

Level I & Level 2 Internal Events PSA Accident Sequence Quantification

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Point Lepreau Generating Station



- **Commercial operation in 1983**
- **Proven to be an economic and environmentally sound source of electricity generation – provides 1/3 of power consumed in New Brunswick**
- **Station continues to perform well, but key reactor components are nearing the point in time in which they will need to be replaced.**
- **Refurbishment Plan: Currently in an 18-month outage**
 - **Life extension by 25 to 30 years**



PLGS PSA

- **Partnership between Atomic Energy of Canada Limited and New Brunswick Power**
 - NB Power provided most reliability models and access to site data.
 - Team effort
 - Level 1 ASQ through to Level 2 ASQ.
 - Currently final Summary Report
 - Both attend meetings with regulator



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 Events

- **Accident Sequence Quantification (ASQ) performed to evaluate the SCDF**
 - Initiating Events (IE) selected
 - Fault Trees (FT) created for mitigating systems and support systems
 - Detailed Event Trees (ET) created
 - Quantify sequences
 - Apply Recoveries



Level 1 Initiating Events

Frequency was derived based on:

- Statistical calculation based on site specific data and CANDU operating experience data
- Pipe failure rate calculations
- Fault tree analysis

82 Initiating Events were created.



Level 1 Fault Trees

Data

- Site specific data
- External generic data combined with site data using Bayesian combination
- Common Cause Failure (CCF) analysis using the Unified Partial Method
- Human Reliability Analysis (HRA) using ASEP

Master Fault Tree

- Over 600 tops
- Database of over 30 000 basic events



Level 1 Event Trees

67 were selected for ASQ as they directly challenged core integrity

Termination of Level 1 accident sequences are classified as plant damage states (PDS)

Eleven different PDS

- **Severe core damage**
- **Widespread fuel damage**
- **Limited fuel damage with economic consequences**
- **No fuel damage but economic consequences**



Recovery

Obtain final results that provides a realistic estimate of SCDF

- **Dependency between operator actions accounted for using SPAR-H**
- **Cutsets reviewed for conservatism**
 - **Recovery applied at cutset level to dominant contributors**
 - **Iterative process**
- **Examples:**
 - **Dominant CCF events recalculated using alpha CCF methodology**
 - **Dominant human actions recalculated using THERP**



Computer Codes

CAFTA 5.3

- Primary Interface for FT, ET and Cutsets

PRAQuant 4.0a

- Interface for sequence quantification

FORTE and FTREX

- Quantifiers

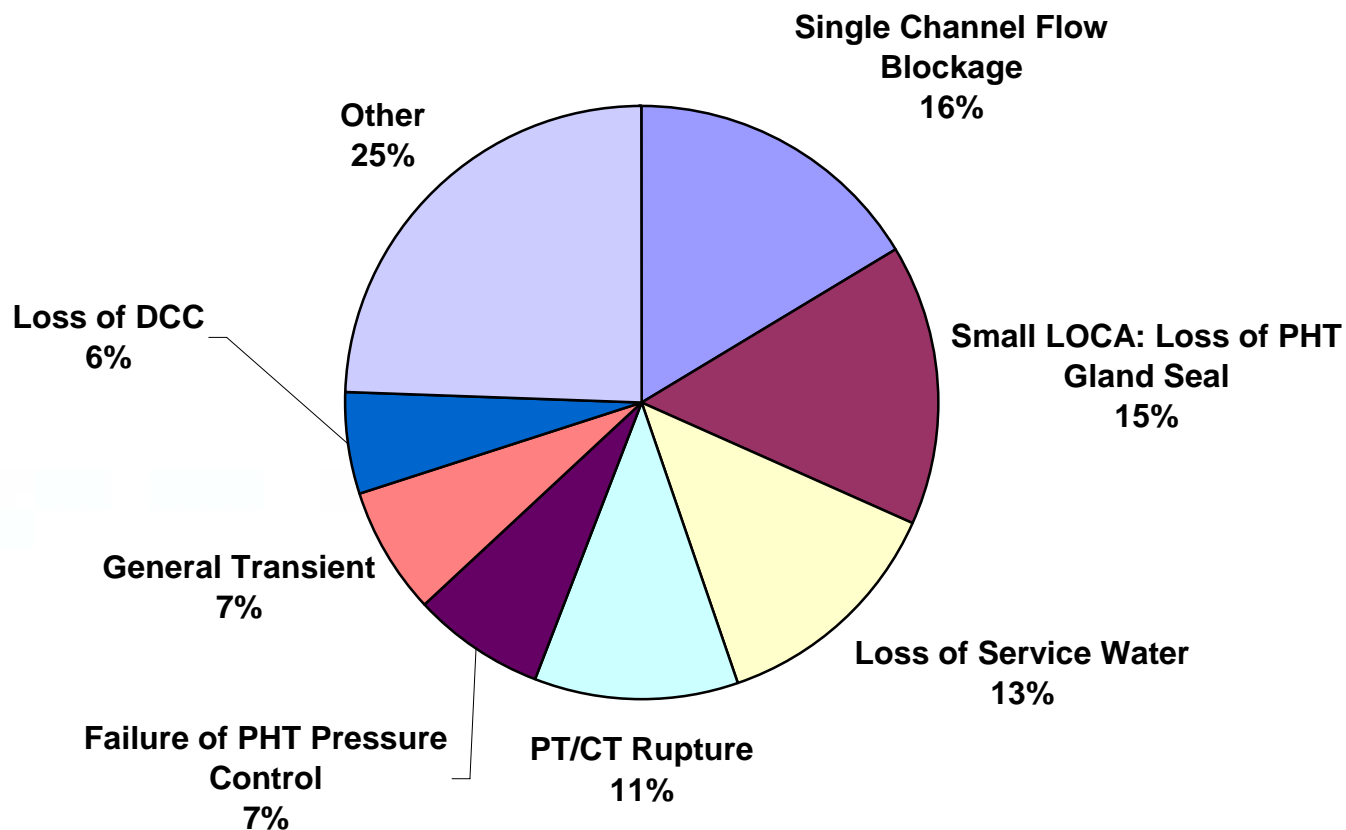
QRecover

- Application of Recovery Actions



Level 1 Results

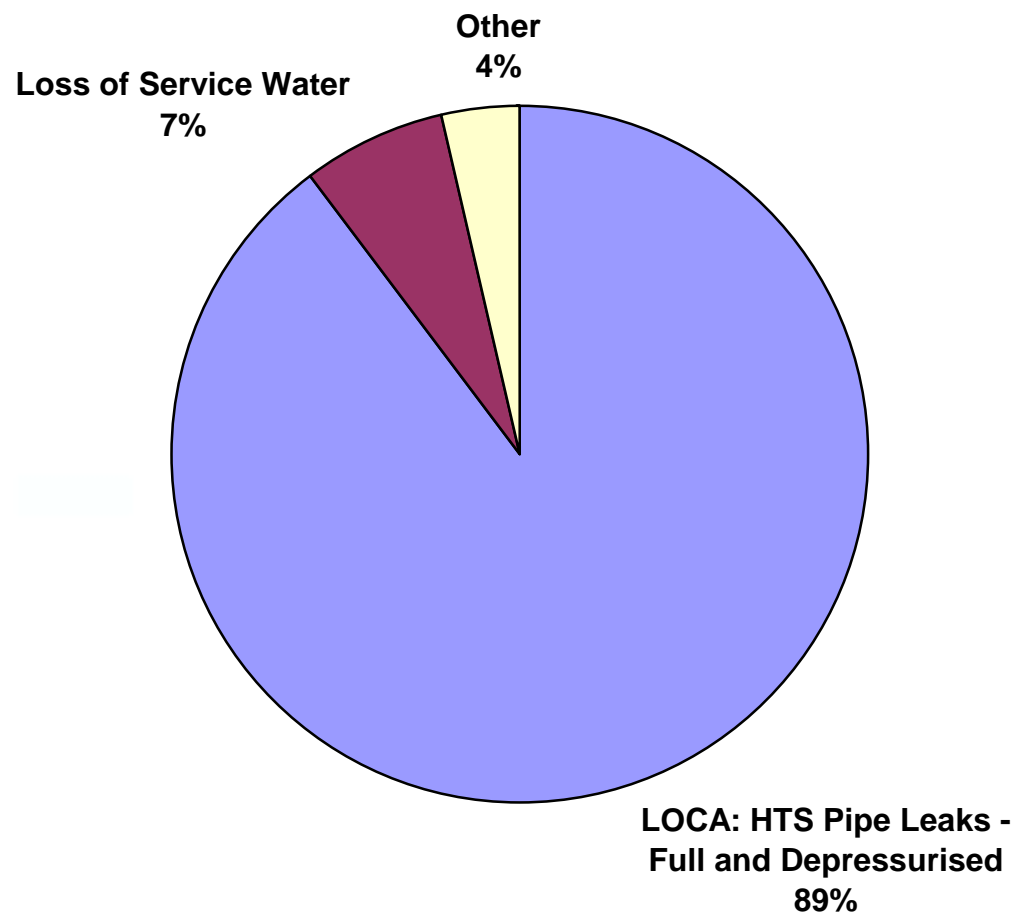
SCDF Full Power Operation = $1.66E-05$ events/yr





Level 1 Results

SCDF Shutdown State = 9.28E-06 events/yr





Level 2 - Internal Events

- **Dominant SCD sequences from Level 1 Internal Events progress to Level 2 analysis**
- **Sequences are grouped into 5 representative SCD accidents for severe accident progression:**
 - **Full Power Sequences**
 - In-core LOCA
 - Small LOCA
 - Station Blackout
 - Containment Bypass
 - **Shutdown State**
 - **Containment Pressure Capacity Determined**



Severe Accident Progression

- **MAAP4-CANDU Version 4.0.5A+ analyses performed to estimate:**
 - Challenges to containment
 - Accident timing and progression
 - Hydrogen and Carbon Monoxide concentrations
 - Fission products transport and releases
 - Effectiveness of the operator in mitigating severe accident consequences



- **Results of MAAP analyses are the basis for containment event trees (CETs)**
- **To delay or stop core damage progression, the main functions of the CETs are:**
 - Isolate containment
 - Control containment pressure
 - Control hydrogen/carbon monoxide
- **Termination of Level 2 accident sequences are classified as one of the external plant release categories (EPRC)**



Level 2 Inputs

187 Level 1 sequences chosen for analysis in Level 2

- Represent top 99.8% SCDF Sequences
- Containment Bypass events
- Level 2 is directly Linked with Level 1

Grouped for Level 2

- Similar Plant Configuration
- Status of Mitigating Systems
- Impact on Containment System availability
- Containment status



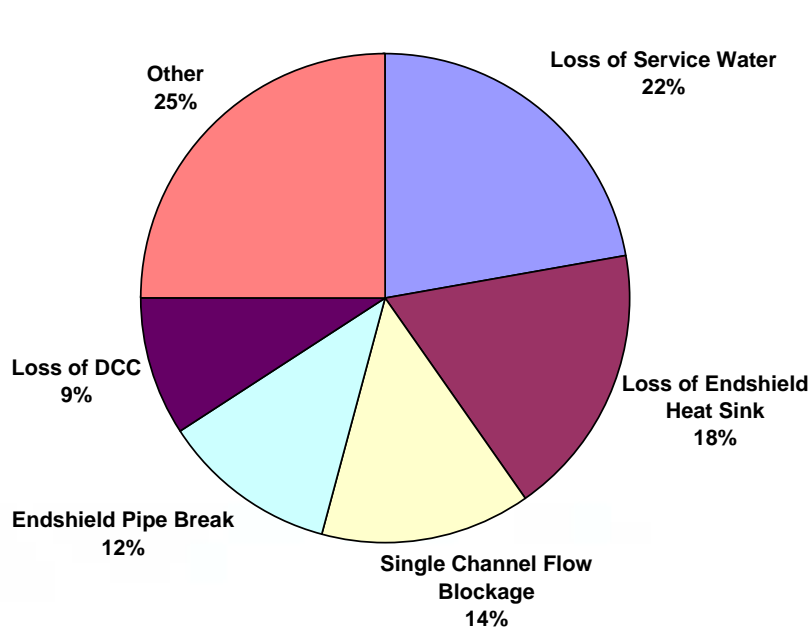
Calandria Vault Makeup and Emergency Venting System

- The new seismically robust system will provide make-up to the calandria vault before calandria vault failure
- Last resort to prevent calandria vessel failure and prevent Molten Core Concrete Interaction and therefore reduce H₂ production during severe accidents
- Used in conjunction with filtered emergency venting system which controls the containment pressure by discharging steam and preventing the airlock penetration failure

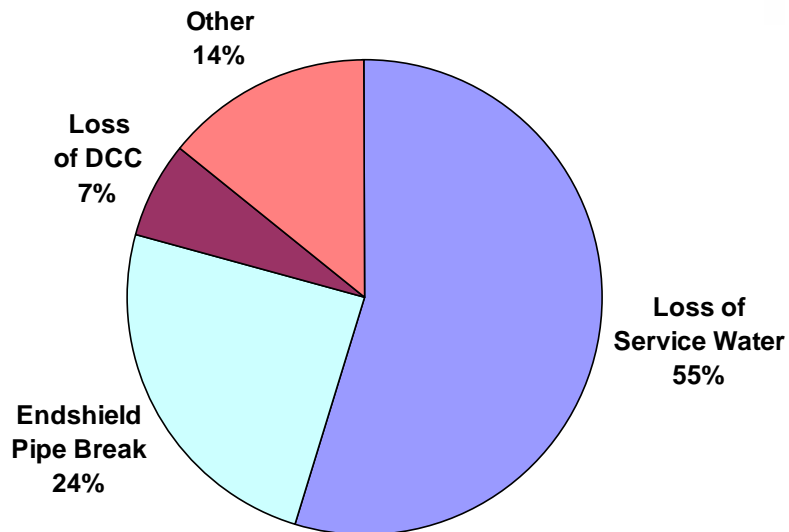


Level 2 Results

LRF Full Power Operation = $1.00\text{E}-07$ events/year



Early Releases

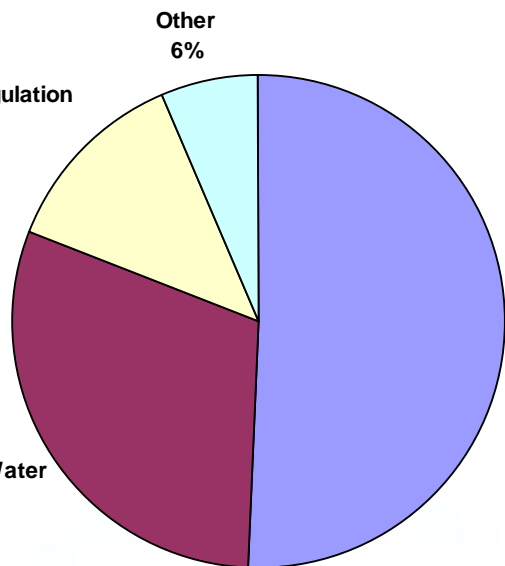


Late Releases

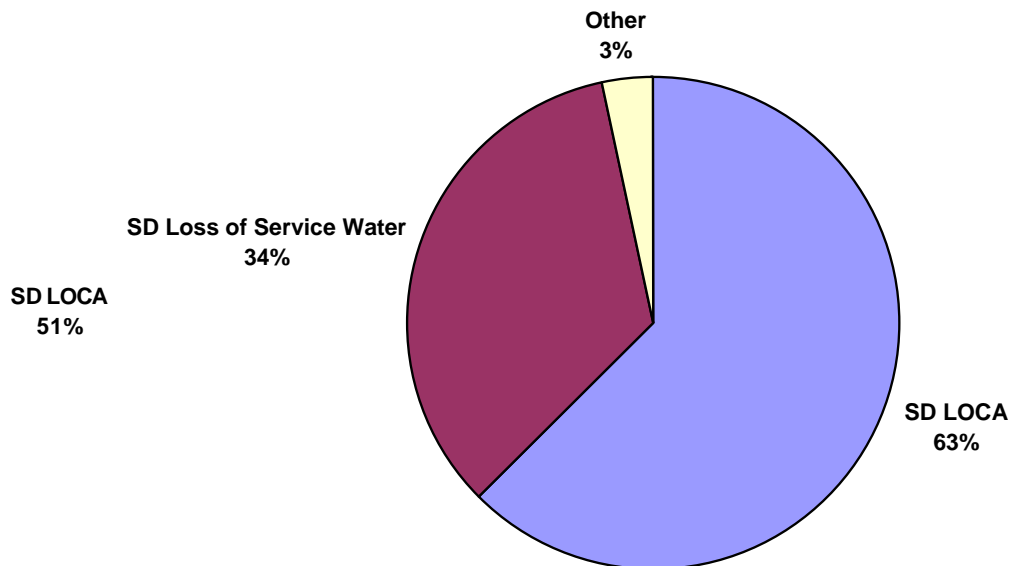


Level 2 Results

LRF Shutdown State = $2.64E-07$ events/year



Early Releases



Late Releases



Internal Events Results Summary

Severe Core Damage Frequency

Full Power Operation = $1.66\text{E-}05$ events/year

Shutdown State = $9.28\text{E-}06$ events/year

Large Release Frequency

Full Power Operation = $1.00\text{E-}07$ events/year

Shutdown State = $2.64\text{E-}07$ events/year

