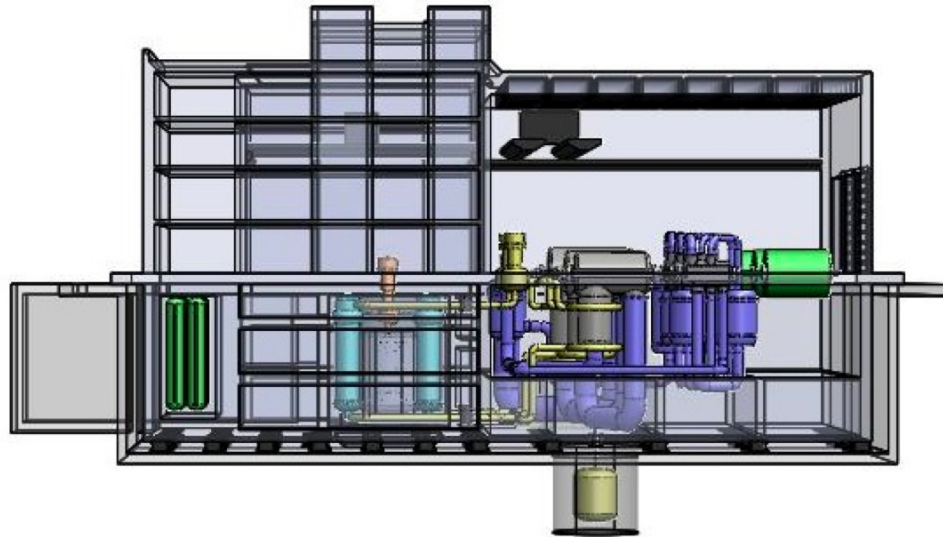


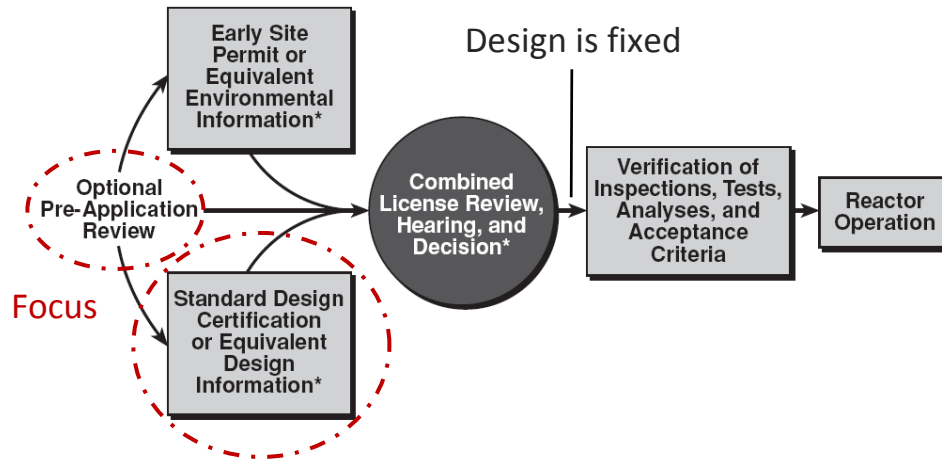
# Role of Licensing in Advanced Reactor Design



January 28, 2009

# Current LWR Licensing Process

- Reactor vendors obtain design certification (DC)
- Approval of generic reactor plant design
- Vendor submits reactor standard technical specifications
- Utilities obtain combined licenses (COL) for construction/operation
- COL will reference a DC
  - Final Safety Analysis Report must be submitted



\*A combined license application can reference an early site permit, a standard design certification, both, or neither. If an application does not reference an early site permit and/or a standard design certification, the applicant must provide an equivalent level of information in the combined license application.

# Overview

- Commercial nuclear power plants are capital-intensive
  - Overnight capital costs range from \$2,400/kWe - \$4,540/kWe<sup>1</sup>
  - Contributions to uncertainty vary widely (e.g. design changes, program management)
  - Future financial and electricity marketplace very uncertain
- Capital costs only tell part of the story for commercial viability
  - Generation costs factor in operating costs and overall project performance in addition to capital and financing costs<sup>1</sup>
- Reactor design plays an integral role in projects overall economic competitiveness
  - Initial phase of the reactor design process can strongly impact system performance throughout the entire lifetime of the plant
  - Safety, reliability, and security represent potential synergistic design objectives
- Licensing process can unfold many different ways however only one acceptable outcome

# Current Status of Designs under USNRC Review

## Gen III+

Design	Applicant
AP1000 Amendment*	Westinghouse Electric Company
Economic Simplified Boiling-Water Reactor (ESBWR)	GE-Hitachi Nuclear Energy
U.S. Evolutionary Power Reactor (U.S. EPR)	AREVA Nuclear Power
U.S. Advanced Pressurized-Water Reactor (US-APWR)	Mitsubishi Heavy Industries, Ltd.

Design	Applicant
Advanced Boiling Water Reactor (ABWR)	General Electric (GE) Nuclear Energy
System 80+	Westinghouse Electric Company
Advanced Passive 600 (AP600)	Westinghouse Electric Company
Advanced Passive 1000 (AP1000)	Westinghouse Electric Company

**DESIGN CERTIFICATION**

## Gen IV

Design	Applicant
International Reactor Innovative and Secure (IRIS)	Westinghouse Electric Company
NuScale	NuScale Power Inc.
Pebble Bed Modular Reactor (PBMR)	PBMR, Westinghouse Electric Company
Toshiba 4S	Toshiba/Westinghouse

**PRE-APPLICATION**

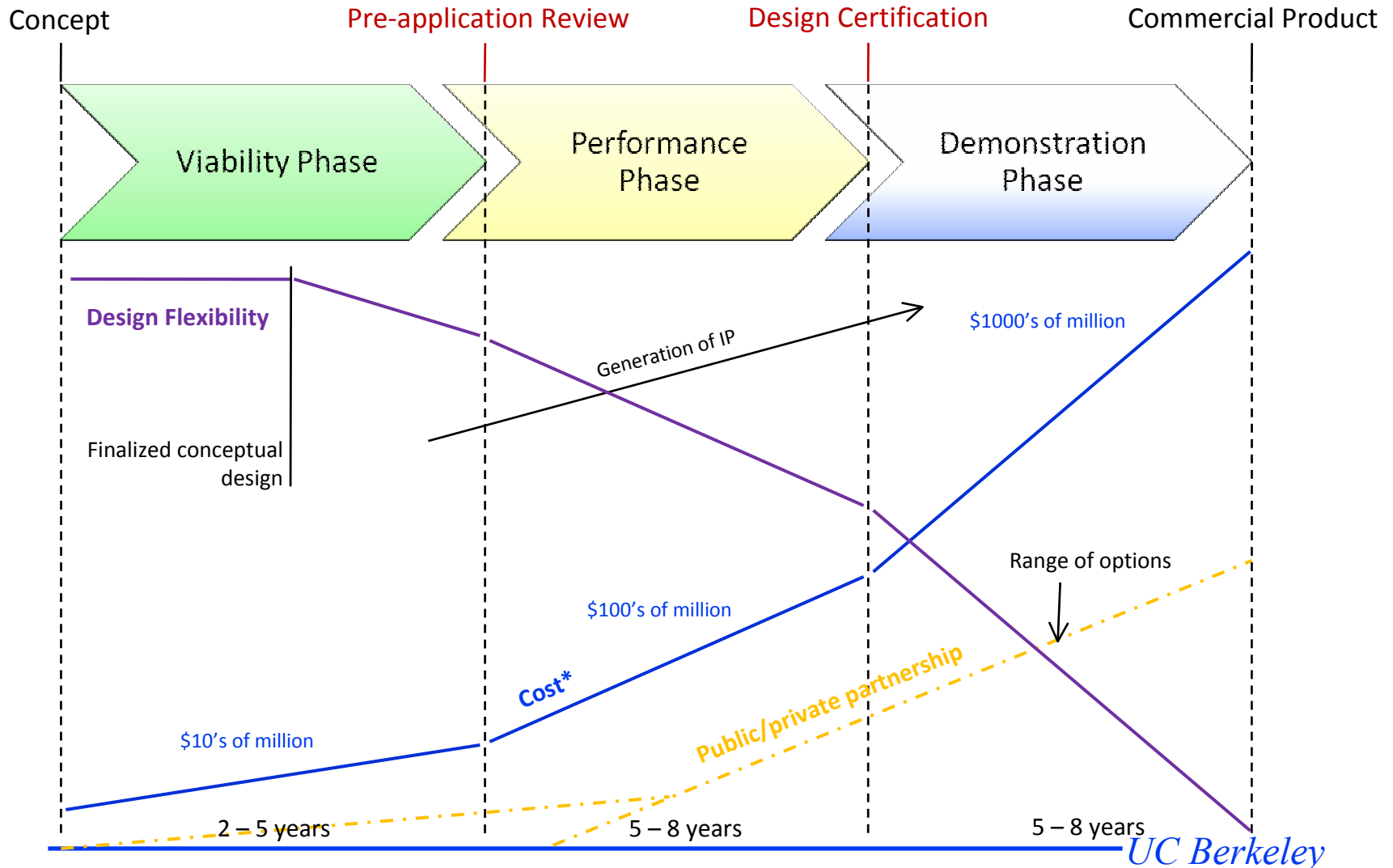
**UNDER REVIEW**

\* Westinghouse is currently iterating with NRC on design changes from previously certified design (2006). NRC is expected to complete DC review by 2011.

**“COMPLETED”**

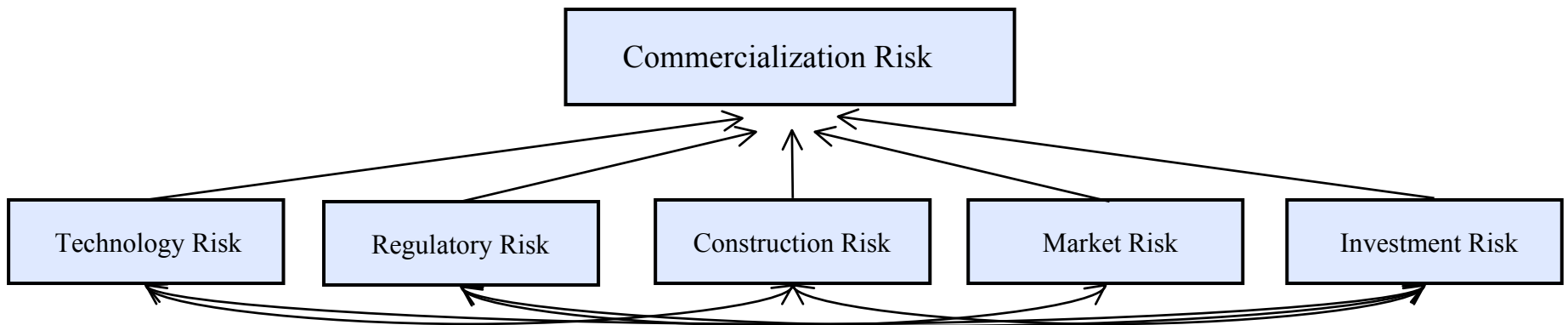
(<http://www.al.com/business/huntsvilletimes/index.ssf?/base/business/122812656223160.xml&coll=1&thispage=1>)

# Conceptualized evolution from Powerpoint™ to commercialization of “near-term” nuclear technologies



•Cost numbers and approximate time scales are more indicative of larger scale plants (> 200 MWth).

# Commercial Reactor Risk Allocation



1. Technology Risk – Will it work? Materials and fuels qualification? Operational experience? Keeping proposed schedule?
2. Regulatory Risk – Safety code qualification? Adequate testing? Competent engineering? Co-located facility? NRC knowledgeable?
3. Construction Risk – modular vs. monolithic construction? Contractor oversight?
4. Market Risk – Preference for small or large plants? Supply market inelasticity? How big is market for proposed products (electricity/heat/hydrogen/desal)? Overall need for nuclear?
5. Investment Risk – How long will the project take? When can one expect returns? Financial guarantees? How rapidly can uncertainties be reduced?

*Reactor design decisions very rarely only impact one area of risk*

*- “Any time someone starts out on a new idea in nuclear power design, they need to understand the inertia of that marketplace and the regulatory context of that market which is vast.”<sup>1</sup>*

<sup>1</sup> Jon Phillips, *Pugent Sound Business Journal*

# Can research at the university level play a role in reducing commercialization risk?

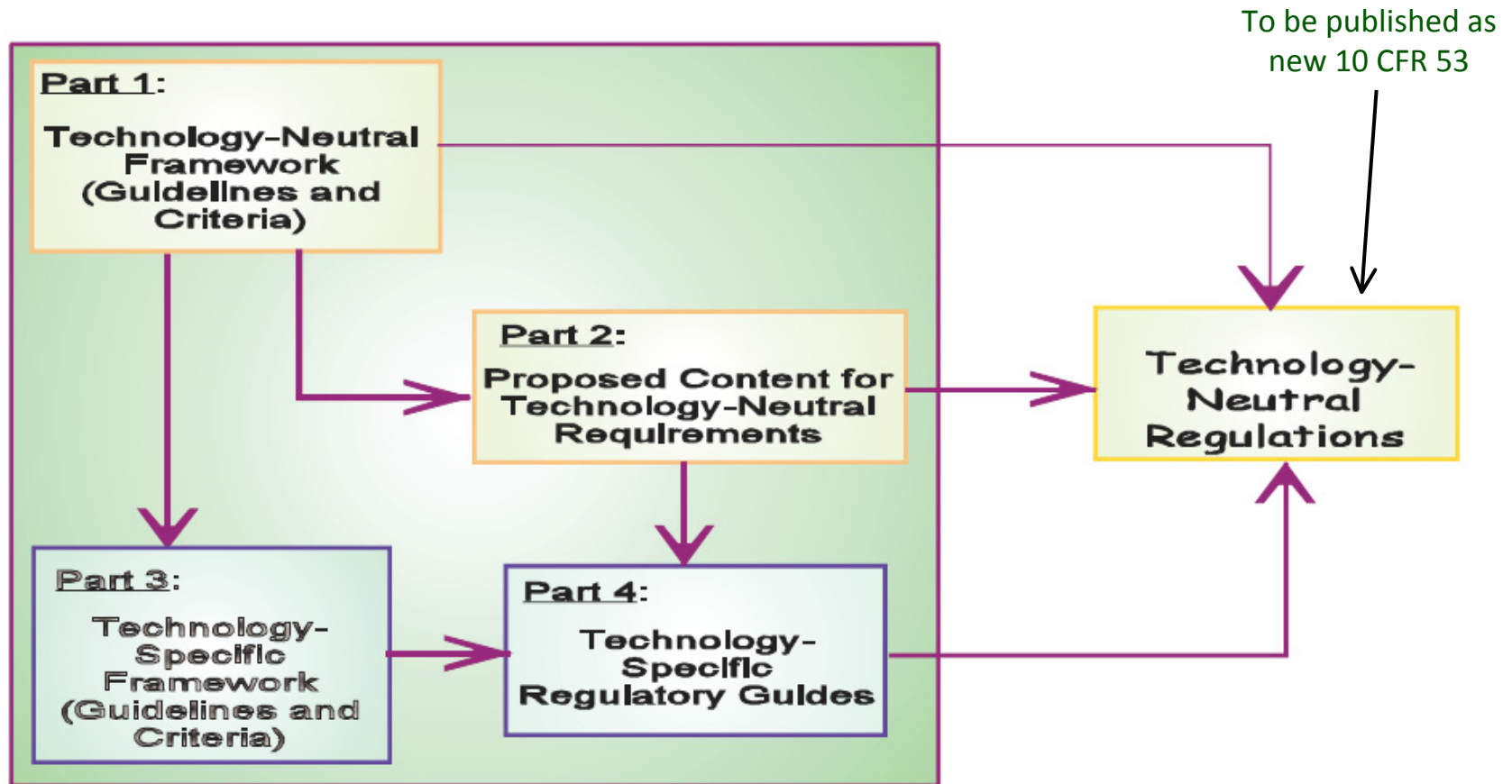
- Some general limitations
  - Different objectives, limited resources
  - Large focus on improving our understanding of phenomena of technology of interest
    - » e.g. higher fidelity computational modeling
  - Implementation and long-term reliability can be treated as an afterthought
    - » Current fleet performance increasing nuclear attractiveness
      - Industry has demonstrated strong competency in long-term plant reliability
    - » Latest construction costs and reactor build performance metrics are much more uncertain
      - Construction experience in China with AP-1000 will be important
  - Risk and level of impact can be difficult to quantify
    - » Unclear what level of resolution necessary

# Role of licensing and technology-neutral approach

- Licensing is the first pathway to commercial market
- Novel nuclear technologies require sophisticated regulatory body
  - Scales with financial resources
  - Financial responsibility falls on applicant and “back-and-forth” game develops with regulator
    - » Regulator needs funding to perform review to certify design but applicant needs design certification to demonstrate commercial viability
- Current USNRC climate is LWR-specific
  - Resources have been devoted to reviewing COL applications and “more mature” design certification reviews
  - Staff has developed an overarching framework for a technology-neutral licensing regulatory structure
- Limited operational experience for new nuclear technology
  - Increases need for risk-informed and defense-in-depth approaches



# US NRC proposed framework for regulatory structure for new plant licensing



# Recent important licensing developments – NGNP Licensing Strategy

- Report delivered to Congress in August, 2008
  - mandated under Energy Policy Act of 2005
- Considered 4 options
  - Option 1: Deterministic Approach. This option uses deterministic engineering judgment and analysis to establish the licensing basis (including selection of events) and licensing technical requirements. This approach has been used for licensing operating LWRs and involves no use of PRA information and insights.
  - Option 2: Risk-Informed and Performance-Based Approach. This option uses deterministic engineering judgment and analysis, complemented by NGNP design-specific PRA information, to establish the licensing basis (including selecting licensing basis events) and licensing technical requirements. The use of the PRA would be commensurate with the quality and completeness of the PRA presented with the application.
  - Option 3: Risk-Informed and Performance-Based Approach (with greater emphasis on PRA). This option places greater emphasis on the use of the NGNP design-specific PRA in complementing deterministic engineering judgment and analysis, to establish the licensing basis (including selecting licensing basis events) and licensing technical requirements. As in Option 2, the use of the PRA would be commensurate with the quality and completeness of the PRA presented with the application.
  - Option 4: New Body of Risk-Informed and Performance-Based Regulations. This option would use a new body of regulations to establish the licensing basis (including selecting licensing basis events) and licensing technical requirements. The new body of regulations would make extensive use of the risk-informed and performance-based regulatory structure, and would require rulemaking to be implemented.
- *Alternative 3: 10 CFR Part 52 Licensing Process (COL) was selected for procedure*
- Although a more conservative approach, timetable forced decision and TNF (option 4) is still on the table for future non-LWR technology

Transition to a TNF costs significant resources (~\$250 million) →

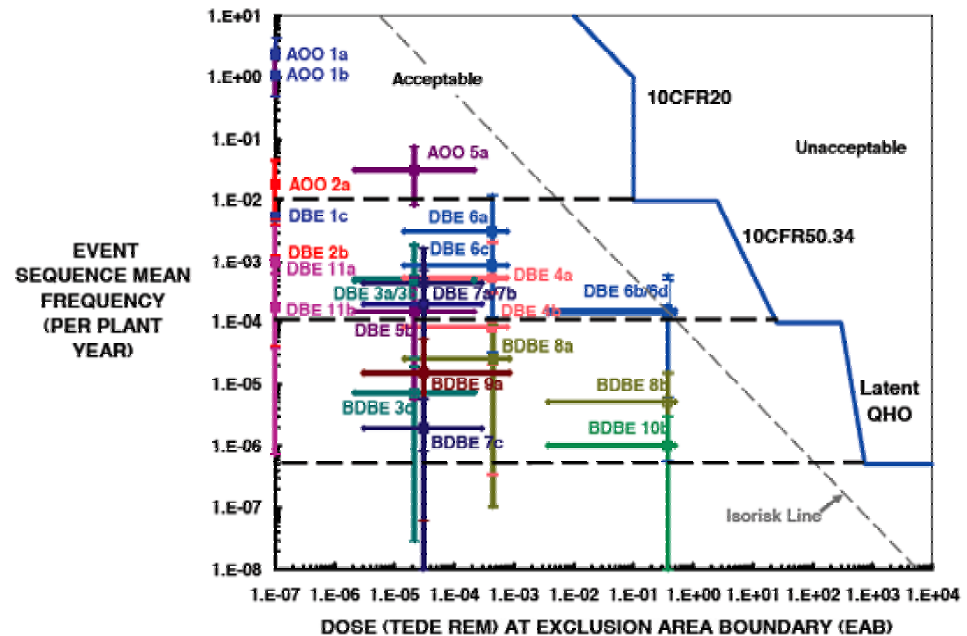
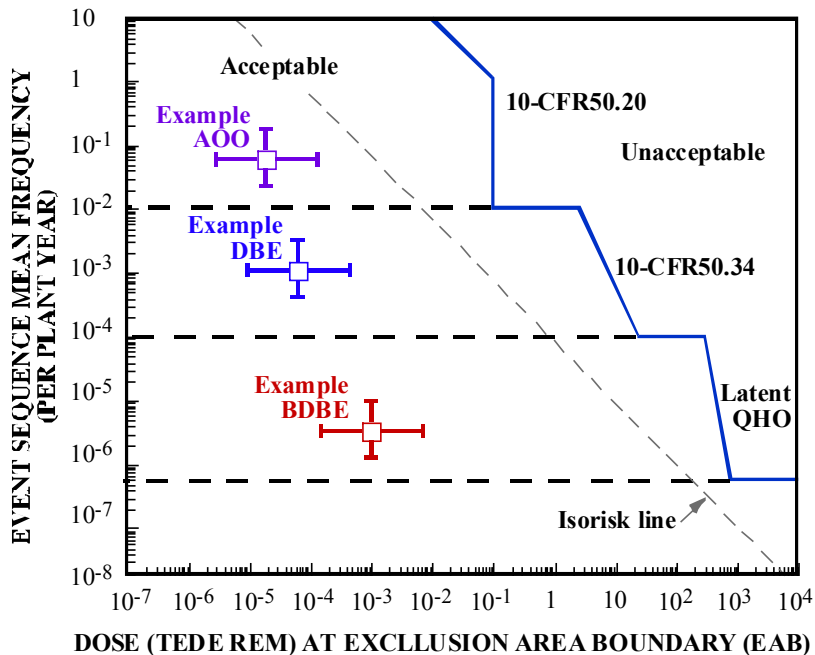
# PB-AHTR approach to licensing

- Adopted PBMR proposed licensing approach for USNRC design certification
  - Top-down approach
  - Similar set of high-level functional requirements
  - PBMR approach consistent with previous HTGR US DOE licensing experience
- Departure from deterministic PBMR approach
  - Preference for use of best-estimate code simulations where uncertainties are quantified
  - Scaling arguments allow for code validation at reduced costs
- Licensing overview

Top Level Regulatory Criteria (TLRC)	Establish <i>what</i> must be achieved
LBEs Deterministic DBAs	Define <i>when</i> the TLRC must be met
Safety Functions Defense-in-Depth Regulatory Design Criteria Safety Classification of SSCs	Establish <i>how</i> it will be assured that the TLRC are met
Special Treatment Requirements	Provide assurance as to <i>how well</i> the TLRC are met

# Design Objectives – Event categorization

- Defining a design basis envelope (event categorization)
  - Frequency space
    - » Focus on long-term reliability considerations
    - » Difficult to quantify for new nuclear technology with lack of operational experience and passive system reliability
  - Consequence space
    - » Focus on code validation for system and fuel response under accident conditions
    - » Improved simulation methods and verification work



# Role of Regulatory Design Criteria

- General Design Criteria (GDC) are defined in 10 CFR Part 50 Appendix A and are LWR specific
  - Since written over time, can be duplicative
- “Principal design criteria establishing the necessary design, fabrication, construction, testing, and performance requirements for SSC’s important to safety”
  - Functional requirements
- Regulatory Design Criteria (RDC) is a technology-specific surrogate for GDC and answers the question of how the TLRC will be met
  - At the highest level, safety functions for nuclear power plants are generic in nature such as an objective to protect the health and safety of the public

