Modeling FLEX in Surry Power Station Internal Events and Flooding PRA

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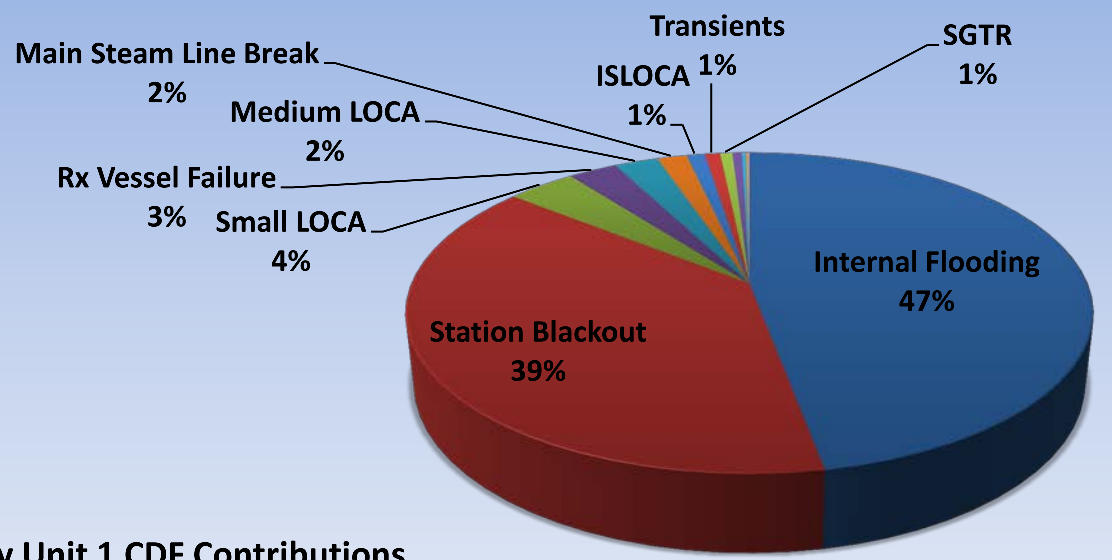
- 2017 PSA Paper "Implementation of FLEX Strategies in Surry PRA" by Aram Hakobyan, Craig Nierode

Overview

- Purpose - Discuss the benefit of crediting FLEX in the Surry Power Station internal events and flooding PRA models
- Discussion points
  - Surry Features including key plant modification
  - Internal Flooding Scenario
  - FLEX Modeling – Flooding
  - FLEX Modeling – SBO
  - Key Assumptions
  - Operator Actions
  - Results/Data Sensitivities

Surry Power Station

Surry Risk Profile
(before FLEX implementation)



Surry Unit 1 CDF Contributions
CDF = 1.0E-05/yr

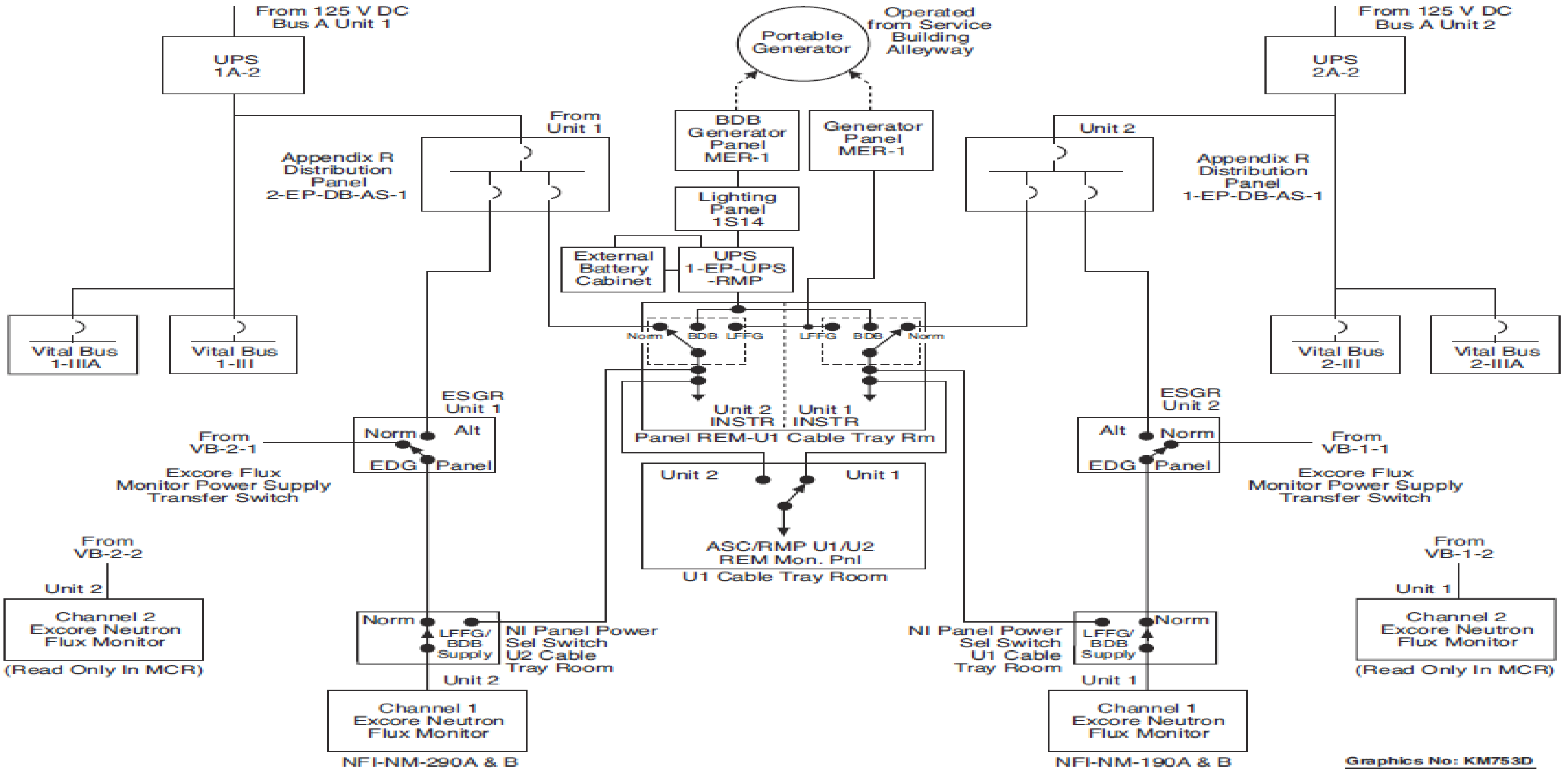
Internal Flooding Scenario

- Turbine Building (TB) Flooding
  - Propagates to emergency switchgear room (ESGR)
  - Causes complete loss of AC and DC power - T(0)
  - Turbine-Driven Auxiliary Feedwater (TDAFW) pump is credited (starts and continues to run)
  - Instrumentation for SG level control is not available (needs to be restored prior to SG overfill in approximately 1.5 hours)

ESGR Dike

Key Plant Modification

- FLEX plant modification installed UPS on Appendix R Remote Monitoring Panel (RMP)
  - UPS provides 12 hours power to RMP after loss of power and ability to install portable 120V power for continued operation.
  - RMP provides both units key instrumentation (steam generator level/pressure, RCS temperature, pressurizer pressure, Gammametrics)



Remote Monitoring Panel

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Surry FLEX Equipment

- BDB High Capacity diesel-driven pumps (2)
- BDB AFW pumps (3)
- BDB RCS Injection pumps (3)
- 120/240 VAC generators (3)
- 480 VAC generators (2)
- Other supporting equipment (e.g. hauling equipment)

Note: Equipment Stored in a protected structure on site

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Surry Plant Features

- New low-leakage N-9000 Reactor Coolant Pump (RCP) seals
  - No significant RCP seal leakage is expected upon loss of seal cooling
  - RCS injection is not required for successful mitigation of an ELAP event
  - Assumption is supported by MAAP analysis
    - After 24 hours, there is plenty of water inventory in the RCS

Surry Plant Features (cont.)

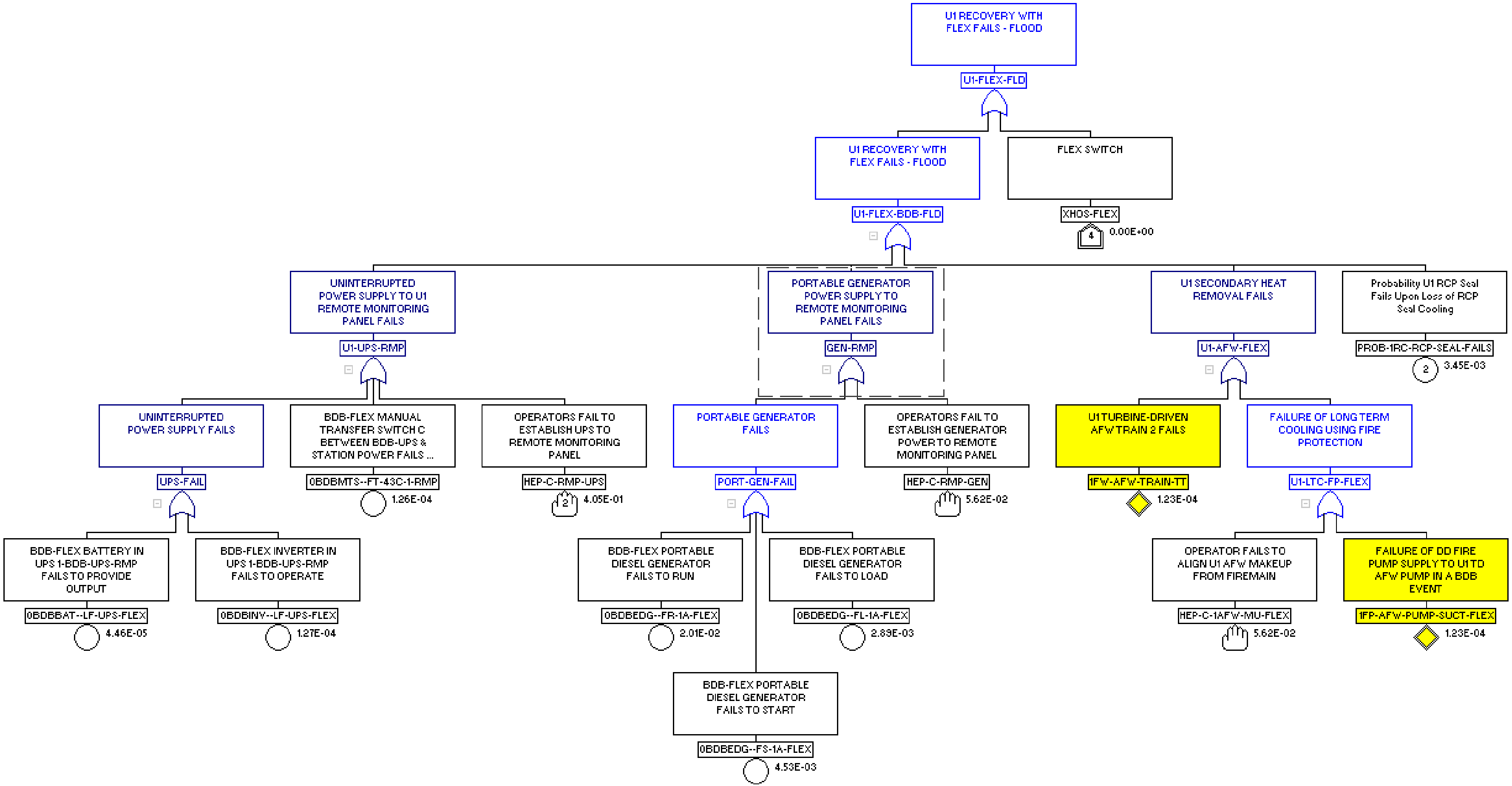
- Remote Monitoring Panel with uninterrupted power supply (UPS) system
  - UPS external battery lasts 12 hours
  - Power supply for instrumentation
- Diesel-driven fire pump
  - Provides water supply to TDAFW pump from the FP tanks after depletion of emergency condensate storage tank (ECST)

FLEX Implementation (Internal Flooding)

- Operators perform the following steps
  - Declare ELAP on loss of AC and DC power after ESGR is flooded, per ECA 0.0 – “Loss of All AC Power”
  - Relocate from the Main Control Room to the Remote Monitoring Panel (RMP) per FSG 7 “Loss of Vital Instrument or Control Power”
  - Start powering the RMP and vital instrumentation from the UPS system by turning the selector switch to “BDB” position
  - Control TDAFWP locally to ensure no Steam Generator Overfill
  - Initiate cooldown per ECA 0-0

FLEX Implementation (Internal Flooding)

- The UPS system is designed to provide uninterrupted power to the RMP for at least 12 hours
- Meanwhile, a BDB portable generator is brought from the on-site storage facility and connected to the existing electrical connections on the RMP



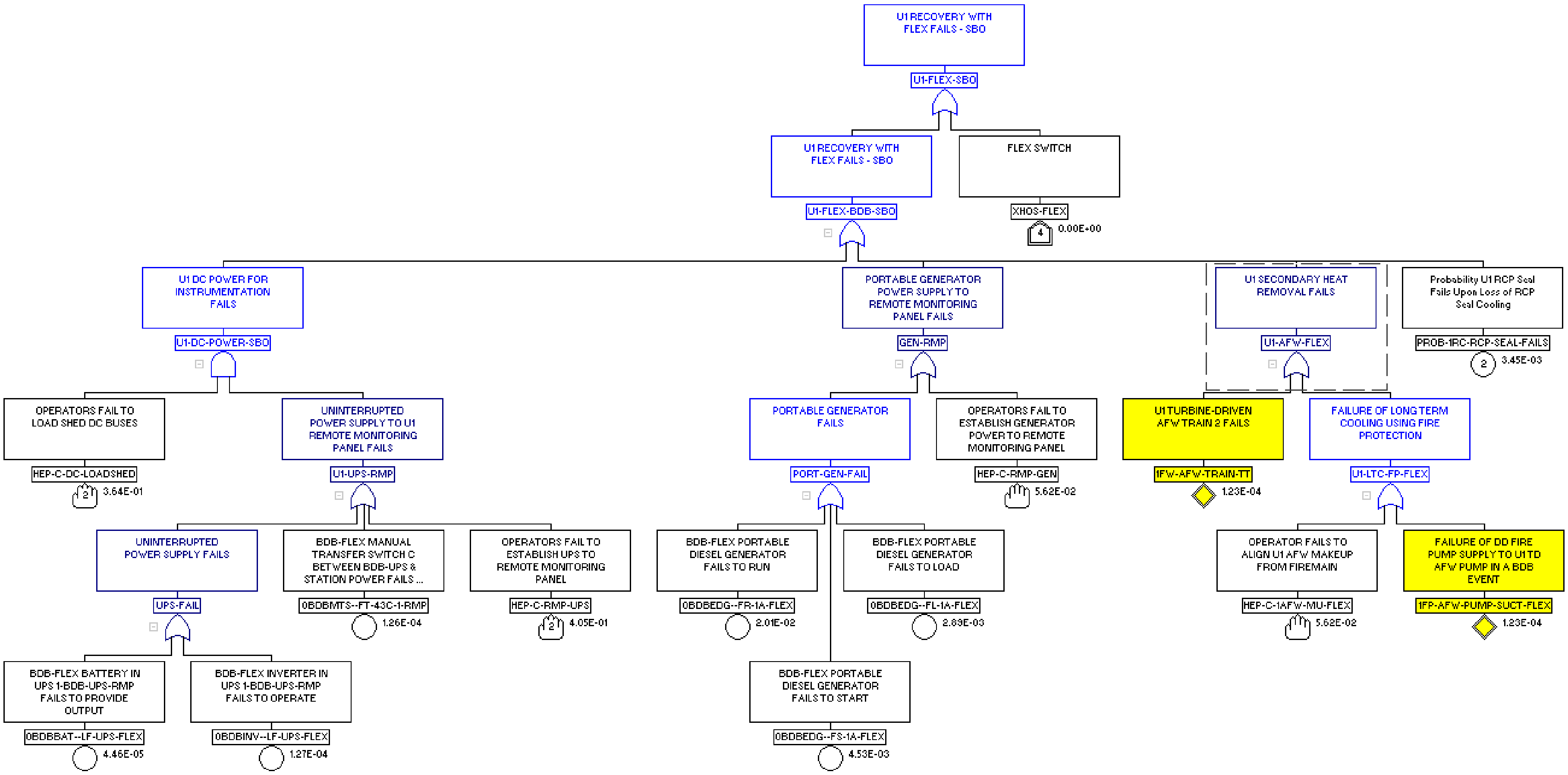
FLEX Internal Flooding

FLEX Implementation (Station Blackout)

- Operators perform the following steps
  - Determine whether power can be restored within 45 minutes
  - Declare ELAP if power cannot be restored per ECA 0-0
  - Load shed DC buses to preserve the charge on the DC batteries for vital instrumentation per FSG-4
    - DC batteries are estimated to last 14 hours with successful load shed

FLEX Implementation (Station Blackout)

- Bring in a BDB portable generator from the on-site storage facility and connect it to the existing electrical connections
- Relocate to RMP after batteries are depleted if DC load shed fails
- AFW flow rate is locally throttled to prevent SG overfill



FLEX – Station Blackout

Analysis Assumptions

- Power restoration is not credited in the Internal Flooding scenario
- After battery depletion and loss of SG level control, SGs are overfilled and TDAFW pumps fails
- If DC bus load shed fails in the SBO scenario, there is not enough time to bring in and connect the portable generator before battery depletion, and relocation to RMP becomes necessary
- DC power is unavailable in the Flooding scenario with failed ESGR

Analysis Assumptions (cont.)

- No test and maintenance term is modeled for the portable generator because there are other generators that can be used to power vital instrumentation
- If TDAFW pump is unavailable or fails, it is assumed that mitigation is unsuccessful and core damage occurs
- If the RCP seals fail catastrophically (low probability event), then FLEX mitigation strategy is unsuccessful

Analysis Assumptions (cont.)

- No Phase III FLEX equipment is credited
- The PRA model was adjusted to account for the slight detrimental impact of the FLEX procedures.
- RCS makeup with a portable FLEX pump is not modeled
- Failure rate data for the BDB portable generator was assumed to be the same as that of Emergency Diesel Generator
  - Additional portable generators are available but not modeled if failure occurs
  - Sensitivity study performed to determine the impact of this assumption

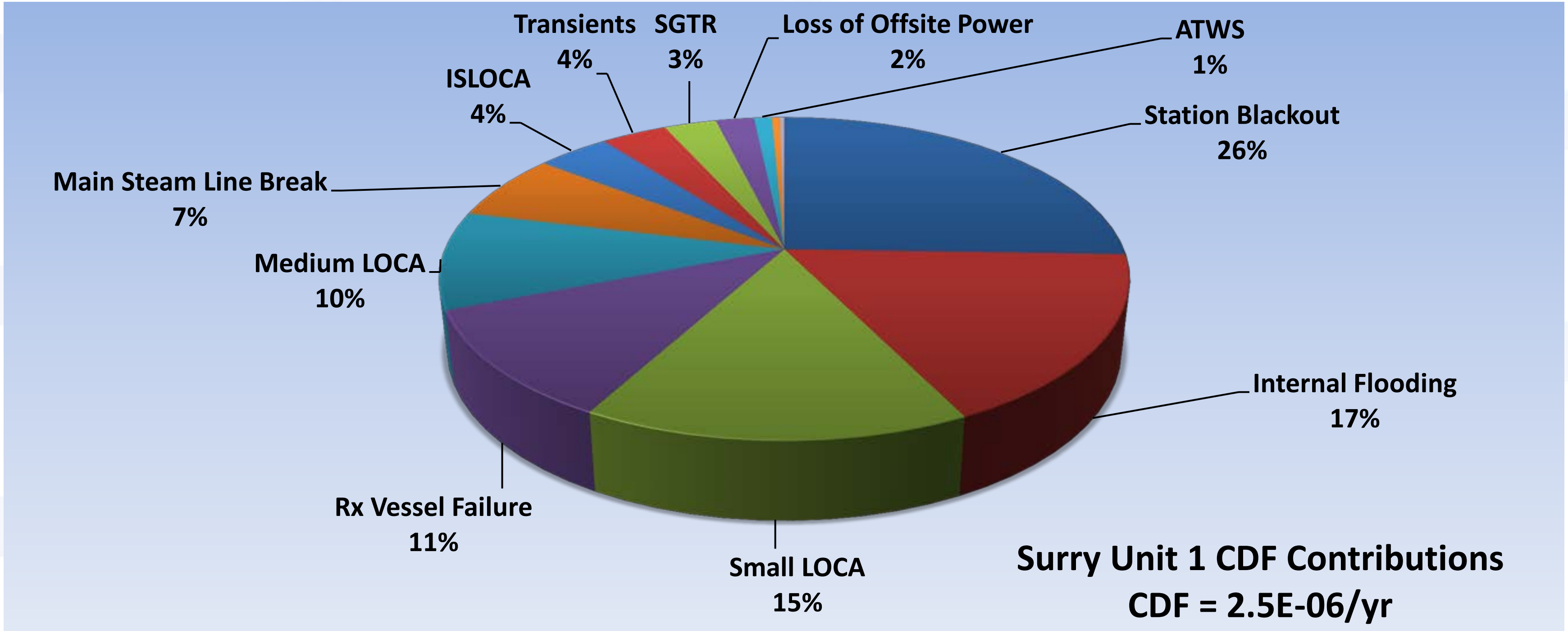
Operator Actions Modeled

- Throttle AFW Flow
  - For both Flooding and SBO events
  - Failure results in SG overfill and loss of TDAFW pump leading to core damage
- Deep DC Load Shed
  - Only for SBO event
  - Failure results in early battery depletion and requires relocation to RMP
- Establish Remote Monitoring Panel
  - For both Flooding and SBO events
  - Failure results in core damage

Operator Actions Modeled (cont.)

- Establish Portable Generator Power to RMP or other 120/480 electrical connections
  - For both Flooding and SBO
  - Failure results in loss of long-term instrumentation leading to core damage
- Align AFW Suction to Fire Water
  - For both Flooding and SBO
  - Failure results in long-term heat removal leading to core damage

Results



Transients
4%
SGTR
3%
Loss of Offsite Power
2%
ATWS
1%
ISLOCA
4%
Station Blackout
26%
Main Steam Line Break
7%
Medium LOCA
10%
Internal Flooding
17%
Rx Vessel Failure
11%
Small LOCA
15%
Surry Unit 1 CDF Contributions
CDF = 2.5E-06/yr

Results (cont.)

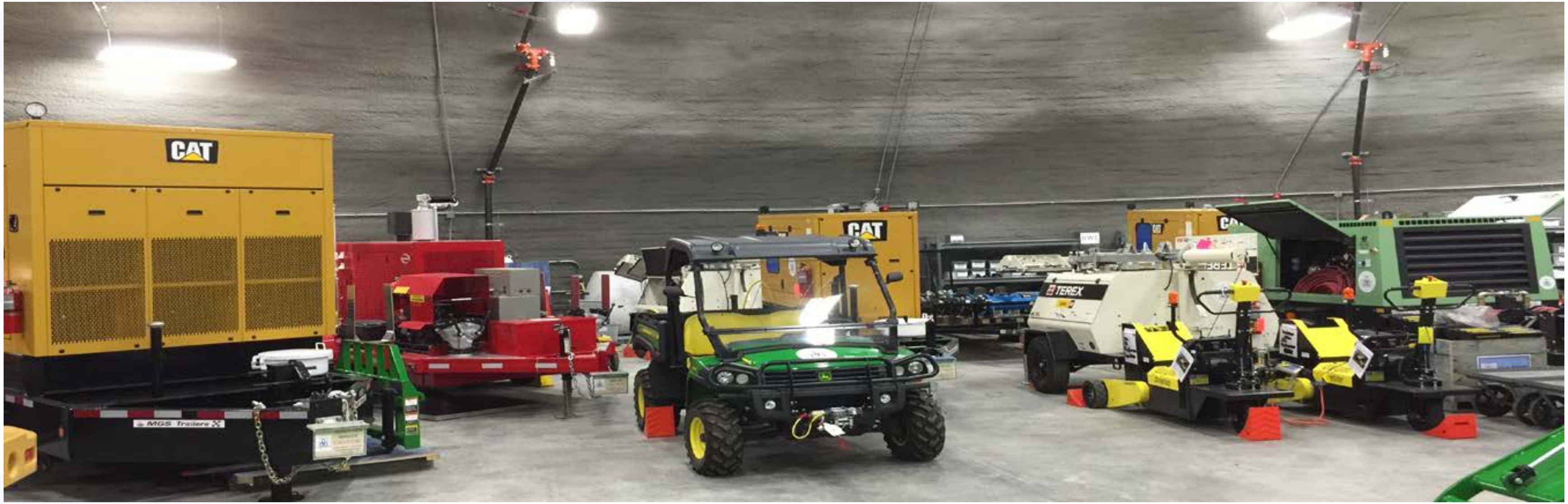
- CDF reduced by 75%
  - From 1.0E-05/year to 2.5E-06/year
- Combined contribution to CDF from SBO and Flooding scenarios dropped from 86% to 43%
- Significant improvement on MSPI margins
- New significant contributors emerged
  - SLOCA
  - Reactor Vessel Failure
  - MLOCA

Data Sensitivity

- Model two portable generators each capable of providing enough power supply for instrumentation
- EDG failure rate increased by a factor of 5 for every failure mode
- CCF modeled for every failure mode assuming non-staggered testing
- Results show minor CDF reduction

Conclusion

- Implementation of FLEX strategies in Surry PRA provided significant risk benefit.
- The main reason for this benefit was that Surry PRA was dominated by TB flooding propagating into ESGR, and Station Blackout scenarios
  - Final CDF contributions from both scenarios dropped significantly
- The risk reduction was achieved without any credit for FLEX AFW or RCS pumps
- The use of EDG failure rates for portable generators is appropriate until enough test data have been obtained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TEREX