U.S. EPR Pre-Application Review Meeting: Probabilistic Risk Assessment (PRA) Preliminary Results for Level 1

AREVA NP Inc. and the NRC
May 9, 2007

Introduction

Ronda Daflucas
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Agenda

- Introduction and Meeting Objectives (R. Daflucas)
- PRA Results Overview (R. Turcotte)
- Preliminary Level 1 At-Power, Internal Events Results (V. Dimitrijevic)
- Summary and Next Steps (R. Daflucas)

Meeting Objectives

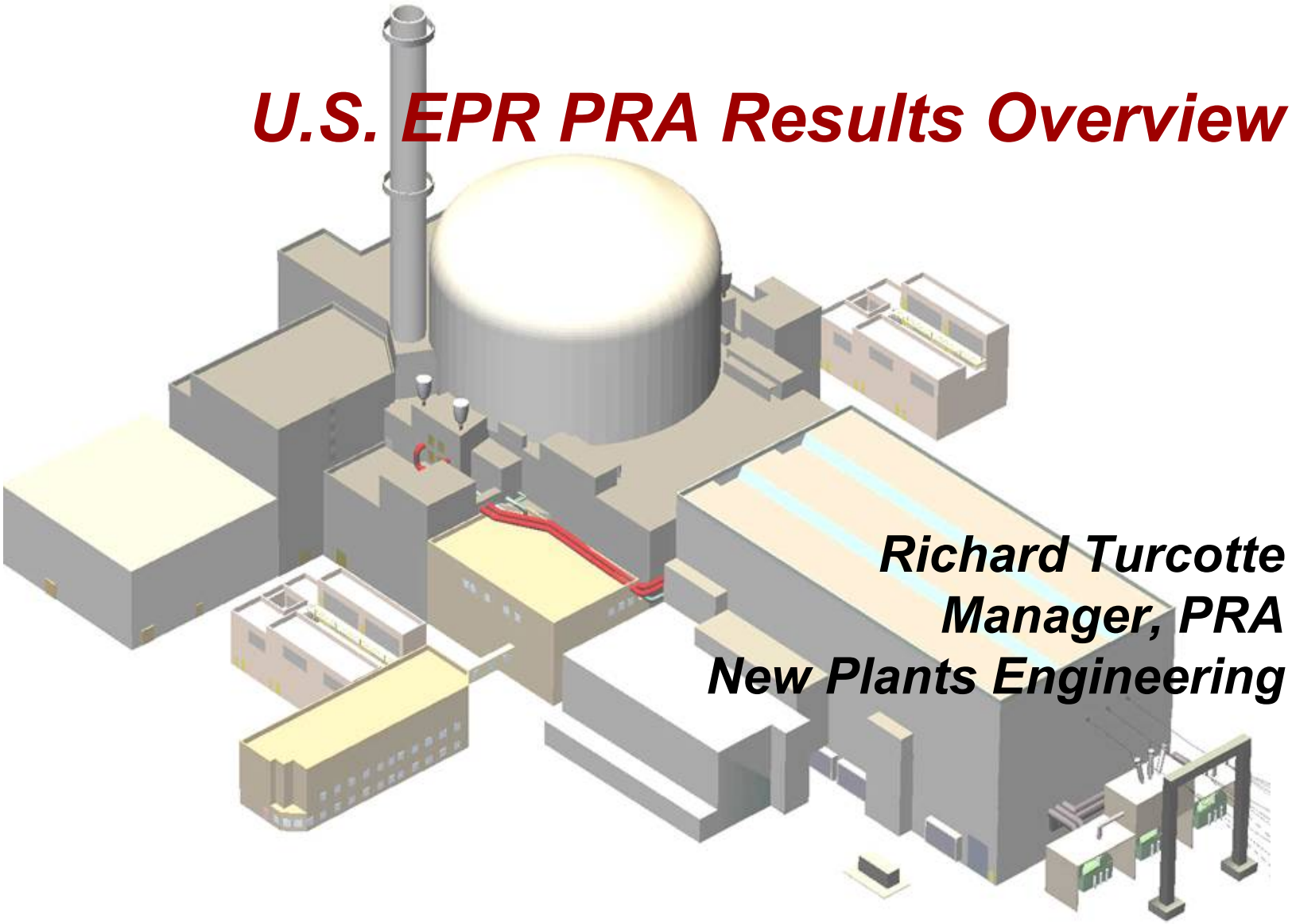
> **Discuss preliminary Level 1 at-power PRA results and insights for U.S. EPR**

> **Obtain timely NRC feedback and interactions to support informed development of the DCD**

Background

- NRC meeting on October 24, 2006 provided an overview of the PRA methods and approach (ML063070257)
  - Described the PRA methods and preliminary results
    - Level 1 at power and shutdown
    - Digital I&C
    - Fire, flood, seismic
    - Level 2 and 3
- Submitted the PRA Methods Report to NRC on December 15, 2006 (ML063540120)

U.S. EPR PRA Results Overview



Richard Turcotte
Manager, PRA
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Overview of Topics

- U.S. EPR probabilistic design goals
- U.S. EPR PRA objectives, scope, quality and technical adequacy
- Success criteria/tools
- U.S. EPR design features contributing to low risk
- Preliminary Level 1 results (at-power, internal events)
  - Scope of initiating events and frequencies
  - Systems modeled
  - Human actions modeled (post-initiator)
  - Key PRA assumptions
  - CDF results and contributors
  - Importance rankings
  - Uncertainty
  - Sensitivity
- Insights from preliminary Level 1 analysis
- Conclusions

U.S. EPR Probabilistic Design Goals

- Core Damage Frequency (CDF) <1E-5 per year
- Large Release Frequency (LRF) <1E-6 per year
- Including internal and external events (seismic and sabotage excluded) for all operating modes

CDF and LRF goals are consistent with NRC safety goals (SECY-90-016)

PRA Objectives

- Apply Reg. Guide 1.200/ASME PRA Standard
- Use bounding/realistic-type assumptions where detailed design information is not available for design certification
- Follow developments of other industry consensus standards
- Use of good practices

Objective is to demonstrate robustness of U.S. EPR design features and show that U.S. EPR design goals are met with margin

PRA Scope

- Level 1 – Core Damage Frequency
- Level 2 – Large Release Frequency
- Level 3 – Offsite Dose Consequence
- Scope of initiating events for design certification
  - Internal events (at-power and low power/shutdown)
  - External events
    - Internal flood and internal fire events (at-power and limited scope at shutdown)
    - Seismic-PRA-based margins (at power)
    - Other externals – high level, qualitative

PRA Quality and Technical Adequacy

> **Quality**
- Qualified personnel
- Procedures to control documentation development and revision, independent review/checking of calculations and information used in the PRA
- Procedures for documentation and maintenance of records
- Corrective action process

> **Technical adequacy**
- Meet NRC guidelines on PRA technical adequacy
- Participate in technical review meeting(s) and technical exchange with European counterparts
- Formal peer review to be conducted as part of detailed design

PRA developed in conformance with NRC guidance

Success Criteria

- Postulated events and plant responses are analyzed to determine whether or not the sequence leads to core damage
- Core damage defined as:
  - Uncovery and heat up of the reactor core to the point at which prolonged oxidation and severe fuel damage involving a large fraction of the core is anticipated
- Acceptance criteria used to indicate no core damage
  - For transients and accidents, PCT<2200°F
  - For ATWS overpressure events, P<130% design pressure
  - For low pressure shutdown events, fuel is covered (conservative)
- Achieve stable state within 24 hours

Success Criteria Tools

> **Analysis is conducted with:**

- **MAAP v4.07**
  - Lumped model of primary and secondary
  - Typically used in Level 2 analysis
  - Used for Level 1 analysis with understanding of limitations
  - Convenient, fast-running

- **S-RELAP5**
  - Developed from RELAP5/MOD2
  - Two-fluid two-phase model
  - Detailed nodalization of system
  - Approved for typical PWR FSAR safety analysis (LOCA, non-LOCA)
  - Can be used for realistic analysis, with realistic input parameters

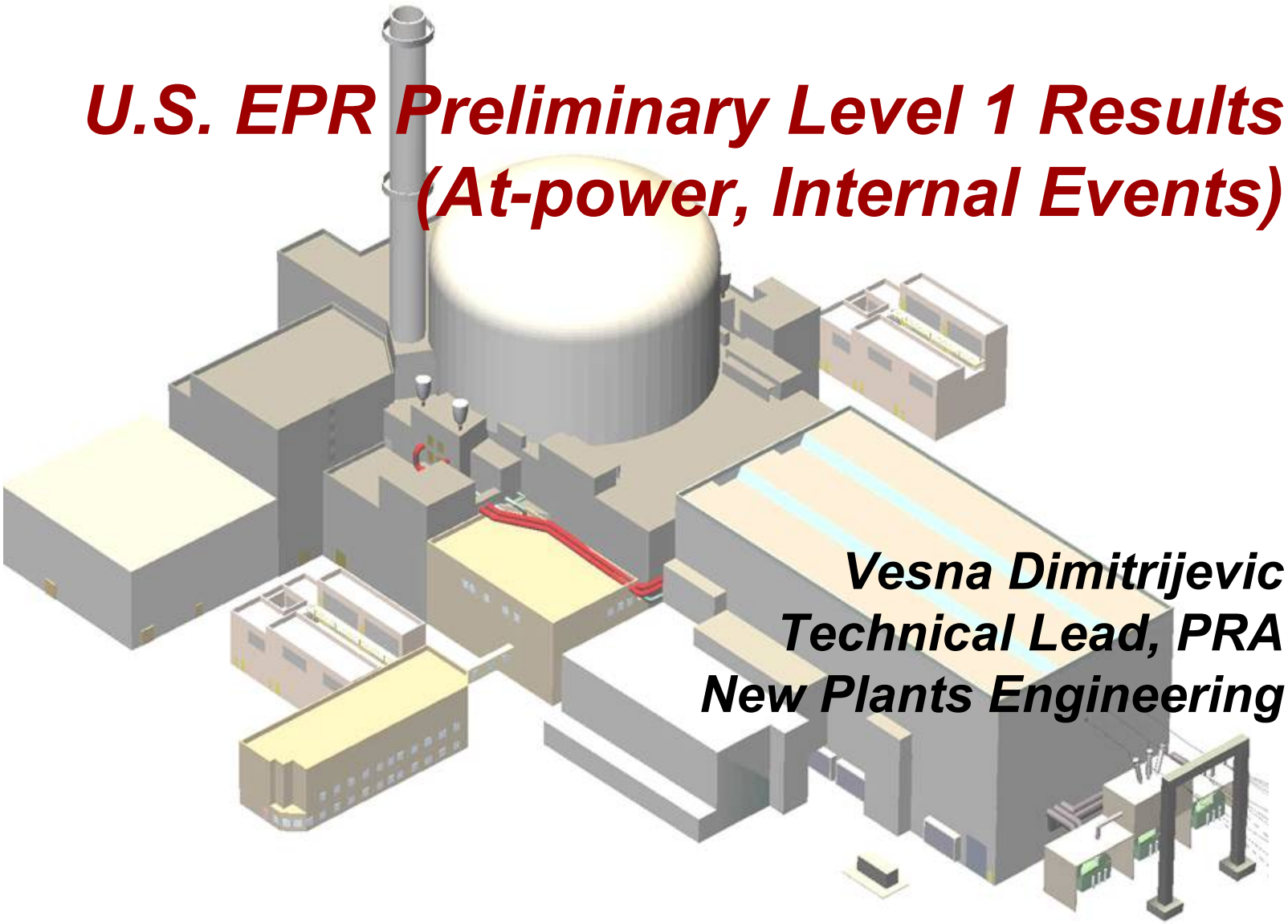
Success Criteria

- General guidance for MAAP-based success criteria:
  - Success
    - PCT $\leq$1400°F
  - Failure
    - PCT $\geq$1800°F
  - Further examination as required
    - 1400°F<PCT<1800°F

U.S. EPR Design Features Contributing to Low Risk

- Increased redundancy and separation
  (4 independent safety trains)
- Separate power divisions for each safety train
- 4 EDGs and 2 SBO DGs
- State-of-the-art digital I&C
- Stand Still Seal System for RCPs
- In-containment refueling water storage tank
- Containment spray not needed for accident mitigation

U.S. EPR Preliminary Level 1 Results (At-power, Internal Events)



Vesna Dimitrijevic
Technical Lead, PRA
New Plants Engineering

Scope of Initiating Events and Frequencies

INITIATING EVENTS AND FREQUENCY VALUES FOR U.S. EPR			
IE	IE Description	Freq. [1/yr]	Basis
REACTOR TRIP / TURBINE TRIP			
GT	General Transient (Includes Turbine Trip and Reactor Trip)	7.5E-01	NUREG/CR-5750
LOSS OF BALANCE OF PLANT (MAIN FEEDWATER / CONDENSER)			
LBOP	Loss of Balance of Plant (Closed Cooling Water or Service Water)	5.1E-02	FT Analysis
LOMFW	Total Loss of Main Feedwater	9.6E-02	NUREG/CR-5750
LOC	Loss of Main Condenser (Includes MSIV Closure)	8.1E-02	NUREG/CR-5750
LOOP AND ELECTRICAL			
LOOP	Loss of Offsite Power	2.3E-02	NUREG/CR-6890 (Modified)
31BDA	Loss of Electrical Division 1	3.5E-02	FT Analysis
LOSS OF COMPONENT COOLING			
LOCCW-ALL	Loss of CCWS - Total Loss of CCWS	2.4E-06	FT Analysis
LOCCW-CH1	Loss of CCWS - Common Header 1 Leakage (multi events)	2E-1 - 2E-5	FT Analysis
LOCCW14-CH12	Loss of CCWS - Trains 1 & 4 and Common Headers 1 & 2	2.2E-07	FT Analysis
LOSS OF COOLANT ACCIDENTS			
SLOCA	Small LOCA (0.6 to 3-inch Diameter)	7.0E-04	NUREG/CR-5750 (Modified)
MLOCA	Medium LOCA (3 to 6-inch Diameter)	4.0E-05	NUREG/CR-5750
LLOCA	Large LOCA (>6-inch Diameter)	5.0E-06	NUREG/CR-5750

Scope of Initiating Events and Frequencies (Continued)

INITIATING EVENTS AND FREQUENCY VALUES FOR U.S. EPR (Continued)			
IE	IE Description	Freq. [1/yr]	Basis
STEAM LINE BREAKS			
SLBI	Large Steam Line Break Inside Containment	1.0E-03	NUREG/CR-5750
SLBO	Large Steam Line Break Outside of Containment	2.1E-03	NUREG/CR-5750 (Modified)
MSSV	Spurious Opening of Steam Safety Valve	1.0E-03	NUREG/CR-5750
SGTR			
SGTR	Steam Generator Tube Rupture	3.5E-03	NUREG/CR-5750
IND SGTR	Induced SGTR (SLB)	1.2E-06	Calculation
ATWS			
ATWS	Anticipated Transient Without Scram	4.2E-08	FT Analysis
LOCA OUTSIDE CONTAINMENT			
ISL-CCW RCPTB	ISLOCA - CCW RCP Thermal Barrier	4.1E-10	FT Analysis
ISLOCA-CVCS	CVCS Pipe, HP Coolers, Reducing Station	4E-10 - 6E-12	FT Analysis
ISLOCA-SIS	Line Breaks (MHSI, LHSI, RHR)	2E-11 - 8E-12	FT Analysis

References:

NUREG/CR-5750 - Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995 11/06 Update (distribution mean)

NUREG/CR-6890 - Reevaluation of Station Blackout Risk at Nuclear Power Plants, Vol. 1, Analysis of Loss of Offsite Power Events 1986-2004

Frontline Systems Modeled

Frontline System	KKS ID
Extra Boration System (EBS)	JDH
Main Feedwater System (MFW)	LAB
Startup Shutdown System (SSS)	LAH, LAJ
Emergency Feedwater System (EFW)	LAR, LAS
Main Steam System (MS)	LB
Reactor Coolant Pump Seals (RCP Seals)	JEB
In-Containment Refueling Water Storage Tank (IRWST)	JNK
Chemical Volume Control System (CVCS)	KBA
Medium Head Safety Injection System (MHSI)	JND
Low Head Safety Injection System/Accumulators (LHSI/ACC)	JNG
Severe Accident Heat Removal System (SAHR)	JMQ
Pressurizer Relief System (PRS)	JEF
Demineralized Water Distribution System (DWS)	GHC

Support Systems Modeled

Support System	KKS ID
AC Electrical Distribution System	Various
DC Electrical Distribution System	Various
Emergency and SBO Diesel Generators (EDG, SBO DG)	XKA
Digital I&C (RPS and ESFAS)	Various
Safeguard Building Ventilation (HVAC)	SAC
Essential Service Water System, Ultimate Heat Sink (ESW/UHS)	PEB, PED
Component Cooling Water System (CCWS)	KAA, KAB
Safety Chilled Water System (SCWS)	QKA, QKC
Operational Chilled Water System (OCWS)	QNA, QNC
Closed Cooling Water System (CLCWS)	PG

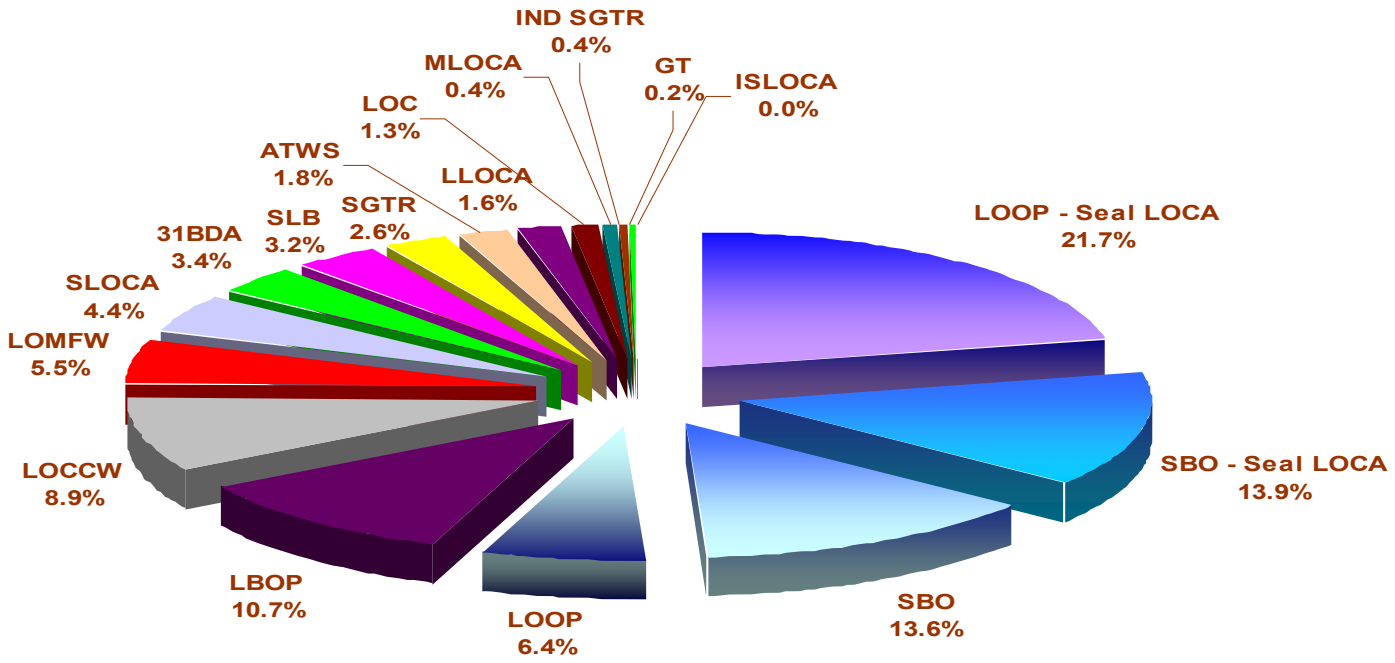
Scope of Human Actions Modeled (Post-Initiators)

Basic Event ID	Basic Event Description	HEP (Mean)
OPD-SBODG90M/FB40M	Dependency (MED) Between Operator Actions for Initiating F&B and Starting SBO DGs	1.4E-01
OPD-FBL90M/EFW6H	Dependency (LOW) Between Operator Actions for Aligning EFW Tanks (Make-Up) & Initiating F&B for Transient with Low Decay Heat	5.0E-02
OPD-RHR4H/SGTR1H	Dependency (MED) Between Operator Actions for Stabilizing SGTR and Initiating RHR	1.4E-01
OPD-RHR4H/SGTR4H	Dependency (LOW) Between Operator Actions for Isolating SG Blowdown Lines and Initiating RHR	5.0E-02
OPD-SAC4H/SAC1H	Dependency (LOW) Between Operator Actions for Starting HVAC Maintenance Trains and Recovering Room Cooling Locally	5.0E-02
OPD- RHR4H/ISLOCA	Dependency (LOW) Between Operator Actions for Isolating ISLOCA and Initiating RHR	1.4E-01
OPE-FB-30M, 40M, 90M, L90M	Operator Fails to Initiate Feed & Bleed for MLOCA, SLOCA, Tansient, LDH Transient	5.3E-02 - 2.8E-04
OPE-FCD-30M, 40M	Operator Fails to Initiate Fast Cooldown for MLOCA, SLOCA	5.3E-02, 1.3E-01
OPE-RHR-4H	Operator Fails to Initiate RHR Within 4 Hours	1.0E-03
OPF-DWS/FST-25M	Operator Fails to Start Emergency DWS Pump to Provide Make-Up to the FST	1.1E-02
OPF-RT-6M	Operator Fails to Trip the Reactor Manually	2.8E-02
OPF-EBS-30M	Operator Fails to Manually Actuate EBS (SLB & ATWS)	2.2E-02
OPF-EFW-6H	Operator Fails to Align EFWS Tanks to Operating Trains (or to Provide EFW Tanks Make-Up)	5.5E-05
OPF-RCP-10M, 30M	Operator Fails to Trip RCPs on Loss of Seal Injection or Loss of Bearing Cooling	6.0E-02, 4.0E-02
OPF-SAC-1H, 4H	Operator Fails to Start Maintenance HVAC Trains after failure of Normal SAC Safety Train or to Recover Room Cooling Locally	2.0E-04, 1.0E-03
OPF-SAHR/IRWST-4H	Operator Fails to Initiate IRWST Cooling with SAHR	4.0E-04
OPF-SBODG-90M, 90MLO	Operator Fails to Start the SBO Diesel Generators from MCR or Locally	4.0E-04, 4.4E-03
OPF-SGTR-1H, 4H	Operator Fails to Isolate SGTR and Initiate Cooldown or Isolate Blowdown Line for SGTR	2.0E-03, 1.1E-04

Key PRA Assumptions

- Failure of all batteries in LOOP is conservatively assumed to lead to core damage (limited instrumentation)
- For the large I&C CCF groups, beta factor is used
- Loss of safeguard building ventilation for longer than four hours is assumed to fail an entire electrical division
- Short-term electrical: For components expected to change their state shortly after an event, HVAC dependency is not considered
- Long-term electrical: Battery backup is not credited for valves that need power to stay in the desired position
- Complete independence is assumed between EDGs and SBO DGs
- Preventive maintenance is assumed at one week per division; engineering judgment used for corrective maintenance

Preliminary CDF Results



Level 1, At-Power, Internal Events

5.1E-07/year

Top Core Damage Cutsets/Sequences

Group No	Sequence No	Sequence Prob	Seq %	Culm Seq %	Initiating Event	Event 1	Event 2	Event 3
1	1	3.46E-08	6.8	6.8	IE LOOP Loss of Offsite Power	BTD01_BAT__ST_D-ALL		
						CCF of Batteries on Demand		
2	2-8, 26-28, 33, 34, 54, 55, 75, 87	8.8E-09 - 9.2E-10	13.0	19.7	IE LOOP Loss of Offsite Power	31BTD01_BATST	REC OSP 1HR	CCWS/ESWS PM3
						ELEC DC, 250V Battery 31BTD01, Fails on Demand	Failure to Recover Offsite Power Within 1 Hour	CCWS/ESWS Train 3 Pump Unavailable due to Preventive Maintenance
						Event 4	**Event 5**	
						OPE-FB-40M	OPD-FB40M/SBODG90M	
						Operator Fails to Initiate Feed & Bleed for SLOCA	Dependency (MED) Between Operator Actions for Initiating F&B and Starting SBO DGs	
3	9-16, 29-32, 44-47, 50-53, 65, 66, 68-73, 91-96	5.6E-09 - 8.2E-10	14.6	34.3	IE LBOP Loss of Balance of Plant	EFWS PM1	OPF-EFW-6H	OPD-FBL90M/EFW6H
						EFWS Train 1 Unavailable due to Preventive Maintenance	Operator Fails to Align EFWS Tanks to Operating Trains (or to Provide EFW Tanks Make-Up)	Dependency (LOW) Between Operator Actions for Aligning EFW Tanks (Make-Up) & Initiating F&B for Transient with Low Decay Heat
4	19, 22, 36	3.9E0-9 - 1.9E-09	1.8	36.1	IE SGTR Steam Generator Tube Rupture	LBA43AA101EFC	OPF-SGTR-1H	OPD-RHR4H/SGTR1H
						MSS, Train 4 MSRCV LBA43AA101, Fails to Close on Demand	Operator Fails to Isolate SGTR and Initiate Cooldown	Dependency (MED) Between Operator Actions for Stabilizing SGTR and Initiating RHR

Top Core Damage Cutsets/Sequences (Continued)

Group No	Sequence No	Sequence Prob	Seq %	Culm Seq %	Initiating Event	Event 1	Event 2	Event 3
5	20, 24, 35	3.9E-09 - 2.0E-09	1.8	37.9	IE LOMFW Total Loss of Main Feedwater	STUCK ROD		
						Stuck Control Rods		
6	21	3.46E-09	0.7	38.6	IE SLOCA (0.6 to 3-Inch Diameter)	JND10AP001EFR_D-ALL	OPE-FCD-40M	
						CCF of MHSI Pumps to Run	Operator Fails to Initiate Feed & Bleed for SLOCA	
7	23, 67	3.4E-09 - 1.2E-09	0.9	39.5	IE SLOCA (0.6 to 3-Inch Diameter)	LBA13AA001PFO D-ALL	OPE-FB-40M	
						CCF to Open Main Steam Relief Isolation Valves	Operator Fails to Initiate Feed & Bleed for SLOCA	
8	25	3.13E-09	0.6	40.1	IE SLOCA (0.6 to 3-Inch Diameter)	JNG13AA005CFO D-ALL		
						CCF to Open LHSI/MHSI Common Injection Check Valves		
9	40-43	1.74E-09	1.4	41.5	IE LOOP Loss of Offsite Power	JEB10AA020EFC	PROB SEAL LOCA	REC OSP 1HR
						RCP Seal, RCP1 Seal Nitrogen Venting Isolation MOV JEB10AA020, Fails to Close on Demand	Probability of Seal LOCA Occurring Given a Loss of Seal Cooling	Failure to Recover Offsite Power Within 1 Hour
						Event 4		
						XKA10_____DFR_D-ALL		
						CCF of EDGs to Run		

Top Core Damage Cutsets/Sequences (Continued)

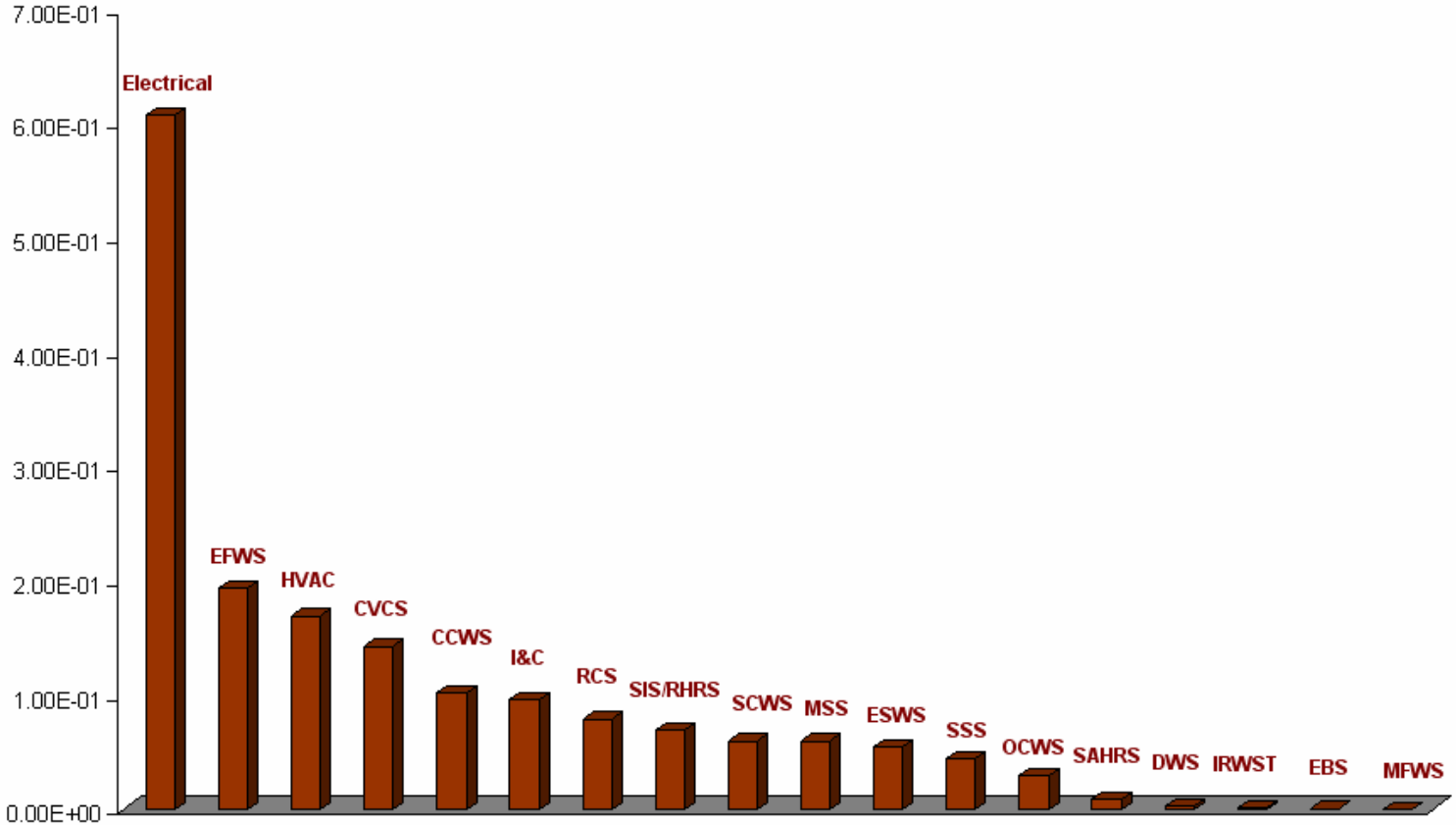
Group No	Sequence No	Sequence Prob	Seq %	Culm Seq %	Initiating Event	Event 1	Event 2	Event 3
10	48, 49, 56, 57,60, 61, 63, 64, 81-86	1.6E-09 - 9.5E-10	3.4	44.9	IE LOOP Loss of Offsite Power	33BTD01_BATST	REC OSP 1HR	XKA10____DFR_D-ALL
						ELEC DC, 250V Battery 33BTD01, Fails on Demand	Failure to Recover Offsite Power Within 1 Hour	CCF of EDGs to Run
11	76-79	9.8E-10	0.8	45.7	IE LOOP Loss of Offsite Power	REC OSP 2HR	XKA10____DFR_D-ALL	XKA50_____DRF
						Failure to Recover Offsite Power Within 2 Hours	CCF of EDGs to Run	ELEC AC, SBO Diesel Generator XKA50, Fails to Run
						Event 4		
						SBODG8 PM4		
						SBO-DG Train 4 Unavailable due to Preventive Maintenance		
12	88	8.40E-10	0.2	45.8	IE SLBI Steam Break Inside Containment	SG4 PRES CCF-ALL		
						CCF of SG4 pressure sensors		
13	89, 90	8.2E-10	0.3	46.1	IE LOOP Loss of Offsite Power	CCWS/ESWS PM3	XKA20_____DFR	LBA11AA191SFO_H-ALL
						CCWS/ESWS Train 3 Pump Unavailable due to Preventive Maintenance	ELEC DG, Emergency Diesel Generator XKA20, Fails to Run	CCF to Open Main Steam Safety Relief Valves

CDF Distributions and Percentages

CDF Percent	Number of Cutsets
50%	96
75%	730
90%	5,479
99%	32,054

Cut set frequencies are evenly distributed; PRA results show no outliers

System Rank Based on Fussel-Vesely Importance



Component Rank Based on Fussel-Vesely Importance (Representative Trains)

No.	System	Component ID	Component Description	FV Total	RIF Max
1	ELE EDG	XKA10_____ Total	EDG Train	**0.255**	2.6
2	ELE DC	31BTD01_BA Total	ELEC DC, 250V Battery 31BTD01 Fails on Demand	**0.169**	150.4
3	ELE DC	34BTD05_BA Total	ELEC DC, 220V-Battery 34BTD05 Fails on Demand	**0.068**	1.0
4	CCWS	KAA30AP001 Total	CCWS/ESWS Train	**0.060**	1.9
5	EFWS	LAS41AP001 Total	EFWS Train	**0.057**	2.5
6	ELE SBO	XKA50_____ Total	SBO-DG Train	**0.053**	2.6
7	SCWS	QKA40GH001 Total	SCWS, Chiller Unit Train	**0.033**	16.5
8	SIS	JND40AP001 Total	MHSI Train	**0.027**	1.5
9	ESWS	PEB30AP001 Total	ESWS, Motor Driven Pump Fails to Run	**0.012**	3.1
10	RCS	JEB10AA020 Total	RCP Seal, RCP Seal Nitrogen Venting Isolation MOV Fails to Close on Demand	**0.012**	4.5
11	MSS	LBA41AA191 Total	MSS, Main Steam Safety Relief Valve	**0.012**	8.7
12	SIS	JNG33AA005 Total	LHSI, CL First SIS Isolation Check Valve Fails to Open on Demand	**0.011**	1.6
13	SAHR	JMQ40AP001 Total	SAHR Train	**0.008**	1.2
14	SSS	LAJ10AP001 Total	SSS	**0.008**	1.2

Component Rank Based on Risk Achievement Worth/Risk Increase Factor (Representative Trains)

No.	System	Component ID	Component Description	FV Total	RIF Max
1	ELE DC	31BTD01_BA Total	ELEC DC, 250V Battery Fails on Demand	0.169	**150.4**
2	SCWS	QKA40GH001 Total	SCWS, Train Chiller Unit	0.033	**16.5**
3	OCWS	QNA23AP043 Total	OCWS, Train Chiller Unit	0.004	**15.0**
4	MSS	LBA41AA191 Total	MSS, Main Steam Safety Relief Valve	0.012	**8.7**
5	ESWS	PEB40AP001 Total	ESWS Train	0.007	**5.0**
6	CCWS	KAA40AP001 Total	CCWS Train	0.002	**4.8**
7	RCS	JEB10AA020 Total	RCP Seal, RCP Seal Nitrogen Venting Isolation Fails to Close on Demand	0.012	**4.5**
8	ELE EDG	XKA10_____ Total	EDG Train	0.255	**2.6**
9	ELE SBO	XKA50_____ Total	SBO-DG Train	0.053	**2.6**
10	EFWS	LAS41AP001 Total	EFWS Train	0.057	**2.5**

Importance Ranking of Human Actions Sorted by Fussel-Vesely

Basic Event ID	HUMAN ACTION - DESCRIPTION	Nom. Val.	FV	RDF	RIF
OPE-FB-40M	Operator Fails to Initiate Feed & Bleed for SLOCA	1.30E-01	**0.206**	1.26	2.4
OPF-EFW-6H	Operator Fails to Align EFWS Tanks to Operating Trains (or to Provide EFW Tanks Make-Up)	5.50E-05	**0.195**	1.24	3543.0
OPD-FBL90M/EFW6H	Dependency (LOW) Between Operator Actions for Aligning EFW Tanks (Make-Up) & Initiating F&B for Transient with Low Decay Heat	5.00E-02	**0.194**	1.24	4.7
PD-FB40M/SBODG90	Dependency (MED) Between Operator Actions for Initiating F&B and Starting SBO DGs	1.40E-01	**0.121**	1.14	1.7
OPF-SAC-4H	Operator Fails to Recover Room Cooling Locally	1.00E-03	**0.101**	1.11	102.0
OPE-FCD-40M	Operator Fails to Initiate Fast Cooldown for SLOCA	1.30E-01	**0.032**	1.03	1.2
OPE-RHR-4H	Operator Fails to Initiate RHR Within 4 Hours	1.01E-03	**0.014**	1.01	14.5
OPF-EBS-30M	Operator Fails to Manually Actuate EBS (SLB & ATWS)	2.20E-02	**0.011**	1.01	1.5
OPD-SAC4H/SAC1H	Dependency (LOW) Between Operator Actions for Starting HVAC Maintenance Trains and Recovering Room Cooling Locally	5.00E-02	**0.009**	1.01	1.2
OPF-SAC-1H	Operator Fails to Start Maintenance HVAC Trains After Failure of Normal SAC Safety Train	2.00E-04	**0.009**	1.01	44.6
OPF-SGTR-1H	Operator Fails to Isolate SGTR and Initiate Cooldown	2.00E-03	**0.007**	1.01	4.4
OPD-RHR4H/SGTR1H	Dependency (MED) Between Operator Actions for Stabilizing SGTR and Initiating RHR	1.40E-01	**0.007**	1.01	1.0
OPE-FB-90M	Operator Fails to Initiate Feed & Bleed for Transient	5.00E-04	**0.005**	1.01	11.4

Importance Ranking of Human Actions Sorted by RIF

Basic Event ID	HUMAN ACTION - DESCRIPTION	Nom. Val.	FV	RDF	RIF
OPF-EFW-6H	Operator Fails to Align EFWS Tanks to Operating Trains (or to Provide EFW Tanks Make-Up)	5.50E-05	0.195	1.24	**3543.0**
OPF-SAC-4H	Operator Fails to Recover Room Cooling Locally	1.00E-03	0.101	1.11	**102.0**
OPF-SAC-1H	Operator Fails to Start Maintenance HVAC Trains After Failure of Normal SAC Safety Train	2.00E-04	0.009	1.01	**44.6**
OPF-SGTR-4H	Operator Fails to Isolate Blowdown Line for SGTR	1.10E-04	0.004	1.00	**35.7**
OPE-RHR-4H	Operator Fails to Initiate RHR Within 4 Hours	1.01E-03	0.014	1.01	**14.5**
OPE-FB-90M	Operator Fails to Initiate Feed & Bleed for Transient	5.00E-04	0.005	1.01	**11.4**
OPE-FB-L90M	Operator Fails to Initiate Feed & Bleed for Transient with Low Decay Heat	2.80E-04	0.003	1.00	**10.8**
OPF-SBODG-90M	Operator Fails to Start the SBO Diesel Generators from MCR	4.00E-04	0.003	1.00	**7.5**
OPD-FBL90M/EFW6H	Dependency (LOW) Between Operator Actions for Aligning EFW Tanks (Make-Up) & Initiating F&B for Transient with Low Decay Heat	5.00E-02	0.194	1.24	**4.7**
OPF-SGTR-1H	Operator Fails to Isolate SGTR and Initiate Cooldown	2.00E-03	0.007	1.01	**4.4**
OPE-FB-40M	Operator Fails to Initiate Feed & Bleed for SLOCA	1.30E-01	0.206	1.26	**2.4**
LAR41AA004MEC3	EFWS, Train 4 Pump Discharge Manual Valve LAR41AA004, Left in Wrong Position	8.00E-03	0.012	1.01	**2.4**
LAR11AA004MEC3	EFWS, Train 1 Pump Discharge Manual Valve LAR11AA004, Left in Wrong Position	8.00E-03	0.011	1.01	**2.4**

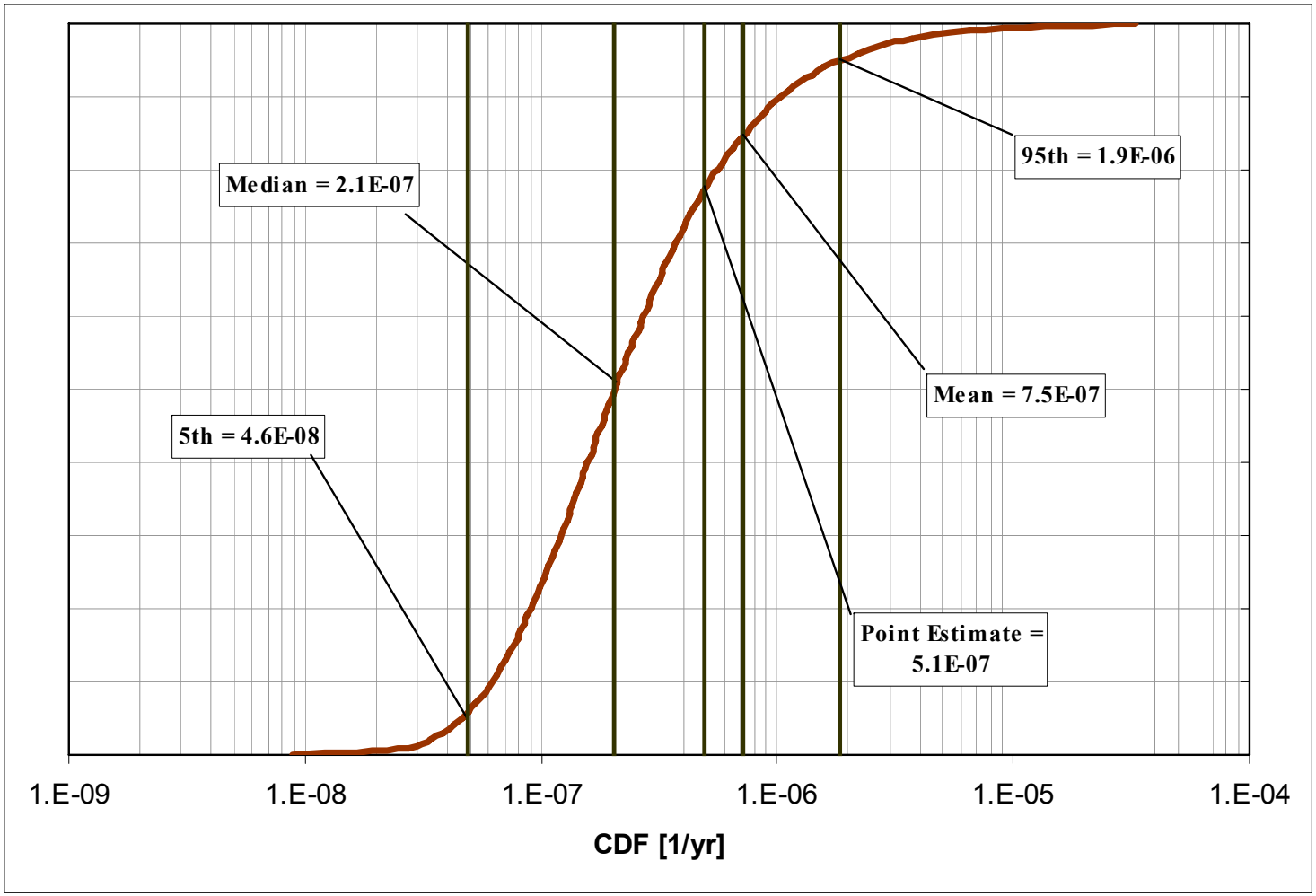
Importance Ranking of Common Cause Groups Sorted by RIF

System	Common Cause Group ID	Component ID	Description	Nom. Val.	FV	RDF	RIF
ELE	BTD01_BAT__ST_D-ALL	BTD01_BAT_	CCF of Batteries on Demand	1.49E-06	6.79E-02	1.07	**45,670.0**
IRWST	JNK10AT001SPG_P-ALL	JNK10AT001	CCF of IRWST Sump Strainers - Plugged	5.65E-07	1.40E-03	1.00	**2,483.0**
SIS	JNG13AA005CFO_D-ALL	JNG13AA005	CCF to Open LHSI/MHSI Common Injection Check Valves	4.48E-06	7.26E-03	1.01	**1,623.0**
MSS	LBA11AA191SFO_H-ALL	LBA11AA191	CCF to Open Main Steam Safety Relief Valves (4)	1.08E-05	1.08E-02	1.01	**1,006.0**
SCWS	QKA10AP107EFR_D-ALL	QKA10AP107	CCF of SCWS Pumps to Run/Start	6.41E-07	5.30E-04	1.00	**827.9**
HVAC	SAC01AN001EFR_D-ALL	SAC01AN001	CCF to Run Normal Air Supply/Exhaust Fans	1.33E-06	9.60E-04	1.00	**720.2**
ELE EDG	XKA10_____DFR_D-ALL	XKA10_____	CCF of EDGs to Run/Start	2.03E-04	8.36E-02	1.09	**413.4**
SIS	JND10AP001EFR_D-ALL	JND10AP001	CCF of MHSI Pumps to Run/Start	3.80E-05	8.53E-03	1.01	**225.4**
MSS	LBA10AA002PFC_D-ALL	LBA10AA002	CCF to Close Main Steam Isolation Valves	1.17E-05	2.38E-03	1.00	**204.3**
EFWS	LAS11AP001EFS_D-ALL	LAS11AP001	CCF of EFWS Pumps to Start/Run	1.13E-05	1.49E-03	1.00	**132.5**
ESWS	PED10AN002EFS_D-ALL	PED10AN002	CCF to Start/Run Standby Cooling Tower Fans	1.85E-05	1.86E-03	1.00	**101.4**
HVAC	SAC61AH001EFS_D-ALL	SAC61AH001	CCF to Start/Run EFW Pump Room Ventilation Fans	3.31E-07	3.08E-05	1.00	**94.2**
SIS	JNG10AP001EFS_D-ALL	JNG10AP001	CCF of LHSI Pumps to Start/Run	1.85E-06	1.57E-04	1.00	**86.0**

Importance Ranking of I&C Common Cause Events Sorted by RIF

No.	Common Cause Group ID	Description	Nom. Val.	FV	RDF	RIF
1	ALU-B CCF NS-ALL	CCF of Protection System Logic Computers Diversity Group B (Non-Self-Monitored)	6.68E-07	2.54E-03	1.00	**3,794.0**
2	ALU-B CCF SM-ALL	CCF of Protection System Logic Computers Diversity Group B (Self-Monitored)	1.81E-07	6.67E-04	1.00	**3,691.0**
3	APU4 CCF NS-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group B2 (Non-Self-Monitored)	6.68E-07	1.60E-03	1.00	**2,396.0**
4	APU4 CCF SM-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group B2 (Self-Monitored)	1.81E-07	4.24E-04	1.00	**2,346.0**
5	SG4 PRES CCF-ALL	CCF of SG4 Pressure Sensors	8.40E-07	1.77E-03	1.00	**2,101.0**
6	PZR PRES CCF-ALL	CCF of Pressurizer (RCS) Pressure Sensors	8.40E-07	1.33E-03	1.00	**1,583.0**
7	APU3 CCF NS-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group B1 (Non-Self-Monitored)	6.68E-07	1.06E-03	1.00	**1,581.0**
8	APU3 CCF SM-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group B1 (Self-Monitored)	1.81E-07	2.76E-04	1.00	**1,526.0**
9	SAS CCF-ALL	CCF of Safety Automation System (SAS) Divisions	1.00E-06	3.11E-04	1.00	**311.5**
10	ALU-A CCF NS-ALL	CCF of Protection System Logic Computers Diversity Group A (Non-Self-Monitored)	6.68E-07	7.34E-05	1.00	**110.8**
11	APU2 CCF NS-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group A2 (Non-Self-Monitored)	6.68E-07	7.34E-05	1.00	**110.8**
12	ALU-A CCF SM-ALL	CCF of Protection System Logic Computers Diversity Group A (Self-Monitored)	1.81E-07	1.56E-05	1.00	**87.5**
13	APU2 CCF SM-ALL	CCF of Protection System Sensor Acquisition Computers Diversity Group A2 (Self-Monitored)	1.81E-07	1.56E-05	1.00	**87.5**

Preliminary CDF, Level 1, At-Power Uncertainty Analysis



Sensitivity Studies

Sensitivity Case	Sensitivity Case Description	SC CDF [1/yr]	Delta CDF [%]
0	Base Case	5.1E-07	0%
1	MSRT Realignment	3.5E-07	-31%
2	W/o Preventive Maintenance	2.5E-07	-51%
3	All Year Preventive Maintenance on Train 1	2.3E-06	351%
4	All HEPs Set to 5% Value	2.1E-07	-59%
5	All HEPs Set to 95% Value	3.5E-06	586%
6	W/o Common Cause Groups	3.6E-07	-29%
7	Uniform CCFs	8.1E-07	59%
8	EDGs & SBO DGs in the same CC Group	2.0E-06	292%
9	No Credit for LOOP Recovery	8.1E-07	59%
10	Increase Size of the EFW Tanks	4.1E-07	-19%

Insights from Preliminary Level 1 At-Power Analysis

- **U.S. EPR is an active plant, thus CDF is dominated by LOOP-type events (>50%). Still, total LOOP CDF is small <3E-07/year. This small contribution is a result of the U.S. EPR high redundancy in trains and diversity in emergency power supplies.**

- **Seal-LOCA contribution to CDF is the second highest contributor (~ 40%). Still, total Seal-LOCA related CDF is small at approximately 2E-07/year. This small contribution is a result of the U.S. EPR stand still seal design, which contributes to RCP seal reliability.**

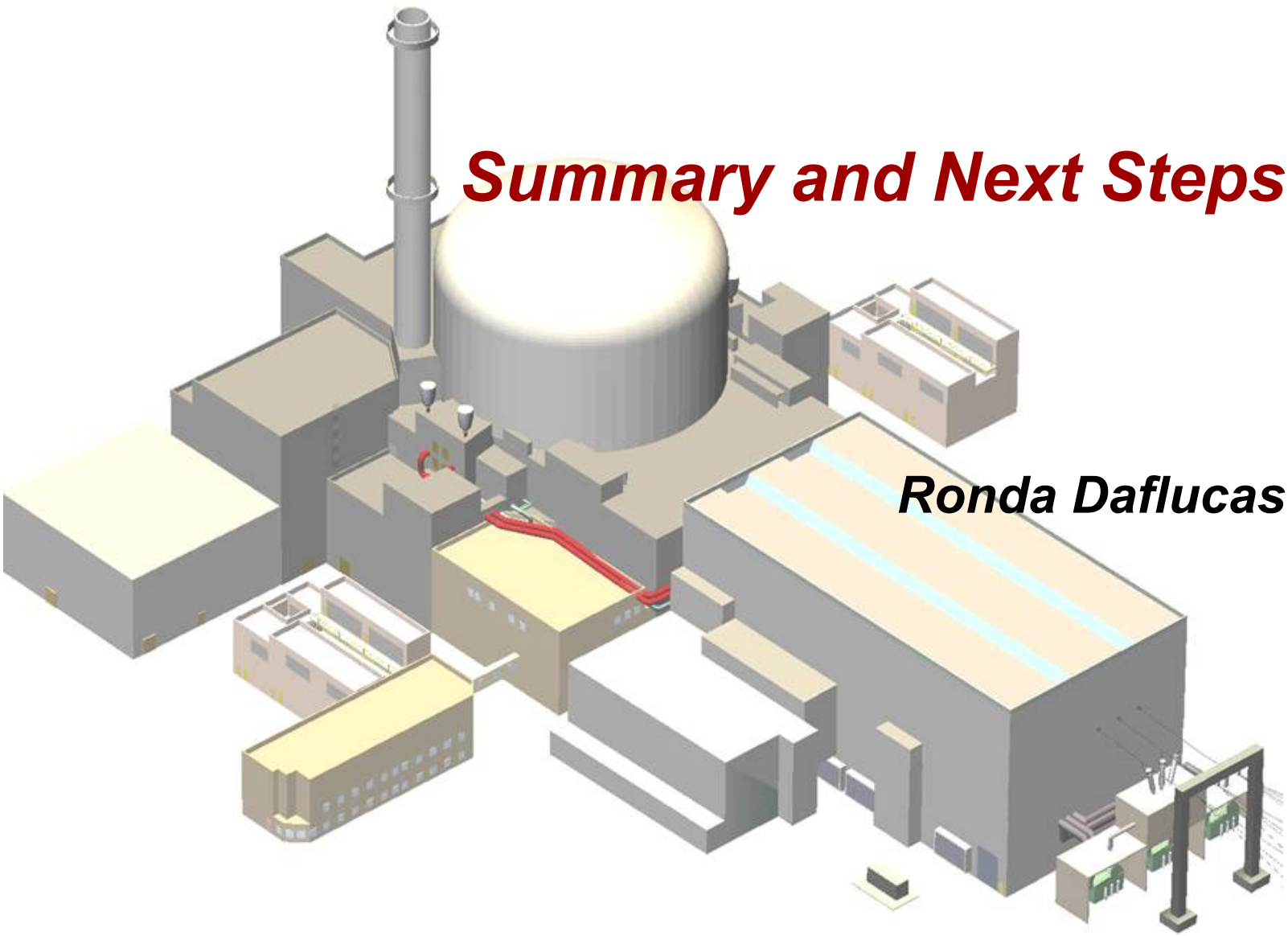
- **Sensitivity studies did not identify any events where the failure rate reduction would lead to significant reduction in the CDF.**

Conclusions

- Preliminary Level 1 PRA (at-power, internal events) shows no outliers and confirms robustness of the U.S. EPR design

- Preliminary Level 1 results indicate that the U.S. EPR design goals will be met with margin

Summary and Next Steps



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Summary

- U.S. EPR is a robust design with design features that contribute to low CDF
- U.S. EPR PRA is being developed in conformance with NRC guidance
- Preliminary Level 1 results provided insights on dominant events and benefit of U.S. EPR redundancy and diversity
- AREVA NP is following NRC and industry guidelines and keeping abreast of ongoing PRA dialogue between NRC and the industry

Abbreviations and Acronyms

> ACC	Accumulator
> ASME	American Society of Mechanical Engineers
> ATWS	Anticipated Transient Without Scram
> CCF	Common Cause Failure
> CCWS	Component Cooling Water System
> CDF	Core Damage Frequency
> CLCWS	Closed and Auxiliary Cooling Water System
> CVCS	Chemical Volume Control System
> DCD	Design Certification Document
> DWS	Demineralized Water Distribution System
> EBS	Extra Boration System
> EDG	Emergency Diesel Generator
> EFWS	Emergency Feedwater System
> ESFAS	Engineered Safety Features Actuation System
> ESW(S)	Emergency Service Water (System)
> F&B	Feed and Bleed
> FSAR	Final Safety Analysis Report
> FV	Fussel-Vesely
> GT	General Transient

Abbreviations and Acronyms (Continued)

> HEP	Human Error Probability
> HVAC	Heating, Ventilation and Air Conditioning
> I&C	Instrumentation and Controls
> IE	Initiating Event
> IRWST	In-Containment Refueling Water Storage Tank
> ISLOCA	Interfacing System Loss of Coolant Accident
> KKS	Kraftwerks Kennzeichen System
> LBOP	Loss of Balance of Plant
> LHSI	Low Head Safety Injection
> LLOCA	Large Loss of Coolant Accident
> LOC	Loss of Main Condenser
> LOCA	Loss of Coolant Accident
> LOCCW	Loss of Component Cooling Water System
> LOMFW	Loss of Main Feedwater
> LOOP	Loss of Offsite Power
> LRF	Large Release Frequency
> MFW(S)	Main Feedwater (System)
> MHSI	Medium Head Safety Injection
> MLOCA	Medium Loss of Coolant Accident

Abbreviations and Acronyms (Continued)

> MSIV	Main Steam Isolation Valve
> MSRT	Main Steam Relief Train
> MSSV	Main Steam Safety Valve
> OCWS	Operational Chilled Water System
> P	Pressure
> PCT	Peak Cladding Temperature
> PDSV	Primary Depressurization System Valve
> PRA	Probabilistic Risk Assessment
> PWR	Pressurizer Water Reactor
> PRS	Pressurizer Relief System
> RAW	Risk Achievement Worth
> RCP	Reactor Coolant Pump
> RCPTB	Reactor Coolant Pump Thermal Barrier
> RCS	Reactor Coolant System
> RHR(S)	Residual Heat Removal (System)
> RIF	Risk Increase Factor
> RPS	Reactor Protection System
> SAC	Electrical Division of Safeguard Building Ventilation System

Abbreviations and Acronyms (Continued)

> SAHR	Severe Accident Heat Removal System
> SBO	Station Blackout
> SBO DG	Station Blackout Diesel Generator
> SCWS	Safety Chilled Water System
> SGTR	Steam Generator Tube Rupture
> SI(S)	Safety Injection (System)
> SLBI	Steam Line Break Inside Containment
> SLBO	Steam Line Break Outside Containment
> SLOCA	Small Loss of Coolant Accident
> SSS	Startup Shutdown System
> UHS	Ultimate Heat Sink