U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Severe Accidents and Options for Proceeding with Level 3 PRA Activities

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Office of Nuclear Regulatory Research

Overview of Severe Accidents

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Accident Terminology

- Design-basis accidents (DBAs)
- Beyond-design-basis accidents
- Core damage accidents
- Severe accidents

Historical Perspective (Pre-TMI)

- Focus on DBAs
- Defense-in-depth safety strategy
- Reactor Safety Study (WASH-1400)
- TMI-2 Accident

Historical Perspective (Post-TMI)

- Severe accident research program
- Severe accident policy statement
- Individual plant examination (IPE) and IPE of external events (IPEEE) programs
- Chernobyl accident

Severe Accident Progression

Station Blackout (SBO) Example:

- Initiating event: Loss of offsite power
- Reactor trip
- Failures lead to unavailability of onsite emergency ac power sources
- Core injection and cooling capability become inadequate

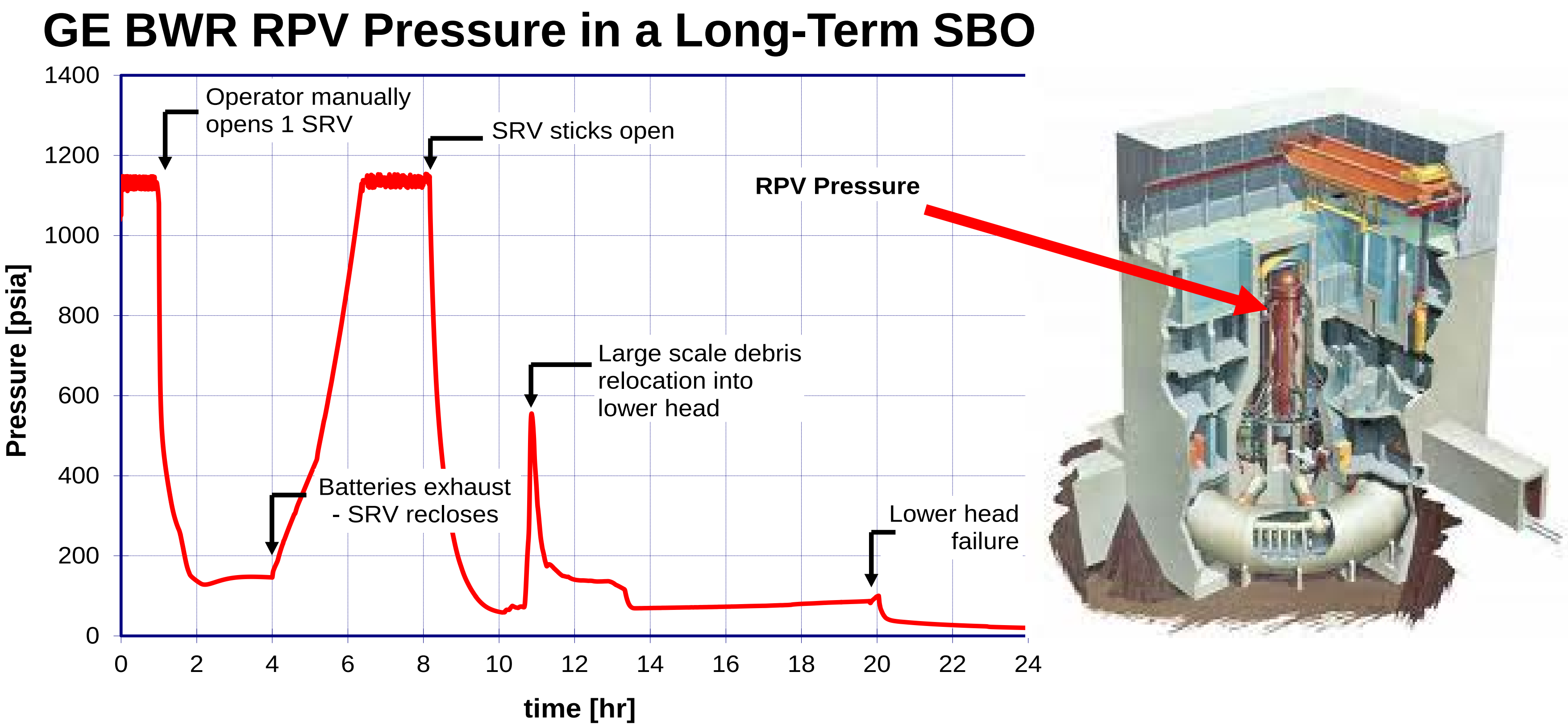
SBO Example (cont.)

- Coolant boiloff leads to sustained core uncovery and heatup
- Oxidation of fuel cladding results in hydrogen production and release of gaseous fission products to coolant
- Clad melting and fuel liquefaction accelerate release to coolant

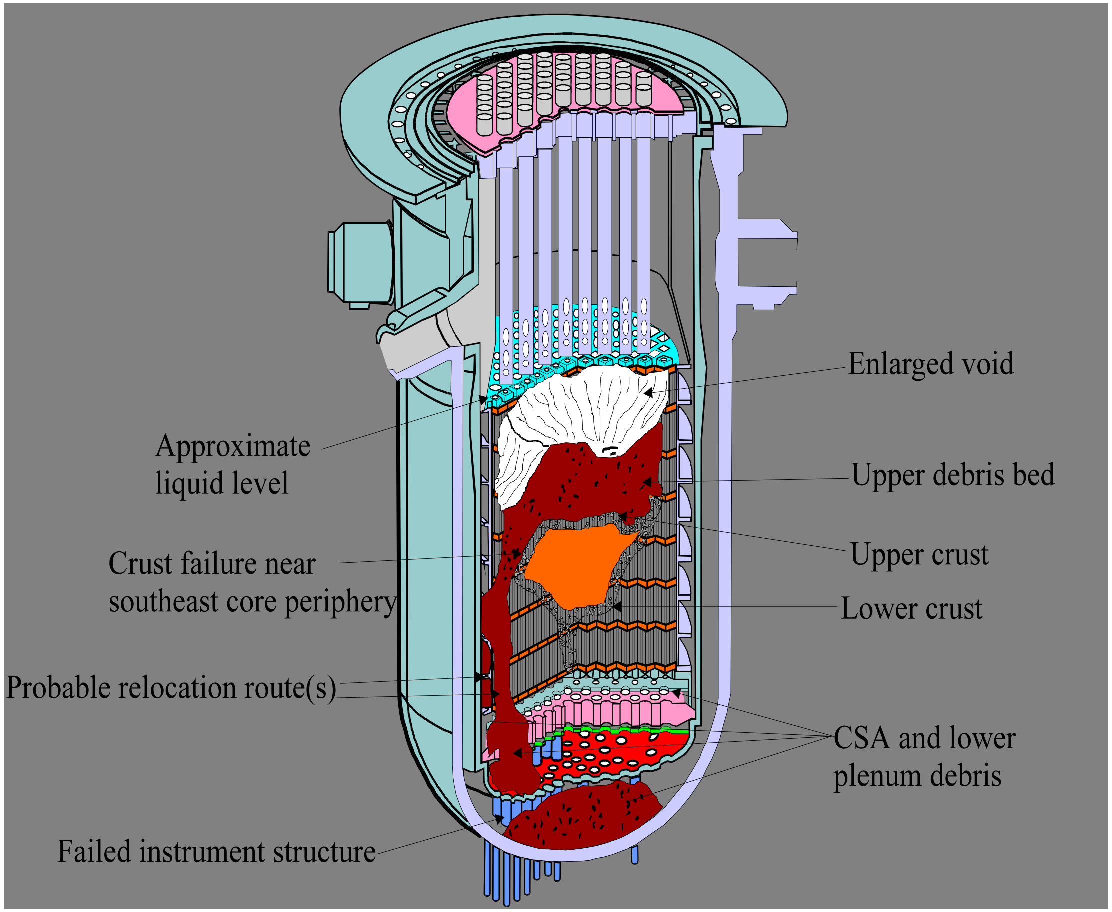
SBO Example (cont.)

- Flow of molten fuel into reactor pressure vessel (RPV) lower plenum
- Failure of RPV and release into containment
- Challenges to containment integrity
- Containment failure and release to the environment

SBO Example (cont.)



TMI-2 Core Relocation



Proposed Level 3 PRA Activities

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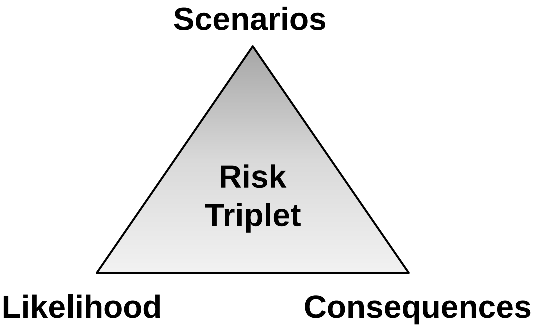
Probabilistic Risk Assessment

PRA is a structured, analytical process that provides both qualitative insights and quantitative estimates of risk.

1) What can go wrong?
2) How likely is it?
3) What are the consequences?



PRA End States

- Level 1 PRA: Onset of core damage or achievement of a safe state
- Level 2 PRA: Release of radioactive material to the environment
- Level 3 PRA: Offsite radiological consequences

Overall Vision

To enhance regulatory decision making by extracting new and improved risk insights by:

- Incorporating technical advances
- Expanding analysis scope
- Achieving analytical consistency

Commission Tasking

Staff requirements memorandum M100218 (March 19, 2010) expressed conditional support and directed the staff to:

- Continue internal coordination efforts and engage external stakeholders
- Provide various options for proceeding which include costs and perspectives on future uses for Level 3 PRAs

Potential Future Uses

- Assess NRC's current use of PRA
- Verify/revise regulatory requirements & guidance
- Support specific risk-informed regulatory applications
- Prioritize generic safety issues & nuclear safety research programs

Potential Future Uses (cont.)

- Develop and pilot test PRA technology, standards, guidance
- Support PRA knowledge management & risk communication
- Support future risk-informed licensing of new/advanced reactors

Primary Options for Proceeding

- Option 1: Status Quo – Evolutionary Development of PRA Technology
- Option 2: Focused Research to Address Identified Gaps Before Performing a Full-Scope Comprehensive Site Level 3 PRA
- Option 3: Full-Scope Comprehensive Site Level 3 PRA – Operating Plant

Other Options

- Limited-scope Level 3 PRA
- Full-scope Level 3 PRA for new or advanced reactor design
- Licensee-developed Level 3 PRA

Option 1: Status Quo

Objectives

- Continue evolutionary development of PRA technology on a resource-available basis

Scope

- Determined by program office user need requests, Commission tasking, and the agency's long-term research plan (LTRP)
- Level 2/3 PRA related projects in LTRP

Option 1: Status Quo

Advantages

- Consistent with the current fiscal climate

Disadvantages

- Insights from a new and more comprehensive site Level 3 PRA would not be realized
- Can result in inconsistent and more costly treatment of potential future issues

Option 2: Focused Research

Objectives

- Address identified gaps in PRA technology

Scope (example research areas)

- Consequential multiple initiating event modeling
- Multi-unit modeling
- Post core damage and external events HRA
- Spent fuel PRA technology
- Level 2 and Level 3 PRA uncertainty analysis

Option 2: Focused Research

Advantages

- Focuses limited available staff and contract support resources on mission-critical work
- Focuses additional resources already requested through budget process on needed research
- Enhances PRA capability in specific areas

Disadvantages

- Delays insights that could be gained

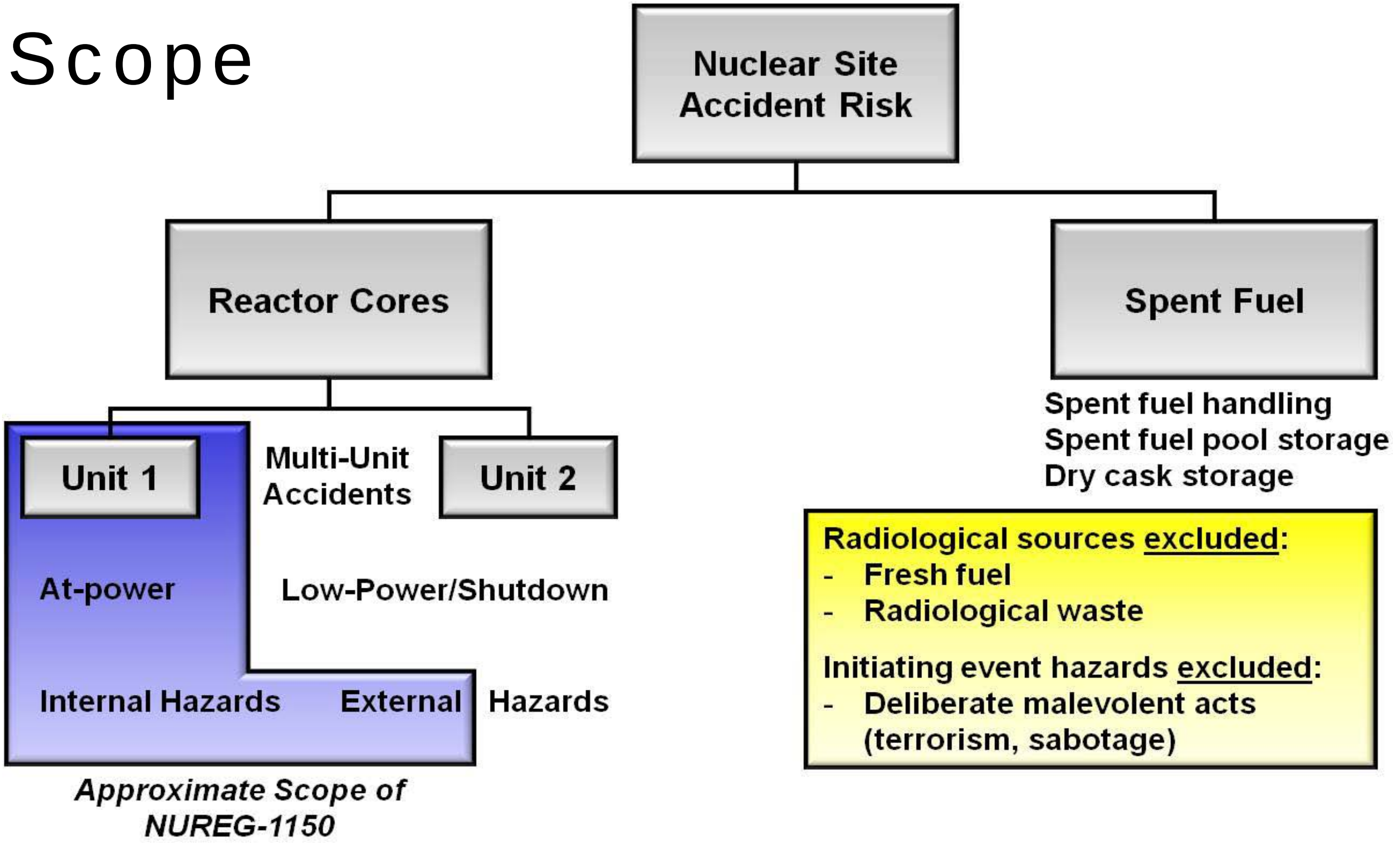
Option 3: Site Level 3 PRA

Objectives

- Extract new and improved risk insights
- Enhance PRA capability, expertise, and documentation
- Demonstrate technical feasibility and evaluate realistic cost of developing new Level 3 PRAs

Option 3: Site Level 3 PRA

Scope



Option 3: Site Level 3 PRA

Advantages

- Provides new and improved risk insights earlier
- Enhances PRA capability, expertise, and documentation earlier

Disadvantages

- Resource-intensive
- Requires reallocation of qualified risk analysts from other ongoing important activities

Staff's Recommendation

- A new and more comprehensive site Level 3 PRA would be beneficial.
- Obtaining additional resources to support this initiative would be challenging.
- The staff recommends the Commission approve Option 2.

Conclusion

Acronyms

BWR	boiling water reactor
CSA	core support assembly
DBA	design-basis accident
GE	General Electric
HRA	human reliability analysis
IPE	individual plant examination
IPEEE	individual plant examination of external events
LTRP	long-term research plan

Acronyms (cont.)

NRC	U.S. Nuclear Regulatory Commission
PRA	probabilistic risk assessment
RES	NRC Office of Nuclear Regulatory Research
RPV	reactor pressure vessel
SBO	station blackout
SRV	safety/relief valve
TMI	Three Mile Island