Level 1 PSA
External Events
Accident Sequence Quantification for Point Lepreau Refurbishment

M. Wei, S. Sawh, A. Nainer, L. Comanescu, B. S. Lee,
E. Elewini, I. Vencel, G. Banaseanu, J. Ha, R. K. Jaitly
AECL

A. Jean, D. Basque, D. Mullin
NB Power

May 19, 2008

AECL EACL

Agenda

- Introduction to PLR PSA
- Level 1 External Events
  - Internal Fire Events
    - Fire-induced SCDF
  - Internal Flood Events
    - Flood-induced SCDF
  - Seismic Events
    - Seismic capacity of the plant expressed as HCLPF

Point Lepreau Generating Station

- NB Power is the utility
- Commercial operation 1983
- Provides 1/3rd of power consumed in province of New Brunswick
- Refurbishment plan: 18 month outage that started March 28 2008

Introduction to PLR PSA

- As part of the Refurbishment Project, a Level 2 PSA has been performed
- Scope includes:
  - internal events for full power and shutdown
  - internal fire and flood for full power only
  - PSA based Seismic Margin Assessment
- Note external fires and floods are included in another analysis for common mode failures

Team Effort

- **Both AECL & NB Power's PSA analysts are participating in the PSA**
  - **NB Power reviews all methodologies and analysis reports**
  - **Data for the models provided by NB Power**
  - **Accident Sequence Quantification: joint exercise**
  - **Both teams attend meetings with regulator as needed**

Énergie NB Power
Nucléaire Nuclear

AECL
EACL

Level 1 and 2 PSA Goals and Limits

- **Severe Core Damage Frequency (SCDF) from Internal and External Events:**
  - **Limit: 1E-04 events/year**
  - **Goal: 1E-05 events/year**
- **Large Release Frequency (LRF) from Internal and External Events:**
  - **Limit: 1E-05 events/year**
  - **Goal: 1E-06 events/year**
- **Seismic Margin corresponding to a High Confidence Low Probability of Failure (HCLPF)**
  - **0.3g for Severe Core Damage**
  - **0.4g for Large Releases**

Level 1 – Internal Fire Events

- 91 fire compartments considered
- 9 fire compartments screened out from qualitative screening analysis
- 64 fire compartments screened out from quantitative screening analysis
- From 18 remaining fire compartments, 916 initiating events screened out, 314 screened in
- 314 fire initiating events correspond to 95 fire scenarios
- 95 fire scenarios retained for detailed analysis
  - 12 in Reactor Building
  - 42 in Turbine Building
  - 41 in Service Building

Fire Detailed Analysis

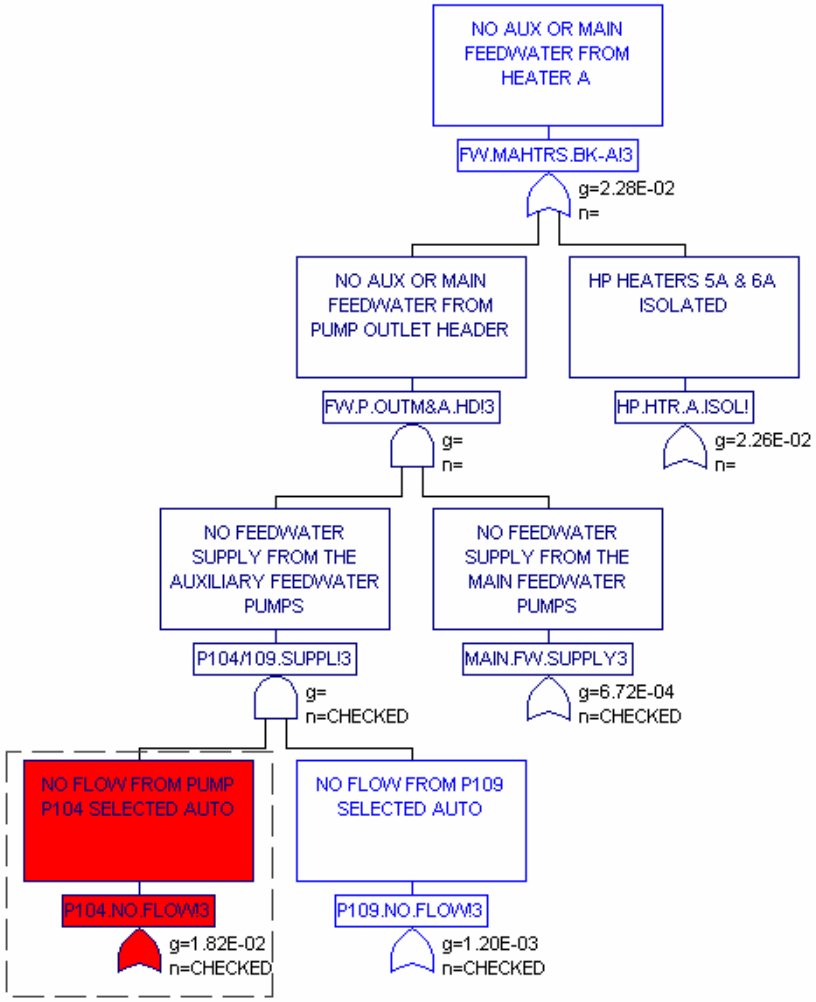
- **Develop event trees**
  - **Identify mitigating systems unavailable due to fire**
- **Create fault trees specific to the fire scenario to reflect partial systems failures**
- **Accident sequence quantification to estimate fire-induced SCDF**

Fire Event Tree Models

- **Termination of Level 1 accident sequences are classified as plant damage states (PDS)**
- **Originally, 11 different PDS were defined for internal events analysis**
  - **No fuel damage but economic consequences**
  - **Limited fuel damage with economic consequences**
  - **Widespread fuel damage**
  - **Severe core damage**
    - **Failure to shutdown**
    - **Loss of heat sinks**

Fire Fault Tree Models

- **Master fault tree for internal events contains all mitigating and support system fault tree models**
- **Modify existing internal events master fault tree to cater to the fire scenario**
- **Removing branches in the model to reflect failed devices and components**



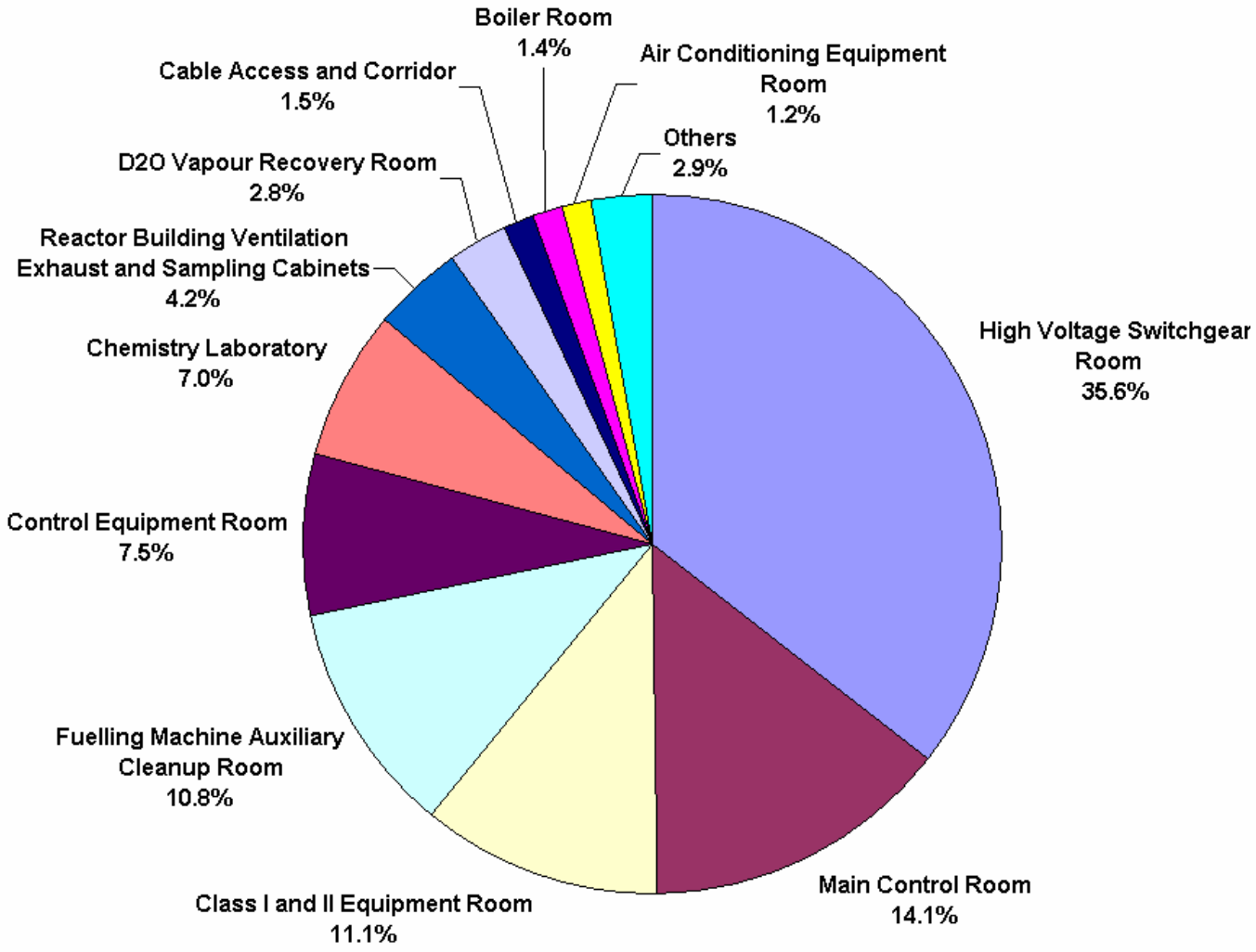
Accident Sequence Quantification

- Quantify severe core damage sequences
- Remove mutually exclusive events from cutsets
- Adjust human error probabilities (HEPs) for operator actions located in the fire vicinity
- Adjust HEPs for dependency using SPAR-H
- For recalculate dominant contributors using less conservative methodologies
  - Alpha method for common cause failures
  - THERP for HEPs
- Credit recovery factors

Level 1 – Internal Fire Results

Location	Fire-induced Severe Core Damage Frequency (events/year)
Reactor Building *with proposed design change	4.13E-06
Turbine Building	1.50E-05
Service Building	1.24E-05
Total	**3.15E-05**

Fire Contributors to SCDF



Level 1 – Internal Flood Events

- All possible sources of water were systematically reviewed including large tanks
- Qualitative screening
- Quantitative screening
- 21 flood scenarios retained for detailed analysis
  - Condenser Cooling Water
  - Raw Service Water
  - Only 2 open circuits in CANDU plants both of which are in Turbine Building

Flood Detailed Analysis

- **Develop event trees**
  - **Operator actions and mitigating systems to stop the flooding**
  - **Identify mitigating systems unavailable due to flood**
- **Use existing ASQ master fault tree for internal events**
- **Accident sequence quantification to estimate flood-induced SCDF**

Level 1 – Internal Flood Results

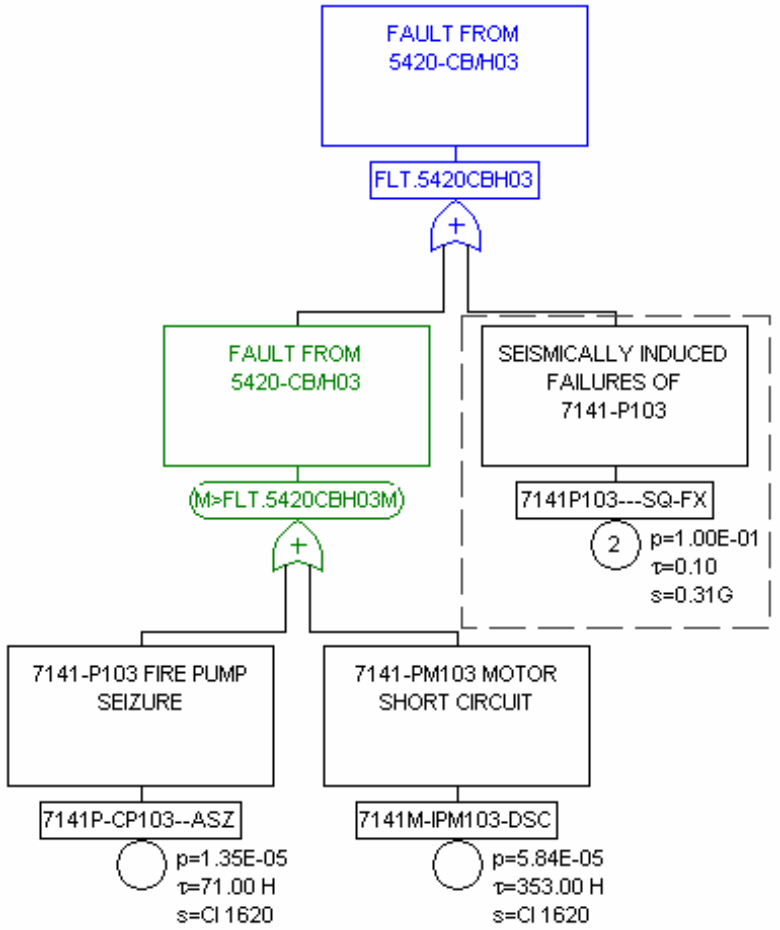
Type of Flood	Flood Induced SCDF (events/year)	Contribution to SCDF
RSW 12” Isolable Break	9.48E-07	79.9%
RSW 24” Isolable Break	1.60E-07	13.5%
RSW 24” Non-Isolable Break	2.56E-08	2.2%
CCW 60” Outlet Break	2.22E-08	1.9%
CCW 60” Inlet Break	1.87E-08	1.6%
RSW 12” Non-Isolable Break	9.20E-09	0.8%
CCW 60” Non-Isolable Break	3.18E-09	0.3%
Total (events/year)	**1.18E-06**	

PSA-Based Seismic Margin Assessment

- Measures the robustness of PLGS to withstand earthquakes of a given g-level
- Establish the Safe Shutdown Equipment List (1400 items)
- Seismic Walkdown
  - Screen out 1000 items from Safe Shutdown Equipment List (SSEL) using EPRI NP-6041-SL
  - Equipment and structures whose structural failure may impact nearby items that are on SSEL
- Fragility Analyses to determine seismic capacity of structures and components not screened out (400 items)

Seismic Fault Tree Models

- **ASQ Master fault tree for internal events contains all mitigating and support system fault tree models**
- **Modify existing ASQ Master fault tree by adding seismic failures (functional and structural failures)**
- **Modify the HRA values**



Seismic Margin Results

- Quantify using the min-max method
- PLGS HCLPF is 0.34g
- Limited by seismic capacity of dousing tank
  - Crack in the dousing dome leads to leaks of dousing inventory, which is necessary for the boiler makeup water system
  - Seismic capacity of backup heat sink is 0.31g
  - Loss of heat sinks lead in severe core damage

- **Results of Level 1 internal fire and flood events summed with Level 1 internal events at full power**

	Severe Core Damage Frequency (events/year)
Internal Events	1.66E-05
Internal Fire Events	3.15E-05
Internal Flood Events	1.18E-06
Total	4.93E-05

- **Results of Level 1 are the input to Level 2**

- **Thank you for your attention**
- **Questions?**