describe industry proposed risk-informed approach to HTGR licensing

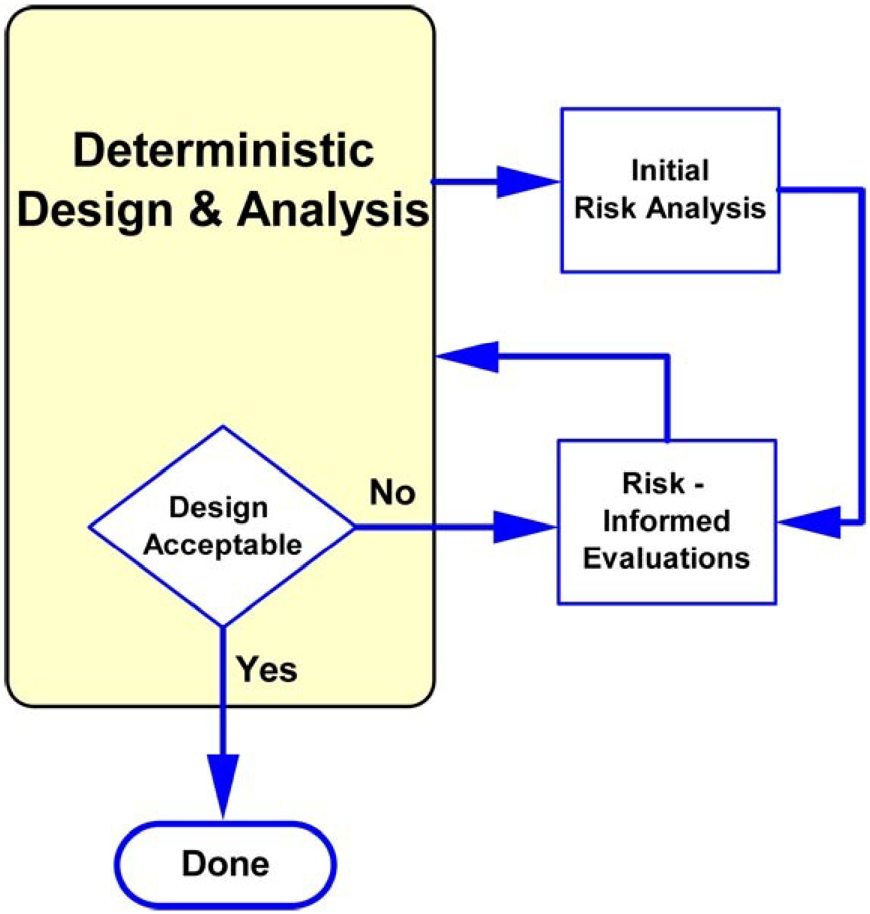
NGNP Licensing Strategy – Report to Congress (Aug. 2008)

"With regard to technical licensing requirements, the Secretary of Energy and the Commission determined that the best option for licensing the NGNP prototype would be to use a risk-informed and performance-based technical approach, in particular, Option 2 (i.e., use of deterministic judgment and analysis, complemented by NGNP-specific PRA information) to adapt the existing LWR technical requirements and to establish the NGNP-unique requirements that are not addressed by existing LWR requirements and guidance."

Summary of Regulatory Expectations for RIPB Methods Use

- Greater use of PRA methodologies and insights are encouraged for operating and new reactors
- Use risk insights to complement deterministic design and licensing decisions
- Assess applicability of existing NRC regulations and guidance
- Use Risk-Informed Performance-Based (RIPB) processes to develop NGNP-specific technical requirements not addressed by existing NRC regulations and guidance for LWRs

Industry Proposed RIPB Processes Complement Traditional Engineering Process



Risk Insights: the results and findings that come from risk assessments. They may include improved understanding of the likelihood of possible outcomes, sensitivity of the results to key assumptions, relative importance of the various system components and their potential interactions, and the areas and magnitude of the uncertainties.

Risk-Informed: an approach to decisionmaking in which risk insights are considered along with other factors such as engineering judgment, safety limits, and redundant and/or diverse safety systems. Such an approach is used to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety."
(NRC Strategic Plan - 2008)

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Summary of Industry Proposed Licensing Approach Elements

- **What must be met**
  - Top level regulatory criteria (TLRC)
- **When TLRC must be met**
  - Licensing basis events
- **How TLRC must be met**
  - Safety functions
  - SSC safety classification
  - Regulatory design criteria
- **How well TLRC must be met**
  - Deterministic DBAs
  - Defense-in depth
  - Regulatory special treatment

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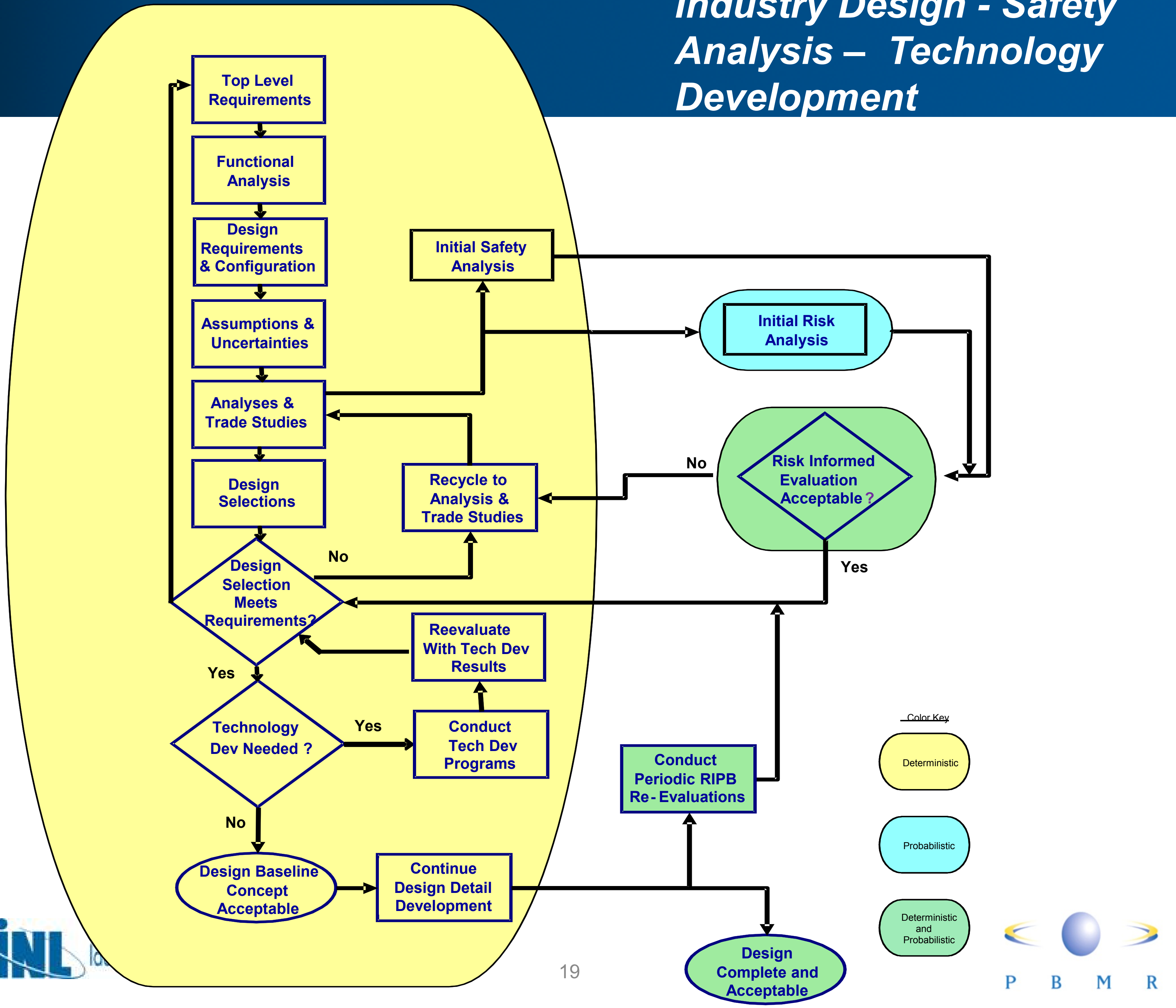
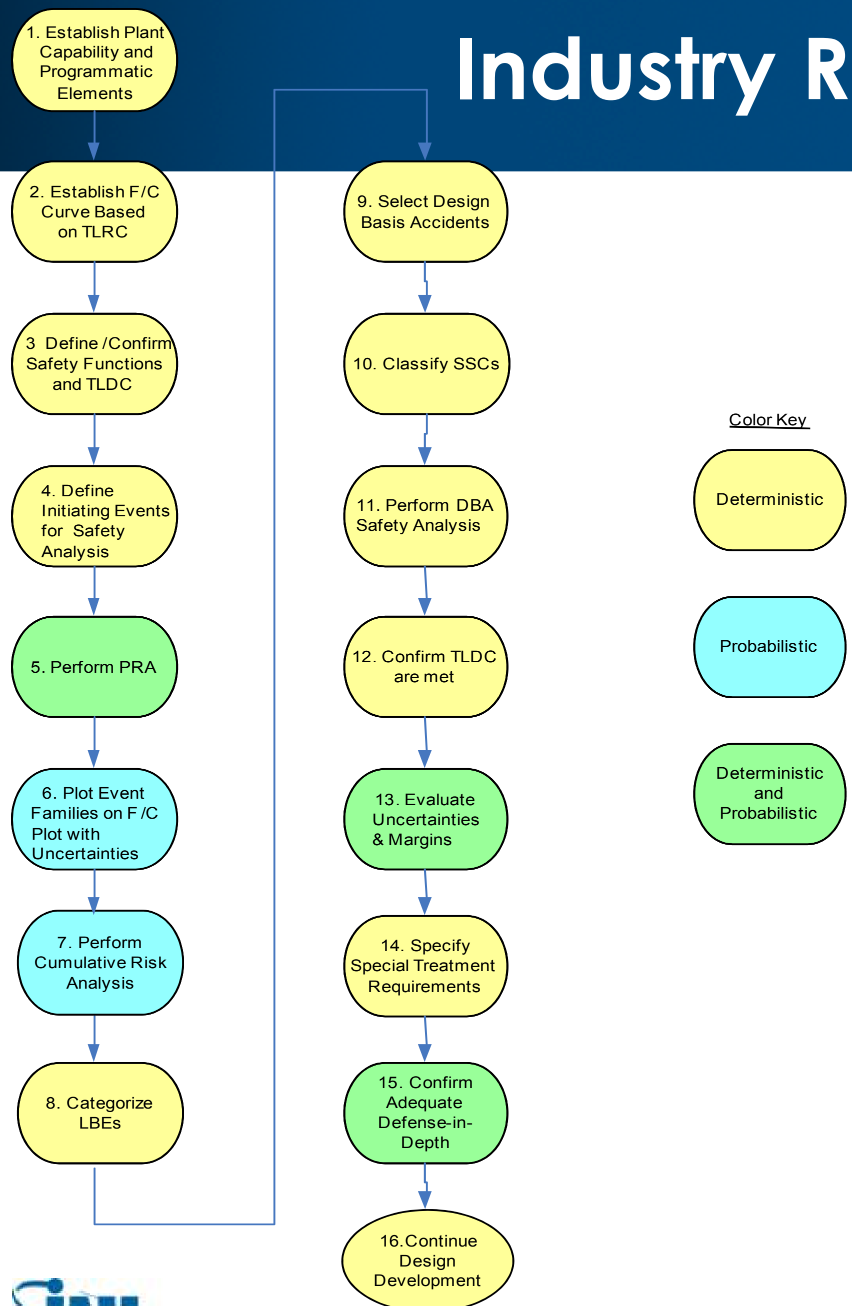
Industry Design - Safety Analysis – Technology Development

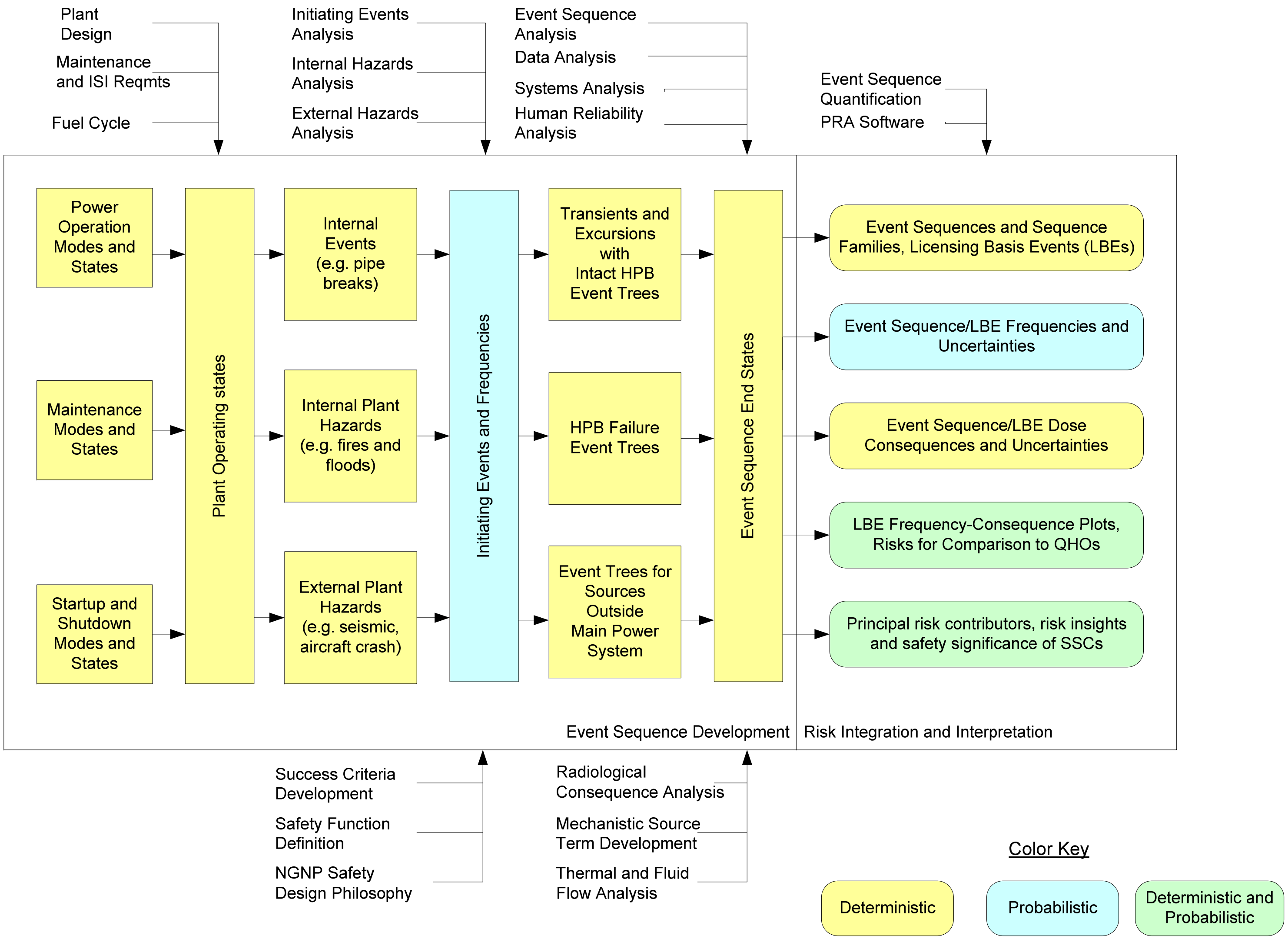


Industry RIPB Design Processes



- Flow of activities that complement traditional engineering flow
- Done at different stages in design development process
- Detail increases as detail increases in design
- Safety and DID assessments are more integrated within design processes
- Better supports development of SAR

Overview of Industry Proposed PRA Elements



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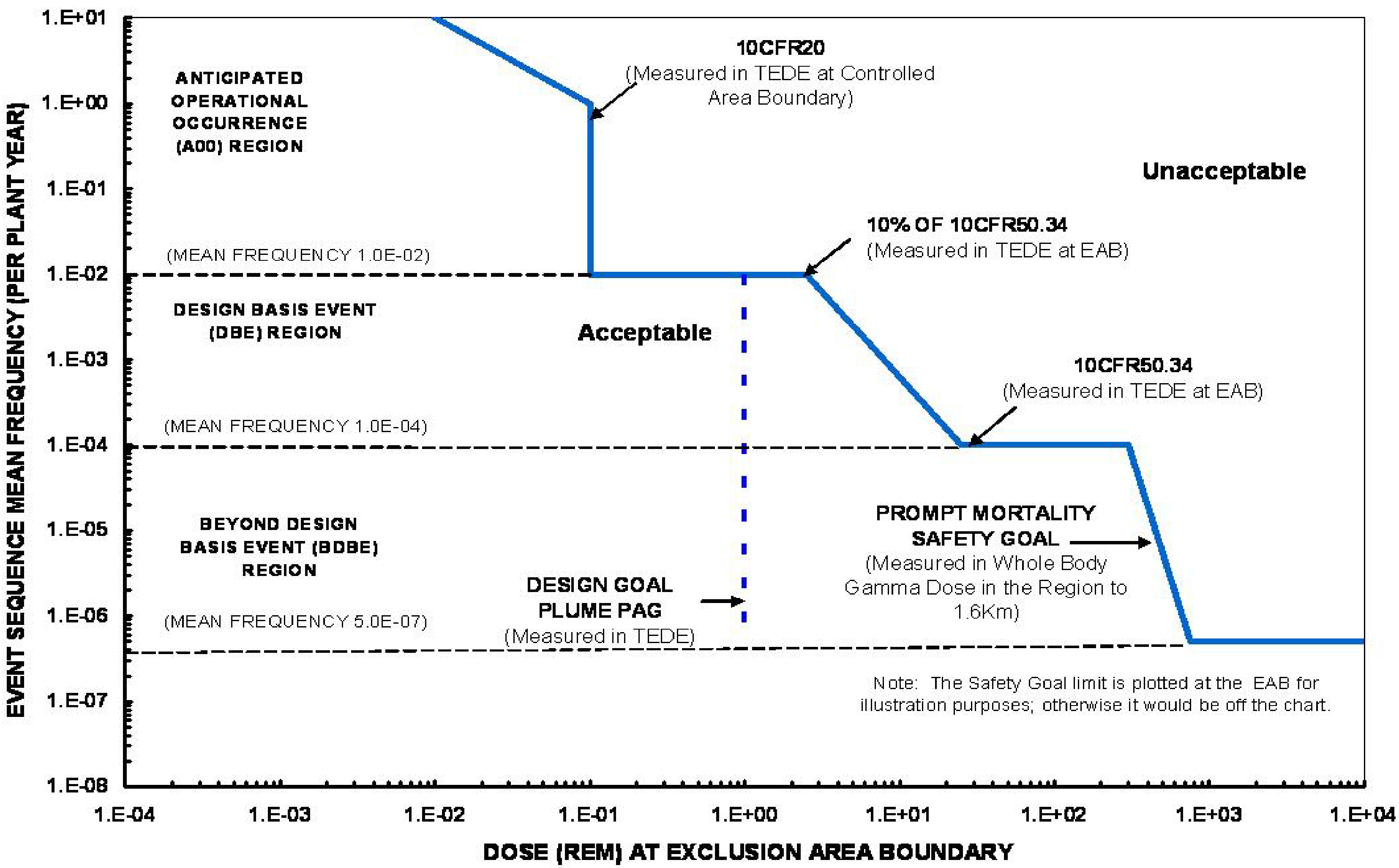
Industry Proposed Frequency-Consequence Curve



Design goal is to meet the EPA Protective Action Guideline (PAG) at 425m EAB rather than the 16,000m EPZ for existing LWRs

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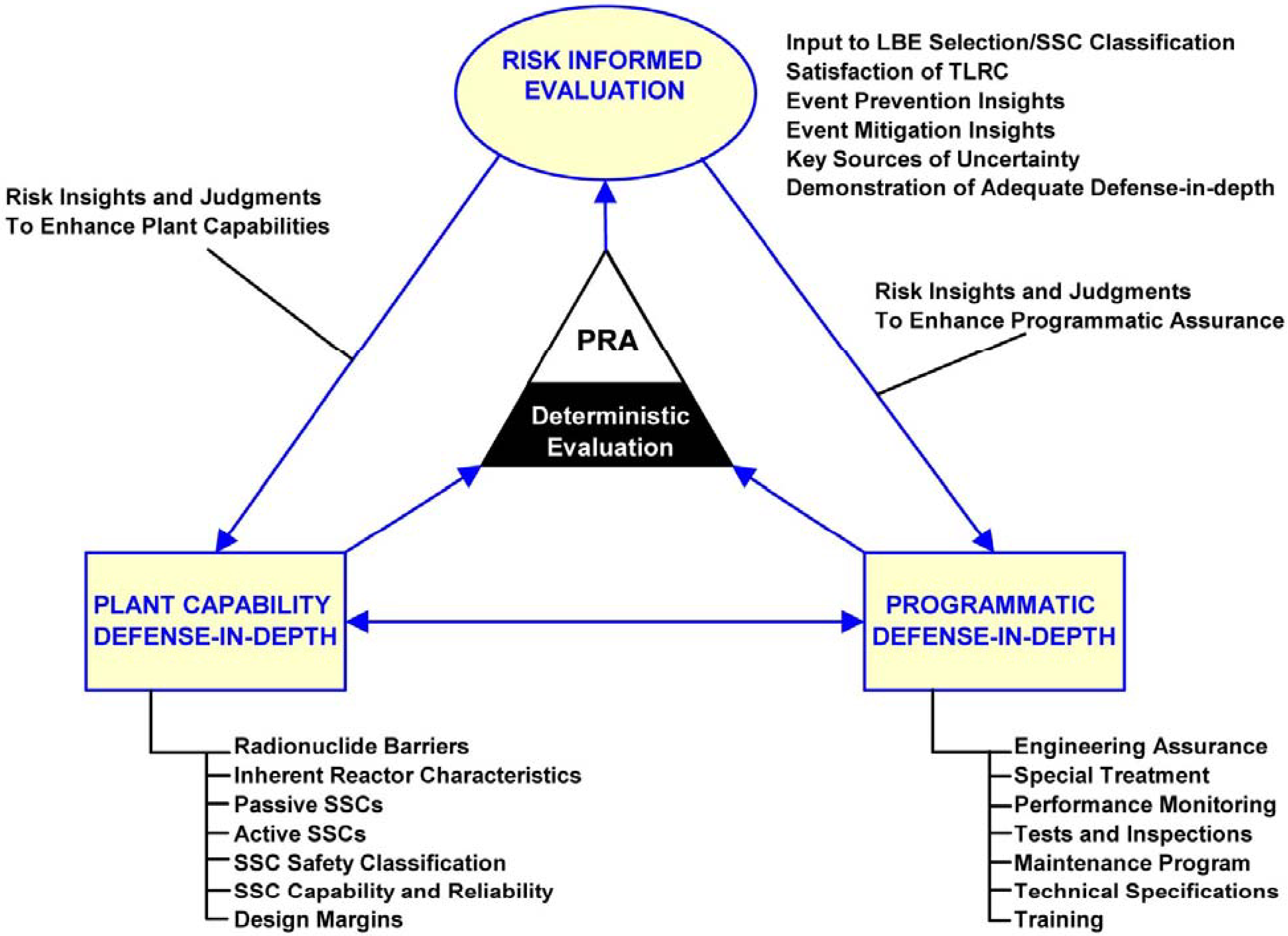
Detailed Elements of Industry Proposed DID Framework



Mechanistic Source Terms

- **In SRM for SECY-03-0047, the Commission reaffirmed the concept of using scenario-specific accident source terms for licensing decisions retaining "the Commission's guidance contained in the July 30, 1993, SRM that allows the use of scenario-specific source terms, provided there is sufficient understanding and assurance of plant fuel performance and deterministic engineering judgment is used to bound uncertainties."**

Mechanistic Source Terms

- **July 30, 1993 SRM approves source term recommendations found in SECY-93-092. In SECY-93-092, the staff recommended the use of mechanistic source terms for advanced designs provided:**
  - Performance of the reactor and fuel under normal and off-normal conditions is sufficiently well understood to permit a mechanistic analysis. Sufficient data should exist on the reactor and fuel performance through the research, development, and testing programs to provide adequate confidence in the mechanistic approach.
  - The transport of fission products can be adequately modeled for all barriers and pathways to the environs, including specific consideration of containment design. The calculations should be as realistic as possible so that the values and limitations of any mechanism or barrier are not obscured.
  - The events considered in the analysis to develop the set of source terms for each design are selected to bound severe accidents and design-dependent uncertainties.

Mechanistic Source Terms

- **SECY-05-0006 provided staff preliminary views* on Mechanistic Source Terms:**
  - Scenarios are to be selected from a design-specific PRA.
  - Source term calculations are based on verified analytical tools.
  - Source terms for design basis compliance should be 95% confidence level values based on realistic (mechanistic) calculations.
  - Source terms for emergency preparedness should be mean values based on best estimate calculations.
  - Source terms for licensing decisions should reflect scenario-specific timing, form, and magnitude of the release.

*** No staff final recommendations or Commission decisions have been made at this time**

Containment System Functional Requirements

- **In SECY 03-0047 the Staff provided recommendations for resolving policy issues for non-LWR licensing. Regarding containment design:**
  - The staff recommends the Commission take the following action:
    - Approve the use of functional performance requirements to establish the acceptability of a containment or confinement structure (i.e., a non-pressure retaining building may be acceptable provided the performance requirements can be met).
    - If approved by the Commission, develop the functional performance requirements using as a starting point the guidance contained in the Commission's July 30, 1993, SRM and the Commission's guidance on the other issues contained in this paper.

Containment System Functional Requirements

- **The SRM for SECY 03-0047 disapproved the recommendation and directed the Staff to:**
  - The staff should develop performance requirements and criteria working closely with industry regarding options, taking into account such features as core, fuel, and cooling systems design.
  - The staff should pursue the development of functional performance standards and then submit options and recommendations to the Commission .

Containment Systems Functional Requirements

- **In SECY-04-0103 the NRC Staff summarized its updated views* on non-LWR containment functions**
  - Encourage prevention
  - Maintain adequate DID
  - Establish functional performance standards for design vs. prescriptive criterion
  - Recognized that all functions are not exclusively reactor building functions

*** No staff final recommendations or Commission decisions have been made at this time**

Containment System Functional Requirements

- **In SECY-05-0006 the NRC Staff provided additional updated views on non-LWR containment functions:**
  - Protecting risk-significant SSCs from internal and external events
  - Physically supporting risk-significant SSCs
  - Protecting onsite workers from radiation
  - Removing heat to prevent risk-significant SSCs from exceeding design or safety limits
  - Providing physical protection (i.e., security) for risk-significant SSCs
  - Reducing radionuclide releases to the environs and limiting core damage

*** No staff final recommendations or Commission decisions have been made at this time**

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Joint NRC / DOE NGNP Licensing Strategy

- **Report to Congress, August 2008 in response to EPACT 05 requirements to address:**
  - A description of the ways in which current NRC LWR licensing requirements need to be adapted for the types of reactors considered for the project
  - A description of the analytical tools that the NRC will need to independently verify the NGNP design and its safety performance
  - A description of other research or development activities that the NRC will need to review an NGNP license application
  - A budget estimate associated with the licensing strategy

NGNP Licensing Strategy

- **DOE / NRC licensing approach:**
  - The best alternative for licensing the NGNP prototype will be to submit a combined license (COL) *(10 CFR Part 52)*.
  - The best approach to establish the licensing and safety basis for the NGNP will be to develop a risk-informed and performance-based technical approach
  - Analytical tools, models, and associated data in major technical areas of the NGNP design will be required
  - Areas expected to require regulatory infrastructure development include guidance documents to address NGNP-specific issues involving security and safeguards, spent fuel, environmental matters, and inspection and startup testing. For NGNP prototype plant, interim guidance based on LWR experience may be sufficient
  - Other issues may be identified and NRC will engage the NGNP applicant during the pre-application phase to address them...

NGNP Licensing Strategy

- **Other aspects of NGNP licensing strategy:**

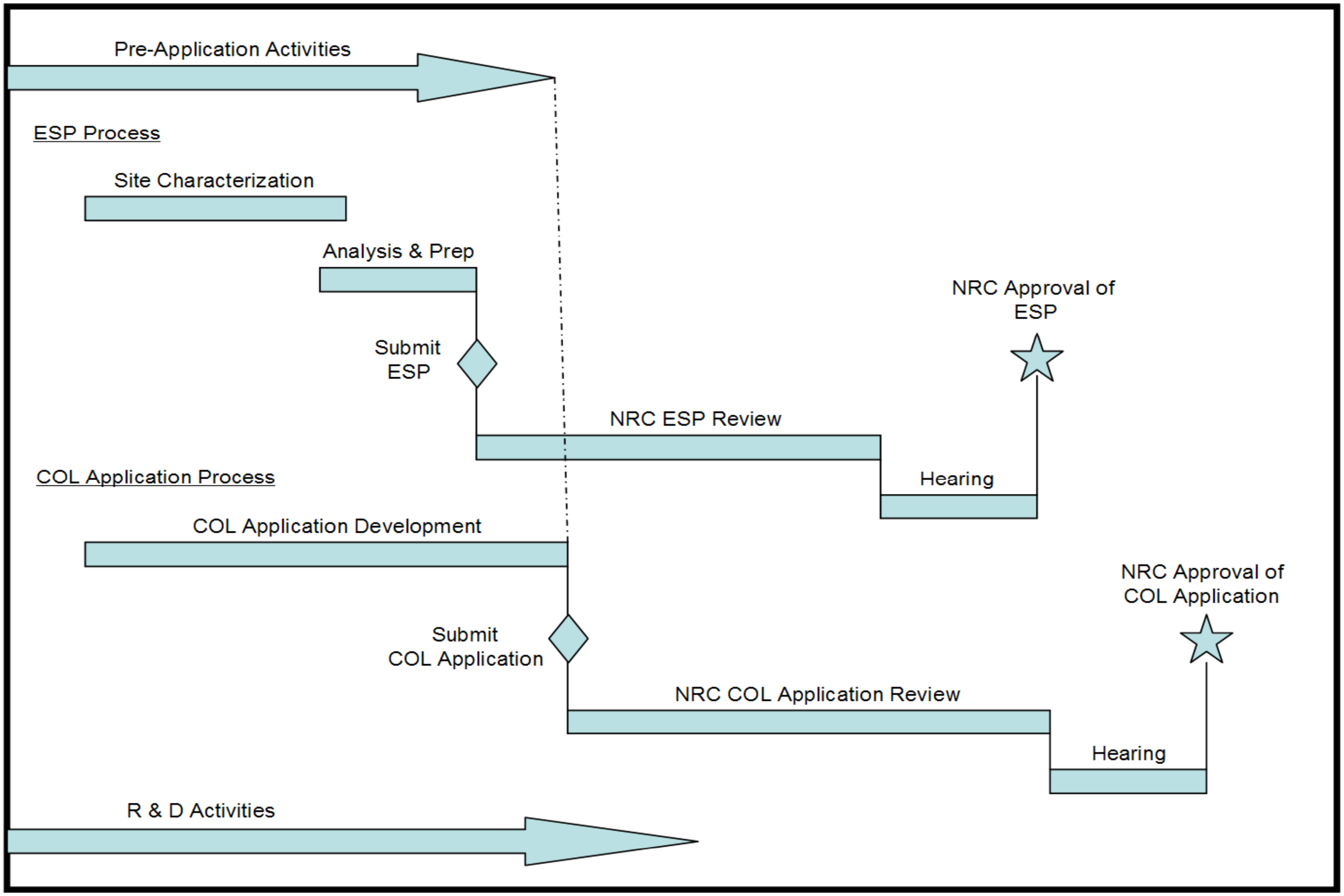
  Additional guidance provided:

  - Focus on key areas, including planning, training, design familiarization, and identification of programmatic and technical issues.
  - Identify the specific reactor technology to be built in advance of the pre-application review. The strategy presented in this document is based on a single reactor technology proceeding through licensing.
  - Expand the pre-application review for the specific NGNP design to a 3-year period starting in FY 2010 to address and resolve NGNP technical and programmatic issues, to the extent feasible, before the application is submitted.

DOE NGNP Licensing Plan – June 2009

- **Plan contains the following key points:**
  - Identifies and implements activities that will support the issuance of a COL in accordance with applicable 10 CFR 52 requirements (Section 2.1).
  - Implements a risk-informed and performance-based licensing approach to be consistent with the licensing process-related recommendations included in the *Report to Congress* (Section 2.2).
  - Builds on previous pre-licensing efforts and NRC interactions associated with gas-cooled reactor technology (Section 2.2).
  - Identifies earliest and highest priority pre-application issues for the pre-application period, independent of
    - reactor design selected,
    - site where this reactor will be located
    - whether or not an Early Site Permit (ESP) is submitted.
  - Establishes the proposed regulatory basis and proposed COL application content guide similar to RG 1.206 for licensing the NGNP by the NRC (Section 2.4 and Section 2.5).

Overview of DOE/NGNP Licensing Process



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Industry Perspective on HTGR Safety and Licensing

- **Use of RIPB approach**
  - Exelon pre-application
  - ASME PRA Standard for non-LWR
  - ASME Section XI Div 2 – Reliability Integrity Management Requirements for Non-LWRs
  - ANS 53.1-200X – Nuclear Safety Criteria and Safety Design Process for Modular Helium-Cooled Reactor Plants
- **ASME- "Roadmap for the Development of ASME Code Rules for High Temperature Gas Reactors"**
- **Industrial User needs**
  - Industrial Users (e.g. NGNP Industry Alliance) familiar with hazards analysis and RIPB approach
  - Must address the regulatory issues with co-location without significant impact to non-nuclear operations or vice versa

Industry Perspective on HTGR Safety and Licensing (con't)

- **ANS President's Special Committee on Small and Medium Sized Reactor (SMR) Generic Licensing Issues. (Jan. 2010)**
  - "…established to identify, prioritize and propose resolution of generic issues for all SMR types."
  - 14 topics identified and being prioritized; several common to HTGR designs
  - Intent is to be responsive to NRC desire for consolidated treatment of issues generic to more than a single applicant.

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PBMR

Recent International Licensing Activities

- **South Africa**
  - 400MWt Brayton cycle PBMR electric demonstration power plant (DPP)
  - Environmental assessment for DPP
  - Development of "Requirement Documents"; "Licensing Guides" to supplement regulations
  - Use of IAEA standards and guides as part of establishing regulatory infrastructure
  - MDEP involvement
  - Gen IV framework signatory

Current International Licensing Activities

- **MDEP / CORDEL**
  - "Multinational Design Evaluation Program"
  - Long term program seeking greater regulatory standardization, effectiveness and efficiency
  - Regulator's forum with invited participation on selected topics or DCWGs
  - World Nuclear Association's Working Group on "Cooperation in Reactor Design Evaluation and Licensing" (CORDEL)
    - AIM: "*…promote the achievement of a worldwide regulatory environment where internationally accepted standardized reactor designs can be widely deployed without major design changes.*"
    - Industry participants forum
    - Published integrated strategy in 2010

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Summary

- HTGR plants have been licensed worldwide
- Current LWR-based technical regulatory requirements and guidance pose challenges to establishing the technical requirements for HTGR licensing
- NRC policies, requirements, and practices provide a framework for HTGR licensing
- NGNP Licensing Strategy involves a risk-informed, performance-based approach
- Technical and policy issues have to be resolved

Suggested Readings

1. Next Generation Nuclear Plant Licensing Strategy; A Report to Congress, August 2008,
2. NGNP Licensing Plan PLN-3202 Revision 0, June 2009
3. PBMR Risk Informed Performance Based Approach White Papers (series) 2006 (NRC Project 732)
4. INL Letter December 9, 2009, Next Generation Nuclear Plant Project Licensing White Paper Submittal- Next Generation Nuclear Plant Defense-in-Depth Approach – NRC Project #0748
5. NUREG 1338 "Pre-Application Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor (MHTGR)" U.S. Nuclear Regulatory Commission, March,1989
6. NUREG-1338, "Pre-Application Safety Evaluation Report for the Modular High-Temperature Gas-Cooled Reactor (MHTGR) - Draft Copy of the Final Report," U.S. Nuclear Regulatory Commission, December 1995. (SECY 1995-0299)(ADAMS Accession No. ML052780519))
7. Letter- NRC Staff's Preliminary Findings Regarding Exelon Generation's [Exelon's] Proposed Licensing Approach for the Pebble Bed Modular Reactor [PBMR], dated March 26, 2002
8. "International Standardization of Nuclear Reactor Designs – A Proposal by the World Nuclear Association's Working Group on Cooperation in Reactor Design Evaluation and Licensing (CORDEL Group)" 2010 http://www.world-nuclear.org/uploadedFiles/org/reference/pdf/CORDELreport2010.pdf