# NRC/EPRI Workshop on "The Treatment of PRA Uncertainties"

February 29 and March 1, 2012

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# Draft LPSD Standard PRA Elements

**For Internal Events:**

- Plant Operating State Analysis (LPOS)
- Initiating Events Analysis (LIE)
- Accident Sequence Analysis (LAS)
- Success Criteria (LSC)
- Systems Analysis (LSY)
- Human Reliability Analysis (LHR)
- Data Analysis (LDA)
- Quantification (LQU)
- LERF Analysis (LLE)

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# PRA Elements for Other Hazards (Continued)

- **Internal Flooding**
  - Internal Flood Plant Partitioning (LIFPP)
  - Internal Flood Source Identification and Characterization (LIFSO)
  - Internal Flood Scenarios (LIFSN)
  - Internal Flood-induced Initiating Events (LIFEV)
  - Internal Flood Accident Sequences and Quantification (LIFQU)
- **Seismic Events**
- **High Winds**
- **External Floods**
- **Other External Hazards**

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# Also Covered in LPSD Standard

- Requirements for Qualitative Risk Assessment (QLRA) for Shutdown Operation Using Defense-in-Depth Principles
  - NUMARC 91-06 Key Safety Functions
  - Spent Fuel Pool Included
  - Internal Events Only
- Interpretation of Requirements for LPSD PRA for Specific Outage Applications
  - Configuration Risk Management

# Candidate Sources of Uncertainty for LPSD Conditions Relative to Capability Category II Supporting Requirements

Internal Events Only

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# Plant Operating State Analysis (LPOS)

- Exclusion of evolutions involving low frequency safe stable states; e.g. feed and bleed, high pressure recirculation
- Time(s) chosen to define decay heat level/RCS level/RCS temperature and pressure conditions for each POS
- Selection of outage representative cause for controlled shutdowns and for forced outages
- Evaluation of POS durations based on existing data but for future evolutions

# Initiating Events Analysis (LIE)

- Exclusion of reactivity insertion events except for boron dilution, which is then modeled as in NUREG/CR-6144, for Surry (1995)
- Omission of heavy load drops
- Fixed set of generic initiators and frequencies does not lend itself to detailed frequency assessment to account for plant specific operating conditions and maintenance practices and potentially greater plant impacts
- Interpretation of accident precursor data from other plants which did not cause an IE, but may at the specific plant analyzed, or vice-versa.

# Accident Sequence Analysis (LAS)

- Incorporation of phenomenological conditions (e.g. RCS break location, assumption of ”bounding” break sizes, access to high temperature locations at < boiling), and debris (NPSH, plugging) into the sequence models for each POS, particularly for temporary conditions resulting from testing or maintenance
- Assumption of operating equipment failing at time of first demand eliminates development of sequences for conditions after start; e.g. RHR relief valve is no longer isolated after pump start. Failure to credit RHR cooldown could lead to a similar omission.
- Implicit credit for early manual reactor trip in advance of automatic trip when evaluating allowable operator response times; e.g. feed and bleed

# Success Criteria (LSC)

- Assumed minimum mission time of 24 hours
- Availability of computer codes and past generic analyses for shutdown sequence conditions; e.g., RCS partially vented with steam generators full, accident progression while pressurized on RHR
- Time of year & day for accident initiation caused by planned test, maintenance, and evolution activities; e.g. shutdown as hurricane approaches, scheduling of mid-loop.

# Systems Analysis (LSY)

- Incorporation of spatial and environmental hazards (e.g. removal of flood barriers, fire barriers, or ventilation changes), shutdown activities affecting system configurations (instrument tube bolt detensioning with RCS not yet vented), and debris (NPSH, plugging) into the system models for each POS, particularly for unusual or temporary alignments

# Human Reliability Analysis (LHR)
# Pre-Initiator HFEs

- Identification of pre-initiator HFEs affecting indications, other than those that impact RCS Level indication
- Applicability of standard HRA methods to shutdown conditions for pre-initiator HFEs (e.g., work crew familiarity with written procedures, timing of post-maintenance restoration tasks)

# Human Reliability Analysis (LHR)
# Post-Initiator and Recovery HFEs

- Applicability of standard HRA methods to shutdown conditions for post-initiator HFEs; e.g., quality of training (including just-in-time training for complex evolutions), availability of indications, and distractions caused by parallel tasks involving tests, maintenance activities, and evolution steps
- Applicability of HEP dependency methods to shutdown conditions; e.g. between pre-,post-, and at-initiator HFEs, especially considering command and control of local activities
- HEP dependency methods fail to consider intervening successful actions as prescribed by NUREG/CR-1278
- Propagation of uncertainties through HEP models (e.g. in allowable response time, diagnosis time, and execution times) versus assignment of range factors based on point value
- Limits for manual access to high temperature locations containing near boiling water

# Human Reliability Analysis (LHR) At-Initiator HFEs

- Question of completeness in identifying at-initiator HFEs by
  - 1) reviews of industry operating experience and
  - 2) related reviews of plant specific test and maintenance activities as part of the pre-initiator HFE evaluation process
- Criteria for assigning dependence between at-initiator HFEs and POST-Initiator HFEs

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# Data Analysis (LDA)

- Applicability of CCF parameter estimates derived from generic data for at-power conditions for use for specific plants during shutdown
- Justification for use of generic CCF parameter estimates for multiple POSs, and under different operating system alignments; e.g., one of two versus two of two RHR trains initially running
- Justification for use of at-power corrective maintenance frequencies and adjusted repair durations for use during shutdown conditions

# Quantification (LQU)

- Assumption of convergence when a 1 decade decrease in truncation limit changes CDF and LERF less than 5%
- Adequacy of selected POS intervals as compared to a more refined selection
- Assumption that use of a truncated model solution in a Monte Carlo routine is adequate to “ESTIMATE the uncertainty interval for CDF accounting for state-of-knowledge correlation”; i.e., as opposed to resolving CDF each Monte Carlo sample

# LERF Analysis (LLE)

- Omission of Potential LERF Contributors
  - Hydrogen Combustion (equipment survivability)
  - Steam Explosions (with RV head unbolted)
  - Induced RHR System Failure (containment bypass)
- Availability of Computer Codes and Past Generic Analyses for Shutdown Sequence Conditions
  - Source Terms for Shutdown Sequences
  - Shutdown on RHR Cooling with RCS Pressurized (induced SGTR or RHR failure)
  - RCS Depressurized with RV Head Unbolted/Removed and Obstructions between RV and Containment Dome Removed (steam explosions)

# LERF Analysis (LLE) (continued)

- Assumption that closure of the containment equipment and personnel hatches as appropriate means that containment is then isolated; i.e., no other openings during applicable shutdown POSs
- Assumption that quickly closed containment hatches (without fully bolting ) have the same overpressure capacity as initially fully closed hatches
- Assumptions regarding operator actions guided by procedures when guidance is left to decision of Technical Support Center

  (addressing known trade-offs between recovery event impacts; e.g., recovery of containment spray)

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