Impact of Fire PRA Conservatisms on NextEra Energy Fire PRA Risk Models

Keith Vincent – NextEra Energy Fire PRA Technical Lead

Fire PRA Workshop, October 3-5, 2017

Impact of Fire PRA Conservatisms on NextEra Energy Fire PRA Risk Models

Electrical Cabinet Specific Method Improvements

Site	Driving Metric	Cab-to-Cab*	18 Min. Growth	24 Min. Growth	NSP	Stays in Cab
NEE01	CDF	2.0%	10.5%	14.0%	10.5%	1.8%
NEE02	CDF	2.0%	12.2%	16.4%	12.2%	2.7%
NEE03	CDF	2.0%	13.4%	18.0%	13.4%	~0%
NEE04	CDF	2.0%	12.6%	16.8%	12.6%	~0%
NEE05	CDF	--	10.5%	17.4%	10.5%	--
NEE06	CDF	--	11.7%	19.4%	11.7%	--

* - Reduction value estimated

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Electrical Cabinet Specific Method Improvements

Site	Driving Metric	MCR NSP Floor	HEAF NSP	HEAF ZOI	Trans. Control	Trans. Growth
NEE01	CDF	0.2%	0.1%	0.0%	1.1%	16.9%
NEE02	CDF	1.6%	0.1%	0.0%	6.3%	19.2%
NEE03	CDF	0.3%	1.3%	2.1%	0.3%	0.2%
NEE04	CDF	0.3%	0.0%	0.0%	0.9%	2.2%
NEE05	CDF	3.5%	--	8.6%	7.1%	--
NEE06	CDF	3.5%	--	11.7%	3.4%	--

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Other Method Improvements

Site	Driving Metric	Cable 500C	Obst. Rad*	Incipient Improvements	Radiation ZOI
NEE01	CDF	In Analysis	2.0%	N/A	2.0%
NEE02	CDF	In Analysis	2.0%	N/A	2.0%
NEE03	CDF	In Analysis	2.0%	N/A	2.0%
NEE04	CDF	In Analysis	2.0%	N/A	2.0%
NEE05	CDF				
NEE06	CDF				

* - Reduction value estimated

Impact of Fire PRA Conservatisms on NextEra Energy Fire PRA Risk Models

Summary of Insights

- **The benefit of the modeling approaches is dependent on the site and in some cases the unit**
- **Amount of risk change is impacted by accepted methods during Fire PRA development and transition to NFPA 805**
- **Risk Reduction Methods with Significant Risk Decrease Across NEE Fleet**
  - Longer electrical cabinet fire growth rate
  - Reduced electrical cabinet NSPs
- **Site Specific Methods with Significant Risk Decrease**
  - Transient Fire Growth Rate
  - HEAF ZOI Impact

Impact of Fire PRA Conservatisms on NextEra Energy Fire PRA Risk Models

Day-to-Day Benefit of New Methods/Approaches

- Realistic treatment of fire risk allows for a more clear picture of the overall risk profile.
- Will refine risk models to reflect lessons learned from transition; focus on risk significant fire areas and ensuring that resources are effectively used to manage risk.
- More complete assessment of electrical panel fires simplifies the development and review of modifications

Fire PRA Method Improvements

October 3-5, 2017

Benefits to Fire PRA Method Improvements

- Improvements to Fire PRA realism encourage focus on components that are actually risk significant.

	X01	X02
Cabinet-to-Cabinet	N/A	N/A
Cabinet Growth (18 min)	8.8%	10.1%
Cabinet Growth (24 min)	13.2%	15.2%
Cabinet Only	negligible	negligible
MCR NSP Floor	negligible	negligible
HEAF ZOI	2.8%	3.1%
Transient Zones	negligible	negligible
HEAF NSP	0.3%	6.2%
Cable Ignition	2.4%	2.8%
Cable Spread	7.0%	9.4%
Transient time to peak	8.8%	5.7%
Obstructed Radiation	negligible	negligible
VEWFDS	7.2%	7.0%
Radiation ZOI	negligible	negligible

Insights

- Electrical Cabinet growth profile and NSP are significant
- MCR NSP floor is less significant
- HEAF contribution is small
- Cable Ignition is more significant than indicated due to cable location assumptions
- NSP transition from Electrical to Cable fire is significant
- VEWFDS benefit is significant

- Electrical Cabinet and Transient fires are significant contributors to calculated risk

Benefits to Fire PRA Method Improvements

- Improvements to Fire PRA realism encourage focus on components that are actually risk significant.

Xcel Energy®

Entergy®

Sensitivity Study for Plant Specific Insights on FPRA Conservatisms using Entergy Fire PRA Data

Joseph Renner
JENSEN HUGHES

October 2017

WE POWER LIFE℠

Sensitivity Study

- **The sensitivity study was performed using two active Fire PRA risk models from Entergy.**
  - Model #1 (Site E01) that has implemented the latest guidance in NUREG-2169 and NUREG-2178.
  - Model #2 (Site E02) utilizes NUREG/CR-6850 Supplement 1 ignition frequencies, and NUREG/CR-6850 heat release rates.
- **The results driven by Fire CDF, LERF values are expected to follow proportionally.**
- **Incipient detection credit was removed and not replaced with NUREG-2180.**

The Results

Method	Site E01 (%Total CDF)	Site E02 (%Total CDF)
Cab-to-Cab (EC-003)	2% (Estimated)	2% (Estimated)
Panel Growth 18min (EC-005)	13.2%	16.4%
Panel Growth 24min (EC-005)	18.5%	23.0%
NSP (EC-006)	13.2%	16.4%
Partial Cabinet Damage (EC-007)	8.5%	23.3%

The Results cont.

Method	Site E01 (%Total CDF)	Site E02 (%Total CDF)
NSP Floor Value (MCR)	1.6%	0.6%
HEAF ZOI	9.0%	3.8%
Transient Controls	1.80%	1.20%
HEAF NSP (HEAF-002)	5.60%	2.40%
Cable Tray Ignition 500C (CBLIGN-001)	In current analysis.	In current analysis.

The Results cont.

Method	Site E01 (%Total CDF)	Site E02 (%Total CDF)
Cable Spread (CBL)	0.30%	0.60%
Trans Range (TRANS-005)	Negligible	Negligible
Obst Rad (EC-002)	2% (Estimated)	2% (Estimated)
Incipient (INCIP)	N/A	N/A
Rad ZOI	2% (Estimated)	2% (Estimated)

Risk Insights – Significant Impact

- **Fire Growth (EC005), NSP (EC006) are the significant contributors to potential risk reduction.**

Method	Site E01 (CDF)	Site E02 (CDF)
18 Min Growth (EC-005)	13.20%	16.40%
24 Min Growth	18.50%	23.00%
NSP (EC-006)	13.20%	16.40%

Risk Insights – Moderate Impact

- **Risk Reduction for Fire in cabinet (EC007) primarily associated with control room panels with high CCDP/multiple trains.**
- **HEAF Frequency and NSP associated with switchgear room fires.**

Method	Site E01 (CDF)	Site E02 (CDF)
Partial Cabinet Damage (EC-007)	8.50%	23.30%
HEAF ZOI	9.00%	3.80%
HEAF NSP (HEAF-002)	5.60%	2.40%

Risk Insights – Limited Impact

- **Obstructed Radiation for EC/Improved ZOI for Radiation**
- **Plume damage is pushing the results.**
  - Method would be more applicable at sites with risk significant cable tray risers or sites that have equipment in a cable spreading room (a room with risk significant horizontal targets).
  - Some risk benefit in control room scenarios where potential risk is concentrated around adjacent cabinets.
- **Cable fire spread rate – More beneficial at sites that have open compartments where larger ZOIs could be reduced. Sites that are compartmentalized conceptually have less benefit.**
- **Cable tray ignition included in current analysis**
- **Transient fires – Practical programmatic methods would provide benefit to localize and/or focus the impact of transient fire risk in lieu of using area wide transient free zones.**

Conclusions

- **Primary risk reductions were observed in the conservatism from fire growth and fire suppression timeframes.**
- **Proposed methods still provide benefit for sites that implemented NUREG-2169/NUREG-2178.**
- **Realistic inputs should be pursued over comprehensive fire modeling techniques.**
- **Don't focus solely on overall risk reduction. Most of the development of the fire models are complete. The use of the PRA models for decision making requires realistic inputs going forward.**

QUESTIONS?

Insights on Benefits of FPRA Methods

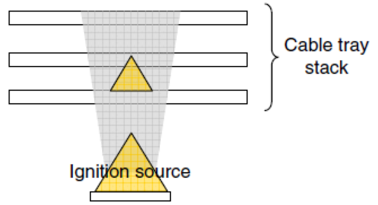
Harold Stiles – Lead Engineer PSA

DUKE ENERGY®

Eliminated cable tray contributions to the formation of HGL where the first cable tray was beyond the distance corresponding to a plume centerline temperature of 500°C.

Most of the risk benefit came from a few scenarios located in places like the cable spreading room where HGL could affect cables for redundant equipment.

There tended to be a greater impact on scenarios with thermoplastic cables.

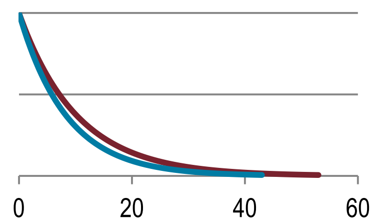


Type	Unit	Metric	Benefit
BWR	D01	LERF	20%
BWR	D02	LERF	23%
PWR	D03	CDF	4%
PWR	D04	CDF	4%
PWR	D05	LERF	11%
PWR	D06	CDF	2%
PWR	D07	CDF	3%
PWR	D08	CDF	4%
PWR	D09	CDF	5%
PWR	D10	CDF	6%
PWR	D11	LERF	3%

EC-006, Update Electrical Cabinet NSP Curve

Increased mean fire suppression rate (λ) for Bin 15 from 0.098 to 0.119, effectively restoring the NSP distribution to that originally provided by NUREG/CR-6850.

This relatively modest change yields a significant cumulative effect on total risk because it is applicable to between 500 to 1500 ignition sources per unit.

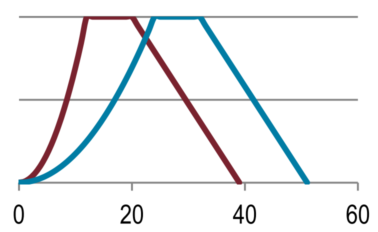


Type	Unit	Metric	Benefit
BWR	D01	LERF	7%
BWR	D02	LERF	7%
PWR	D03	CDF	3%
PWR	D04	CDF	2%
PWR	D05	CDF	3%
PWR	D06	CDF	3%
PWR	D07	CDF	2%
PWR	D08	CDF	2%
PWR	D09	CDF	3%
PWR	D10	CDF	2%
PWR	D11	CDF	2%

Lengthened the Bin 15 fire growth phase from 12 minutes to 24 minutes.

Doubling the length of the growth phase increased the time-to-damage about 40%.

Although considered a secondary effect, some models showed a risk benefit due to delaying the formation of HGL.

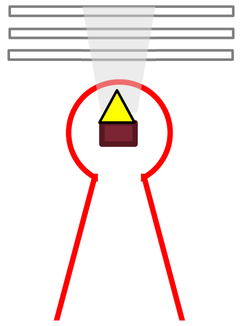


Type	Unit	Metric	Benefit
BWR	D01	CDF	2%
BWR	D02	CDF	3%
PWR	D03	CDF	2%
PWR	D04	CDF	1%
PWR	D05	CDF	3%
PWR	D06	CDF	2%
PWR	D07	CDF	1%
PWR	D08	CDF	2%
PWR	D09	CDF	1%
PWR	D10	CDF	2%
PWR	D11	CDF	2%

HEAF-002, Update HEAF NSP Curve (FAQ-17-013)

Increased the Bin 16 mean fire suppression rate (λ) for cable tray fires caused by the HEAF from 0.013 to 0.029.

HEAF scenarios contribute between 2% and 6% to the total fire risk for different models. Most of the risk impact is from damage to targets in the ZOI of the HEAF.



Type	Unit	Metric	Benefit
BWR	D01	CDF	0%
BWR	D02	CDF	<1%
PWR	D03	CDF	0%
PWR	D04	CDF	0%
PWR	D05	CDF	0%
PWR	D06	CDF	0%
PWR	D07	CDF	0%
PWR	D08	CDF	1%
PWR	D09	CDF	1%
PWR	D10	CDF	1%
PWR	D11	LERF	<1%

Exelon Unit Specific Insights on Benefit of New Methods

Rob Cavedo

Exelon Nuclear Fleet

- Twenty-three Units within Fourteen Sites across five States.
- Fifteen BWR Units and Eight PWRs Units.
- Seventeen Units Driven by Fire CDF; Six Units Driven by Fire LERF

Summary of Insights

- The benefit of these future fire modeling approaches is dependent on the site and in some cases even the unit configuration within a site.
- The amount of benefit is also dependent on the methods and approaches already credited.
- The two most beneficial fire modeling improvements are already FAQs (Bulk Cable Tray Ignition and Transient sub-PAU zones).
- The third most beneficial item is lowering the NSP floor. Sites using NUREG 2178 will see a much larger reduction than sites still using 6850 HRR distributions.
- The benefit of these methods/approaches is not significantly influenced by the type of site (PWR or BWR) or the risk metric analyzed (CDF or LERF).

Day-to-Day Benefit of New Methods/Approaches

Even if it is not cost-effective to globally implement a new method/approach. New approaches provide another tool in the tool box to ensure safe, but cost-effective designs.

For example, more realistic growth and NSP curves will simplify the scope of modification analysis by reducing the total zone of influence considering growth.

Benefit of Buk Cable Tray Ignition to 500 C (FAQ-16-011)

This method appears globally beneficial. The main differential in the degree of benefit appears to be due to which methods and approaches are already credited (e.g. HRR bins modeled, NUREG 2178, etc.).

Type	Code	Driving Metric	Benefit
BWR	E001	LERF	17.8%
BWR	E002	LERF	17.8%
PWR	E014	CDF	15.8%
PWR	E013	CDF	14.5%
BWR	E003	CDF	12.7%
PWR	E010	CDF	12.2%
BWR	E011	LERF	10.4%
BWR	E012	LERF	10.4%
PWR	E021	CDF	9.1%
PWR	E009	CDF	8.4%
PWR	E020	CDF	5.2%
BWR	E005	CDF	5.0%
BWR	E006	CDF	4.7%
PWR	E018	LERF	4.2%
BWR	E015	CDF	2.6%
BWR	E016	CDF	2.6%
BWR	E017	LERF	2.3%
BWR	E004	CDF	2.1%
PWR	E022	CDF	1.5%
BWR	E019	CDF	1.5%
BWR	E007	CDF	0.4%

Average Fleet Benefit: 8%

Transient Combustible Controls within a PAU (FAQ-14-007)

As expected, this benefits sites with transient combustible controls within a PAU. This applies to sites with large PAUs with transient controls only in a small location in the PAU near the risk significant targets.

Type	Code	Driving Metric	Benefit
PWR	E014	CDF	12.7%
BWR	E017	LERF	12.2%
PWR	E013	CDF	10.5%
PWR	E022	CDF	9.7%
PWR	E020	CDF	9.6%
PWR	E021	CDF	7.6%
PWR	E009	CDF	7.3%
BWR	E007	CDF	7.3%
BWR	E011	LERF	4.4%
BWR	E012	LERF	4.4%
BWR	E015	CDF	4.4%
BWR	E016	CDF	3.2%
BWR	E019	CDF	2.7%
PWR	E018	LERF	2.2%
BWR	E004	CDF	1.0%
PWR	E010	CDF	1.0%
BWR	E005	CDF	0.8%
BWR	E006	CDF	0.7%
BWR	E001	LERF	0.6%
BWR	E002	LERF	0.6%
BWR	E003	CDF	0.4%

Average Fleet Benefit: 5%

Exelon.

Reduction of the NSP Floor (New)

The sites that have control room abandonment driven by environmental conditions see a benefit. Those sites that use NUREG 2178 HRR distributions show a larger improvement than those that don't.

Type	Code	Driving Metric	Benefit
BWR	E017	LERF	12.8%
PWR	E018	LERF	11.1%
BWR	E001	LERF	10.6%
BWR	E002	LERF	10.6%
BWR	E019	CDF	9.7%
BWR	E011	LERF	8.5%
BWR	E012	LERF	8.5%
BWR	E006	CDF	6.5%
BWR	E005	CDF	6.1%
BWR	E004	CDF	3.4%
BWR	E007	CDF	2.1%
PWR	E010	CDF	1.8%
BWR	E003	CDF	1.5%
PWR	E022	CDF	1.4%
PWR	E009	CDF	1.3%
PWR	E013	CDF	0.6%
PWR	E014	CDF	0.5%
BWR	E015	CDF	0.0%
BWR	E016	CDF	0.0%
PWR	E020	CDF	0.0%
PWR	E021	CDF	0.0%

Average Fleet Benefit: 5%

Exelon.

Reducing the NSP of Electrical Cabinets (New)
Reducing the Growth of Electrical Cabinet Fires (New)

NSP Improvement

Type	Code	Driving Metric	Benefit
BWR	E006	CDF	12.0%
BWR	E005	CDF	11.1%
BWR	E019	CDF	5.3%
PWR	E022	CDF	4.8%
PWR	E009	CDF	4.2%
PWR	E018	LERF	3.7%
PWR	E010	CDF	3.5%
BWR	E004	CDF	2.7%
PWR	E014	CDF	2.7%
BWR	E017	LERF	1.8%
BWR	E007	CDF	1.6%
BWR	E016	CDF	1.6%
PWR	E013	CDF	1.5%
BWR	E015	CDF	1.5%
PWR	E021	CDF	1.3%
PWR	E020	CDF	1.2%
BWR	E011	LERF	0.9%
BWR	E012	LERF	0.9%
BWR	E001	LERF	0.3%
BWR	E002	LERF	0.3%
BWR	E003	CDF	0.0%

Average Fleet Benefit: 3.0%

The sites with redundant trains above key ignition sources show a larger benefit. Those sites that use NUREG 2178 HRR distributions show a larger improvement than those that don't.

Growth Improvement

Type	Code	Driving Metric	Benefit
BWR	E006	CDF	10.0%
BWR	E005	CDF	9.3%
BWR	E019	CDF	4.4%
PWR	E022	CDF	4.0%
PWR	E009	CDF	3.5%
PWR	E018	LERF	3.1%
PWR	E010	CDF	3.0%
PWR	E014	CDF	2.2%
BWR	E017	LERF	1.5%
BWR	E007	CDF	1.4%
BWR	E004	CDF	1.3%
BWR	E016	CDF	1.3%
PWR	E013	CDF	1.3%
BWR	E015	CDF	1.3%
PWR	E021	CDF	1.1%
PWR	E020	CDF	1.0%
BWR	E011	LERF	0.8%
BWR	E012	LERF	0.8%
BWR	E001	LERF	0.2%
BWR	E002	LERF	0.2%
BWR	E003	CDF	0.0%

Average Fleet Benefit: 2.4%

Partial Damage within an Electrical Cabinet (New)

This improvement has a large degree of site specific variability. A site with a cabinet that controls multiple redundant functions in a single location (e.g. auxiliary shutdown cabinet) could see a large improvement.

Type	Code	Driving Metric	Benefit
BWR	E015	CDF	17.3%
BWR	E016	CDF	17.1%
BWR	E011	LERF	4.0%
BWR	E012	LERF	4.0%
BWR	E005	CDF	1.3%
BWR	E006	CDF	0.9%
PWR	E009	CDF	0.2%
BWR	E001	LERF	0%
BWR	E002	LERF	0%
BWR	E003	CDF	0%
BWR	E004	CDF	0%
BWR	E007	CDF	0%
PWR	E010	CDF	0%
PWR	E013	CDF	0%
PWR	E014	CDF	0%
BWR	E017	LERF	0%
PWR	E018	LERF	0%
BWR	E019	CDF	0%
PWR	E020	CDF	0%
PWR	E021	CDF	0%
PWR	E022	CDF	0%

Average Fleet Benefit: 2.1%

Exelon.

Improved Characterization of Transient Fire HRR/NSP/Growth (New)

This benefits the sites with key pinch point locations where multiple functions can be lost due to a single transient fire. There are even unit specific variations within a given site.

Type	Code	Driving Metric	Benefit
PWR	E014	CDF	4.2%
BWR	E017	LERF	4.1%
PWR	E013	CDF	3.5%
PWR	E022	CDF	3.2%
PWR	E020	CDF	3.2%
PWR	E021	CDF	2.5%
PWR	E009	CDF	2.4%
BWR	E007	CDF	2%
BWR	E011	LERF	1%
BWR	E012	LERF	1%
BWR	E015	CDF	1%
BWR	E016	CDF	1%
BWR	E019	CDF	1%
PWR	E018	LERF	1%
BWR	E004	CDF	0%
PWR	E010	CDF	0%
BWR	E005	CDF	0%
BWR	E006	CDF	0%
BWR	E001	LERF	0%
BWR	E002	LERF	0%
BWR	E003	CDF	0%

Average Fleet Benefit: 1.6%

Exelon.

Improved Cabinet to Cabinet Time to Damage Evaluations (New)

In most cases, cabinets with redundant functions are not adjacent. There are cases where cabinets considered to fail safe can be adjacent. As an example, adjacent sensor cabinets can send spurious actuations that can affect multiple trains.

Type	Code	Driving Metric	Benefit
BWR	E006	CDF	6.0%
BWR	E005	CDF	5.6%
BWR	E019	CDF	2.6%
PWR	E022	CDF	2.4%
PWR	E009	CDF	2.1%
PWR	E018	LERF	1.9%
PWR	E010	CDF	1.8%
PWR	E014	CDF	1%
BWR	E017	LERF	1%
BWR	E007	CDF	1%
BWR	E016	CDF	1%
PWR	E013	CDF	1%
BWR	E015	CDF	1%
PWR	E021	CDF	1%
PWR	E020	CDF	1%
BWR	E004	CDF	1%
BWR	E011	LERF	0%
BWR	E012	LERF	0%
BWR	E001	LERF	0%
BWR	E002	LERF	0%
BWR	E003	CDF	0%

Average Fleet Benefit: 1.5%

Limited Overall Improvement in the Other Methods (<1%)

- HEAF NSP – The initial ZOI impact for HEAFs causes the majority of the risk. In many rooms, the initial impact is similar to the loss of the whole room. HEAF ZOI benefit is large (5% to 10%), but NSP benefit is 0.9%.
- Obstructed Radiation for EC/Improved ZOI for Radiation – More than 99% of the fire scenarios are driven by plume damage. The fleet average benefit of these is in the 0.1% range.
- Cable fire spread rate – Once the trays are on fire, the majority of the damage is done due to the large ZOI of the plume. The spread rate is a smaller factor compared to the initial damage zone. The fleet average benefit is 0.6%

Questions

Improving Fire Ignition Frequency

Nicholas Melly, NRC/Office of Nuclear Regulatory Research
J.S. Hyslop, NRC/Office of Nuclear Reactor Regulation

October 4, 2017

Fire Ignition Frequency

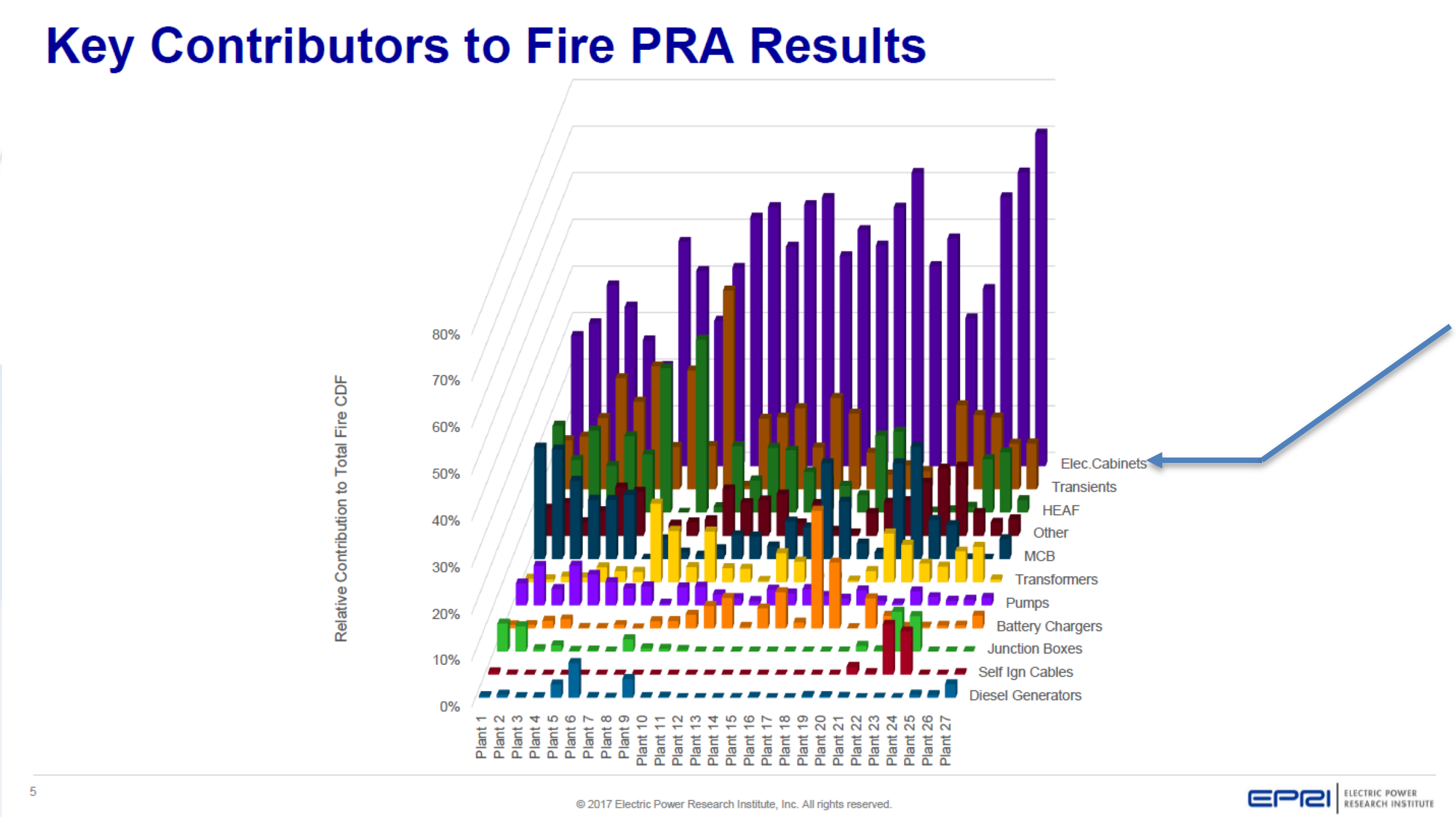
- Task 6 of NUREG/CR-6850 (EPRI 1011989) divides plant fire sources into bins for fire frequency
  - Location
  - Equipment type (includes causal factors)
- Fire frequency bins represented by distributions
  - Produced generic frequencies from data up to 2000
  - In terms of number of events per reactor year
- The current generic fire frequencies in NUREG-2169 (EPRI 300202936) are based on fire event experience through 2009

Need for BIN 15 (electrical enclosure) frequency split

- Application of Fire PRA identify electrical enclosures as the dominant fire ignition source
- With the publication of RACHELLE-FIRE (NUREG-2178), the need for electrical cabinet frequencies subdivided into cabinet type becomes more relevant and necessary
- For example, a subdivision of frequency into cabinet type will enable the PRA to more accurately distinguish between the risk of low and medium voltage electrical cabinets, as the more realistic HRR and frequency will be aligned for cabinet types
- By pairing frequency and HRR of a specific cabinet type, the PRA can be more aligned with methods
  - e.g. Fire PRA FAQ 14-0009 “Treatment of Well Sealed MCC Electrical Panels Greater than 440V”

PRA Risk Significant Contribution

- Presentation by EPRI for the Risk and Safety Management (RSM) Integration Committee Meeting, August 30, 2017



Electrical Enclosures (Bin 15) Highest contributor

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Evolution of Electrical Enclosure Treatment

- NUREG/CR-6850 contained 5 possible HRR bins based on electrical enclosure configuration
- Recent collaborative work under the RES/EPRI MOU work (NUREG-2178) has refined and expanded the electrical enclosure bins to 37 possible bins based on configuration

Ignition Source	HRR kW (Btu/s)		Gamma Distribution	
	75th	98th	α	β
Vertical cabinets with qualified cable, fire limited to one cable bundle	69 [1] (65)	211 [2] (200)	0.84 (0.83)	59.3 (56.6)
Vertical cabinets with qualified cable, fire in more than one cable bundle	211 [2] (200)	702 [3] (665)	0.7 (0.7)	216 (204)
Vertical cabinets with unqualified cable, fire limited to one cable bundle	90 [4] (85)	211 [2] (200)	1.6 (1.6)	41.5 (39.5)
Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	232 [5] (220)	464 [6] (440)	2.6 (2.6)	67.8 (64.3)
Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	232 [5] (220)	1002 [7] (950)	0.46 (0.45)	386 (366)

NUREG-2178 RACHELLE-FIRE

Enclosure Class/Function Group	Enclosure Ventilation (Open or Closed Doors)	Fuel Type* (TS/QTP/SIS or TP Cables)	(a) Default			
			Alpha	Beta	75th Percentile (kW)	98th Percentile (kW)
1 - Switchgear and Load Centers	Closed	TS/QTP/SIS	0.32	79	30	170
	Closed	TP	0.99	44	60	170
2 - MCCs and Battery Chargers	Closed	TS/QTP/SIS	0.36	57	25	130
	Closed	TP	1.21	30	50	130
3 - Power Inverters	Closed	TS/QTP/SIS	0.23	111	25	200
	Closed	TP	0.52	73	50	200
4a - Large Enclosures [>1.42 m^3 (>50 ft^3)]	Closed	TS/QTP/SIS	0.23	223	50	400
	Closed	TP	0.52	145	100	400
	Open	TS/QTP/SIS	0.26	365	100	700
	Open	TP	0.38	428	200	1000
4b - Medium Enclosures [≤1.42 m^3 (50 ft^3)] and > 0.34 m^3 (12 ft^3)	Closed	TS/QTP/SIS	0.23	111	25	200
	Closed	TP	0.52	73	50	200
	Open	TS/QTP/SIS	0.23	182	40	325
	Open	TP	0.51	119	80	325
4c - Small Enclosures [≤ 0.34 m^3 (12 ft^3)]	Not Applicable	All	0.88	12	15	45

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Realistic Bin Refinements

- This task will involve a collaborative effort with EPRI to evaluate the appropriate level of bins based on operational data availability

Old

Bin	Location	Ignition Source	Power Modes	FPRA Counts		
				1968–1989	1990–1999	2000–2009
15	Plant-Wide Components	Electrical cabinets (non-HEAF)	AA	64.5	29.5	25.5

New

Bin	Component Type	Location	Ignition Source	Power Modes	FPRA Counts		
					1968-1989	1990-1999	2000-2009
15	Switchgear Load Center MCC Battery Chargers Power Inverters Low Voltage Electrical Enclosures (Generic)	Plant Wide Components	Electrical Cabinets (non-HEAF)	AA	(Counts need to be evaluated and dealt with using the Bayesian methodology presented in NUREG-2169 for sparse and non-sparse bins)		

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Component Based Frequency

- Refining Bin 15 frequency will bring more realism to the evaluation of risk, and potentially have a significant impact on the most dominating fire risk contribution per EPRI's fire PRA impact study
- However, the eventual goal for both industry and NRC should be the development of component based frequencies based on industry wide data

Improving Fire Frequencies

Ashley Lindeman
Senior Technical Leader

Fire PRA Workshop: Improving Realism
October 4, 2017

Summary of Recent Activity

- Completion of EPRI's Updated Fire Events Database (2013)
  - Supplemented and strengthened 1990s fire event experience
  - Added fire events occurring through 2009
- Provided revised fire frequencies and non-suppression probability estimates in EPRI 3002002936 / NUREG-2169 (2014)
  - No changes for fire binning (e.g. further subdivisions)
  - Insights noted that there was significant variation in the magnitude and consequence of fires, including many relatively low-severity fires that did not grow vigorously but still deemed potentially challenging based on rule set
- INPO collecting fire events in ICES database (ongoing)
  - Provides uniform mechanism to collect industry fire event data

Potential Future Directions

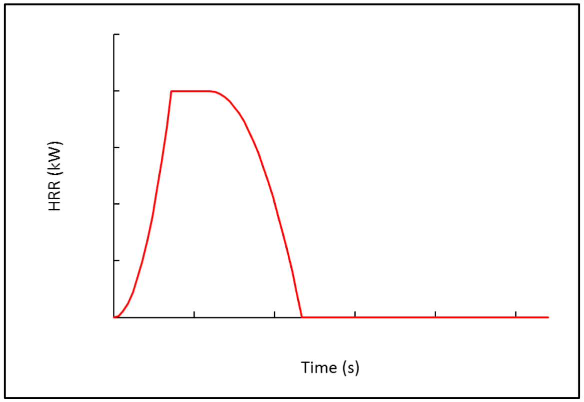
- Plant-based → component-based fire frequencies
  - Verification of equipment counts
- Divide more populated ignition source bins
  - Additional counting guidance / walkdowns
- Address relationships between fire severity, fire growth, and fire suppression. Review of the FEDB data invites the following questions:
  - Do *Challenging* and *Potentially Challenging* fires have different event progressions or growth rates?
    - Majority of bin 15 fire events are *Potentially Challenging*
  - Should *Potentially Challenging and Challenging* fires follow the same suppression rates?
    - *Potentially Challenging* fires are frequently suppressed by plant personnel
    - *Challenging* fires frequently suppressed by fire brigade and fixed suppression systems

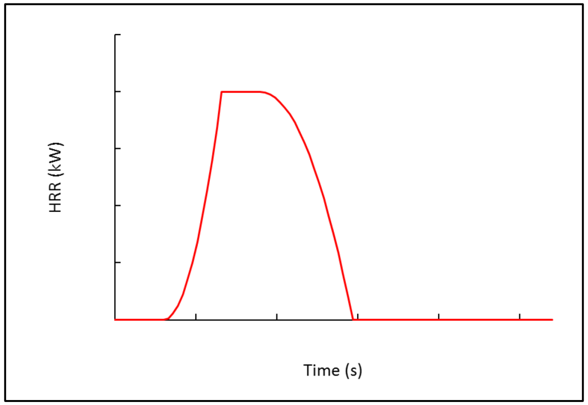
FEDB Insights on Fire Growth

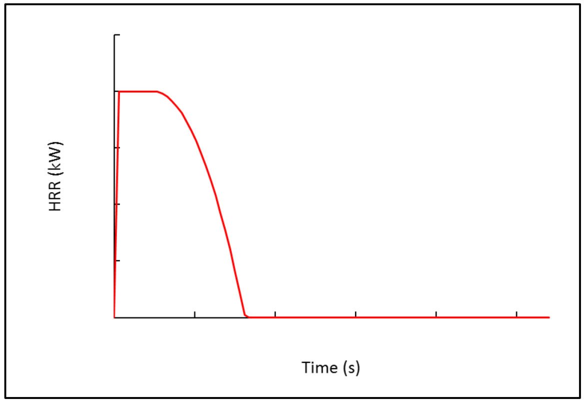
- *Potentially challenging* fires involve limited fire growth, heat release, and damage
  - Damage generally localized within cabinet (not external to cabinet)
- Many/most *Potentially Challenging* fires progress more slowly than experimentally based guidance, assumptions, and model predictions

Fire Growth Progression

- What growth rates are possible and can the growth rates be described consistently?
  - Slow (or delayed) growth: Over heating or smoldering,
  - Normal growth: fire growth prescribed in t^2 profile,
  - Rapid growth: Arc flash (low and medium energy arcing faults)
  - Other?







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FEDB Insights on Suppression (Electrical Cabinets)

- *Potentially Challenging* fires
  - Duration:
    - More than half of these fires suppressed in under 5 minutes
    - Average time to suppress is approximately 8 minutes
  - Suppression Method:
    - Plant personnel (non-fire brigade) extinguished nearly half of fires
    - Almost 90% of fires suppressed via simple actions (self extinguished, removal of power supply, single portable extinguisher, both removal of power supply / single portable extinguisher)
- *Challenging* fires
  - Duration:
    - All fires lasted greater than 10 minutes
    - Average time to suppress: 14 minutes
  - Suppression Method:
    - Are primarily detected by plant personnel
    - Fire brigade and fixed suppression extinguished nearly half of fires

Suppression by Plant Personnel

- Common to all electrical cabinet fires
  - Primarily detected by plant personnel in vicinity
  - Less than 15% detected by fixed detection systems
- Credit early plant personnel suppression (separate from fire brigade actions)
  - Create new branches for plant personnel suppression
    - Available for fires exhibiting slow and normal growth
    - Determine scenarios where personnel suppression not credible

Summary of Technical Work

- Analyze fire event data to develop a technical basis and method to incorporate common fire progressions and credit plant personnel suppression into the fire PRA event tree.
  - Develop a procedure and/or rules for consistent classification of fire events considering fire growth characteristics
  - Develop revised manual suppression approach methodology that allows credit for early intervention or rapid suppression by plant personnel
  - Classify the fire events to support the generation of split fractions
  - Revise of the conceptual event tree model to incorporate fire progression and crediting plant personnel suppression

Together…Shaping the Future of Electricity

Backup Slides

Divide Populated Bins

- Cabinet Type Specific Bins
  - Some bins encompass multiple *types* of ignition sources (Ex. Bin 15)
  - Event data may be used to determine if ignition is certain sub-groups are observed more frequently

- Considerations
  - Redistribute frequency
    - May highlight sub-groups with low count and a high frequency of events
    - Does it matter?
  - Additional counting guidance / walkdowns

- Example: Bin 15 – Electrical Cabinets
    - NUREG-2180
      - Switchgears/Load Centers, Motor Control Centers, Power Inverters
      - Control Cabinets, Lighting/Distribution Panels, etc. (Small/Medium/Large Enclosures)

Divide Populated Bins (cont.)

- Example: Bin 15 – Electrical Cabinets
  – Split out Motor Control Centers and Switchgears

Cabinet Type	Count	Revised Generic Frequency
Other	13	1.66E-02
Motor Control Center (MCC)	5	6.48E-03
Switchgears	7	7.93E-03
Unknown	2	Counted in Other

  – Reduced frequencies for MCCs and Switchgears compared to NUREG-2169
  – Issues observed
    - Reduced frequency but small count at plant results in higher plant specific frequency
    - Ex. Switchgears – Similar number of fires compared to MCCs, but far smaller counts.

Divide Populated Bins (cont.)

- Example: Bin 15 – Electrical Cabinets
  - Split out Motor Control Centers and Switchgears

	Plant 1		Plant 2		Plant 3	
	Counts	Plant Specific Frequency	Counts	Plant Specific Frequency	Counts	Plant Specific Frequency
NUREG-2169 Bin 15	701	4.3E-05	1423	4.23E-05	941	3.2E-05
MCC	150	4.32E-05	388	3.34E-05	203	3.19E-05
SWGR	39	2.03E-04	143	1.11E-04	159	4.99E-05
Others	512	3.25E-05	892	3.73E-05	579	2.87E-05
Sum	701	2.79E-04	1423	1.82E-04	941	1.11E-04

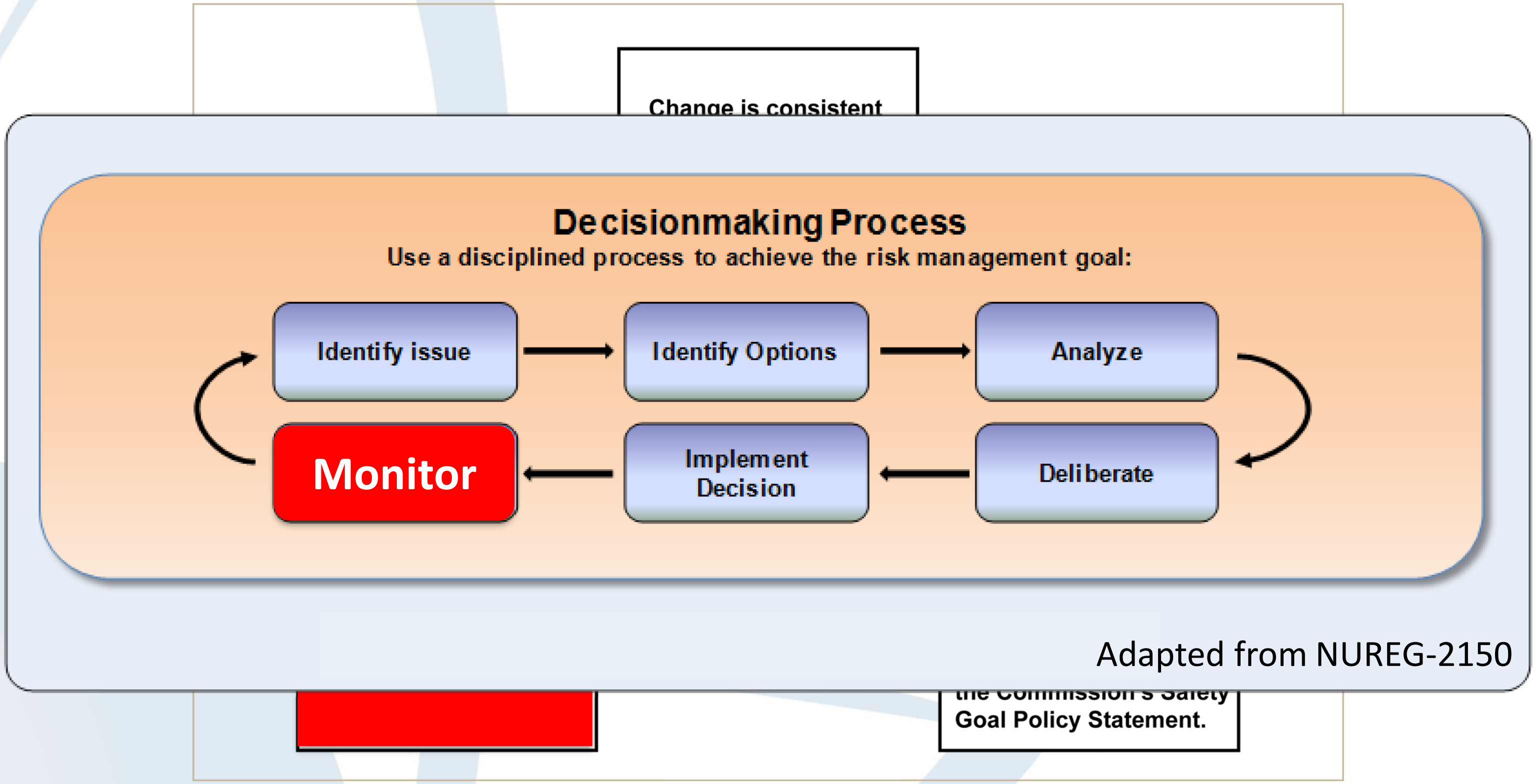
	Plant 4		Plant 5		Plant 6	
	Counts	Plant Specific Frequency	Counts	Plant Specific Frequency	Counts	Plant Specific Frequency
NUREG-2169 Bin 15	468	6.44E-05	957	3.15E-05	1445	4.17E-05
MCC	123	5.27E-05	250	2.59E-05	533	2.43E-05
SWGR	64	1.24E-04	200	3.96E-05	308	5.15E-05
Others	281	5.92E-05	507	3.28E-05	604	5.51E-05
Sum	468	2.36E-04	957	9.84E-05	1445	1.31E-04

Fire PRA: Potential Non-Conservatisms

Nathan Siu, Nicholas Melly
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research

Oct 4, 2017

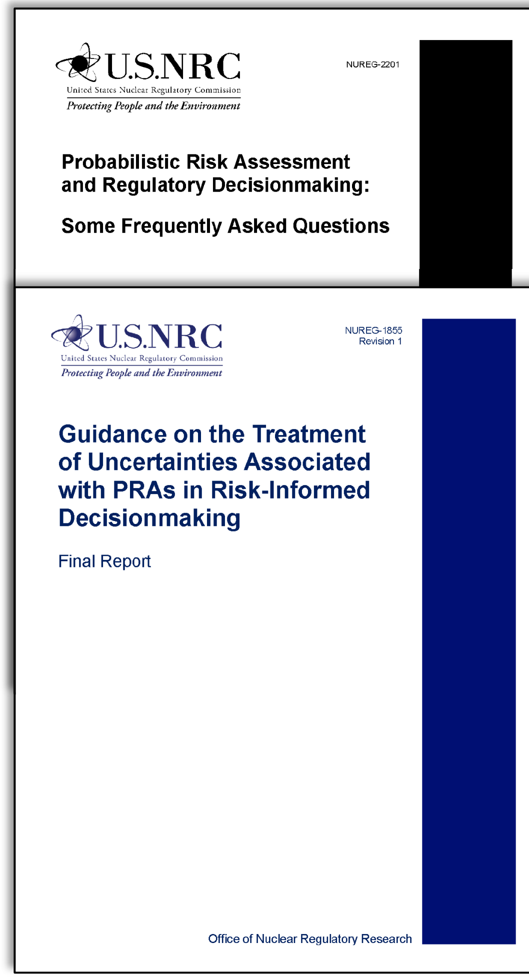
Monitoring and Adjustment: An Integral Part of Risk-Informed Decisionmaking



Adapted from RG 1.174

Fire PRA uncertainties

- PRA models: sufficiently realistic (“good enough”) for purpose
- NUREG-1855, R1 (2017) uncertainty types:
  - Parameter
  - Model
  - Completeness
- NUREG/CR-6850 EPRI 1011989 (2005)
  - Provides guidance where appropriate - does not address some technical areas
  - Technology expected to evolve as Fire PRA matures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NUREG-2201
Probabilistic Risk Assessment and Regulatory Decisionmaking:
Some Frequently Asked Questions

U.S.NRC
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NUREG-1855
Revision 1
Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking
Final Report
Office of Nuclear Regulatory Research

ML17062A466

Historical research needs (circa 1998) NUREG/CP-0162*

1	Adequacy of fire events database
2	Scenario frequencies
3	Effect of plant operations, including compensatory measures
4	Likelihood of severe fires
5	Source fire modeling
6	Compartment fire modeling
7	Multi-compartment fire modeling
8	Smoke generation and transport modeling
9	Circuit failure mode and likelihood
10	Thermal fragilities
11	Smoke fragilities
12	Suppressant-related fragilities
13	Adequacy of data for active and passive barriers
14	Barrier performance analysis tools
15	Barrier qualification
16	Penetration seals
17	Adequacy of detection time data
18	Fire protection system reliability/availability
19	Suppression effectiveness (automatic, manual)
20	Effect of compensatory measures on suppression
21	Scenario-specific detection and suppression analysis
22	Circuit interactions
23	Availability of safe shutdown equipment
24	Fire scenario cognitive impact
25	Impact of fire induced environment on operators
26	Role of fire brigade in plant response
27	Main control room fires
28	Turbine building fires
29	Containment fires
30	Seismic/fire interactions
31	Multiple unit interactions
32	Non-power and degraded conditions
33	Decommissioning and decontamination
34	Fire-induced non-reactor radiological releases
35	Flammable gas lines
36	Scenario dynamics
37	Precursor analysis methods
38	Uncertainty analysis
39	Learning from experience
40	Learning from others
41	Comparison of methodologies
42	Standardization of methods

*N. Siu, J.T. Chen, and E. Chelliah, “Research Needs in Fire Risk Assessment,” NUREG/CP-0162, Vol. 2, 1997.

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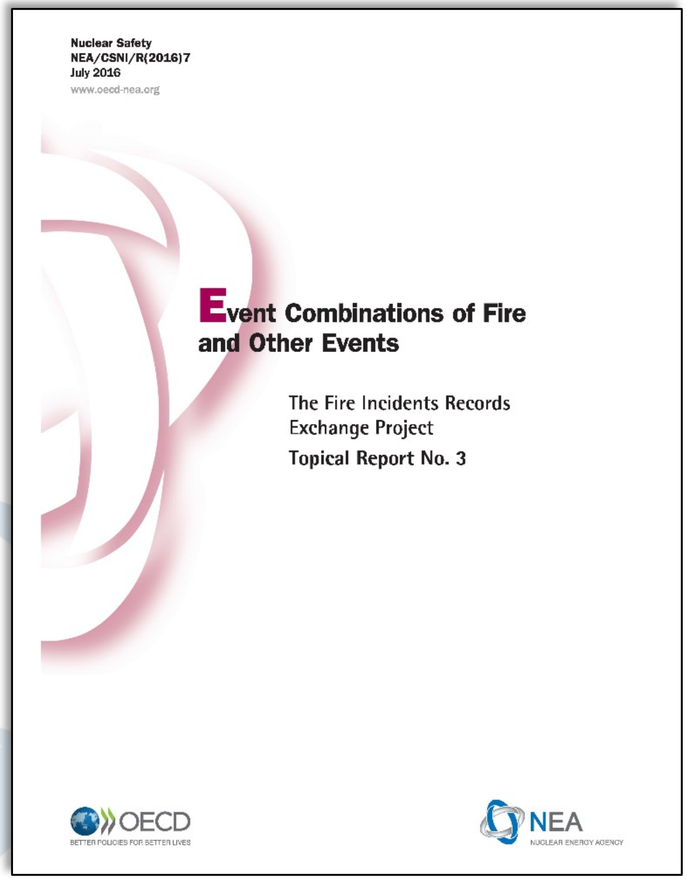
Potential fire PRA non-conservatisms

- Multiple Fires - the occurrence of two or more fires concurrently and in different locations due to the same root cause
  - generally tied to electrical equipment failures
  - events of this type have occurred both in the U.S. and abroad, but are rare
- Multiple hazards from the same root cause
  - E.g. fires in conjunction with flooding
  - https://www.oecd-nea.org/nsd/docs/2016/csni-r2016-7.pdf
- Smoke effects
  - events of this type have occurred both in the U.S. and abroad, but are rare
  - Example: Fort Calhoun, Narora, Maanshan
- Multi unit scenarios


Nuclear Safety
NEA/CSNI/R(2016)7
July 2016
www.oecd-nea.org

Event Combinations of Fire and Other Events

The Fire Incidents Records Exchange Project
Topical Report No. 3

OECD
BETTER POLICIES FOR BETTER LIVES
NEA
NUCLEAR ENERGY AGENCY

Operating Experience: Multiple Fires*

- Armenia- October 15, 1982;
  - large cable gallery fire that severely impacted core cooling capability
- Kalinin- December 18, 1984
  - Large fire in the turbine building involving multiple initial fires on a power cable.
- South Ukraine- December 14, 1984;
  - Cable fire inside containment that propagated to a large area
- H. B. Robinson- January 7, 1989
  - Hydrogen fire at multiple locations during an outage because of maintenance crew error
- Palo Verde- April 4, 1996;
  - multiple fires including a small fire in the main control room
- Shearon Harris- October 9, 1989;
  - multiple fires involving one of the main transformers and electrical equipment in the turbine building
- Calvert Cliffs- March 1, 1989;
  - multiple fires including a small fire in the main control room

* For more detailed information see NUREG/CR-6738

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Operating Experience: Multi-Unit Scenarios

Event	Multi-Unit?			Notes
	Extent	System	Recovery	
Browns Ferry (1975)	√	√		Cable fire, shared CSR. Both units tripped. Unit 1 most affected.
Greifswald (1975)		√		Cable fire. Both units tripped. Unit 1 SBO; Unit 2 shutdown with few complications.
Beloyarsk (1978)				Large TB fire, partial roof collapse, spread to CB. Only Unit 2 affected.
Armenia (1982)	?	√	√	Cable fire. Multiple ignition points, secondary fires and explosions. Both units tripped. Unit 1 (SBO) most affected.
Chernobyl (1991)				Large TB fire and explosion, partial roof collapse. Only Unit 2 affected.
Narora (1993)	√	See Note	√	Large TB fire and explosion, fire spread. Shared MCR abandoned (smoke). Unit 1 SBO (Unit 2 in cold shutdown). DDFP used to feed SGs.

CB = Control Building; CSR = Cable Spreading Room; DDFP = diesel-driven fire pump; MCR = Main Control Room; SBO = Station Blackout; SG = steam generator; TB = Turbine Building

Sources: NUREG/CR-6738 (2001), IAEA TECDOC-1421 (2004), GRS-V-SR2449-1 (2004).

Observations from NUREG/CR-6738

- 3 events involving trips of both units; 1 and perhaps 2 involving serious transients for both units*
- 3 events involving fire and/or smoke effects on both units
- 2 events involving non-proceduralized recovery actions using resources either shared or from less-affected unit
- All 6 events involve asymmetrical impacts
- All 6 events provide modeling challenges
  - Large-scale cable fires
  - Large turbine building fires and explosions
  - Secondary fires and explosions
  - Collapsing structure effects
  - Fire-fighting effects (gaining access, spray on equipment)
  - Non-proceduralized recovery actions
- No severe fire-induced challenges to single- or multi-unit core cooling since 1993**

*NUREG/CR-6738 indicates much greater effects on Armenia Unit 2 than does IAEA TECDOC-1421.
**NUREG/CR-6738 did not include 2001 Maanshan SBO (HEAF)

Addressing non-conservatisms

- Uncertainties (including completeness uncertainties) treated per current guidance (e.g., NUREG-1855, Rev. 1)
- A broader approach to address potential gaps: Generic Issue (GI) Process
  - well-defined, discrete, technical or security issue, the risk/or safety significance of which can be adequately determined, and which: 1) applies to two or more facilities; 2) affects public health and safety, the common defense and security, or the environment; 3) is not already being processed under an existing program or process; and 4) can be resolved by new or revised regulation, policy, or guidance or voluntary industry initiatives. A generic issue may lead to regulatory changes that either enhance safety, or reduce unnecessary regulatory burden
  - Example: Pre-GI-018, “High-Energy Arc Faults Involving Aluminum”

Potential Non-Conservatism- Material Impact of Aluminum

- larger ZOI
- greater likelihood of maintaining arcing at low voltage levels
- Higher risk of fire propagation

Potential Non-Conservatism– Potentially New Failure Mode: Conductive Products of Combustion

- Conductive Aluminum byproducts coated facility after testing
- Shorting out equipment and causing damage to electrical circuits
- Operating experience also shows these phenomena

Test 23

Test 26

Treating non-conservatisms: part of the process

- Past examples
  - Fire frequency
  - Hot short probability
  - Fire-induced errors of commission
- Ongoing: HEAF

Some Closing Personal Views

Investigation Committee on the Accident at Fukushima (7/23/2012): "*TEPCO lacked a sense of urgency and imagination toward major tsunami, which could threaten to deal a fatal blow to its nuclear power plants.*"

- Searching is fundamental to PRA:
  - First question of risk triplet: "What can go wrong?"
  - PRA Procedures Guide and ASME/ANS PRA Standard
- Sparse data, beyond design-basis concerns => imagination needed
- Operational experience:
  - Can fuel, temper, and support imagination
  - Critical for demonstrating realism
  - Should not be considered in isolation

E. De Fraguier, "Lessons learned from 1999 Blayais flood: overview of EDF flood risk management plan," U.S. NRC Regulatory Information Conference, March 11, 2010.

Key Fire PRA Research Efforts

Road to Realism for Fire PRA

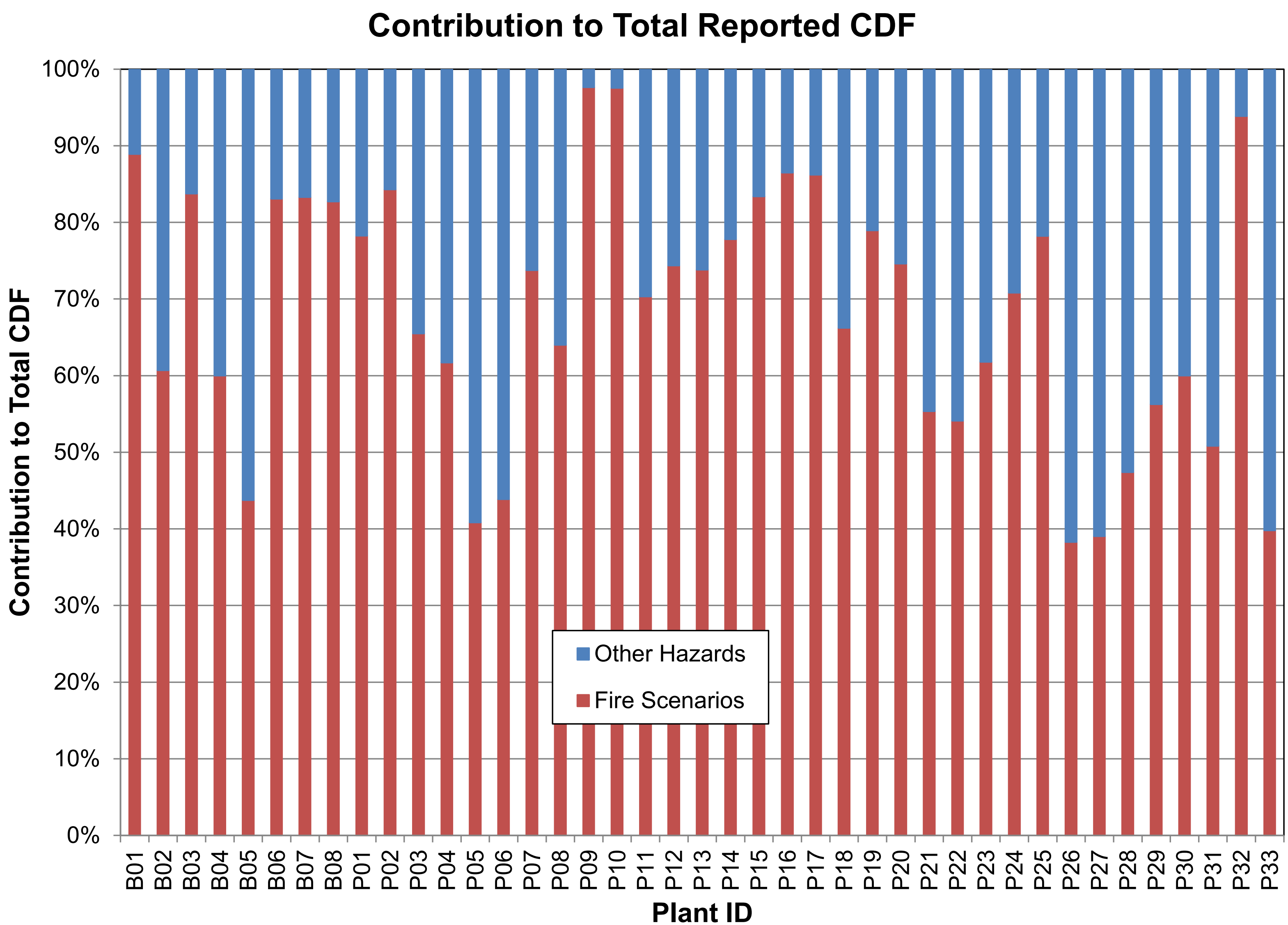
Ashley Lindeman
Senior Technical Leader

Workshop on Improving Realism in Fire PRAs
October 4, 2017

Introduction

- EPRI research plan focused on most impactful research in near term (now through 2019)
  - Top 5-10 research tasks to improve the realism in the fire PRA models
  - Excludes in progress research (obstructed radiation, cabinet to cabinet propagation, motor HRR, etc.)
  - Not intended to be exhaustive list of low hanging fruit or listing of every task or data set to be improved

Motivation



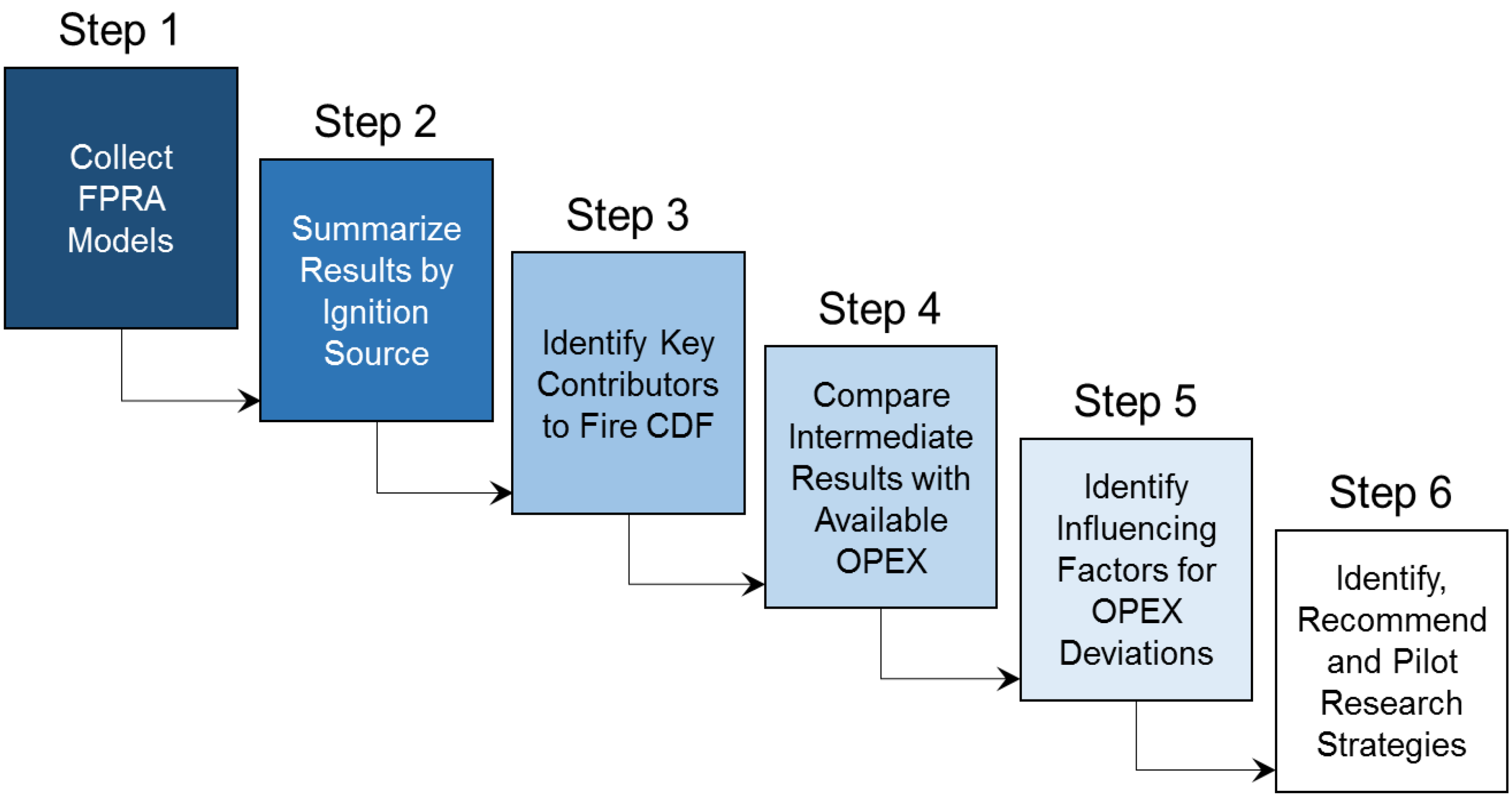
Contribution to Total Reported CDF
Contribution to Total CDF
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Other Hazards
Fire Scenarios
B01 B02 B03 B04 B05 B06 B07 B08 P01 P02 P03 P04 P05 P06 P07 P08 P09 P10 P11 P12 P13 P14 P15 P16 P17 P18 P19 P20 P21 P22 P23 P24 P25 P26 P27 P28 P29 P30 P31 P32 P33
Plant ID

FPRA Skyline

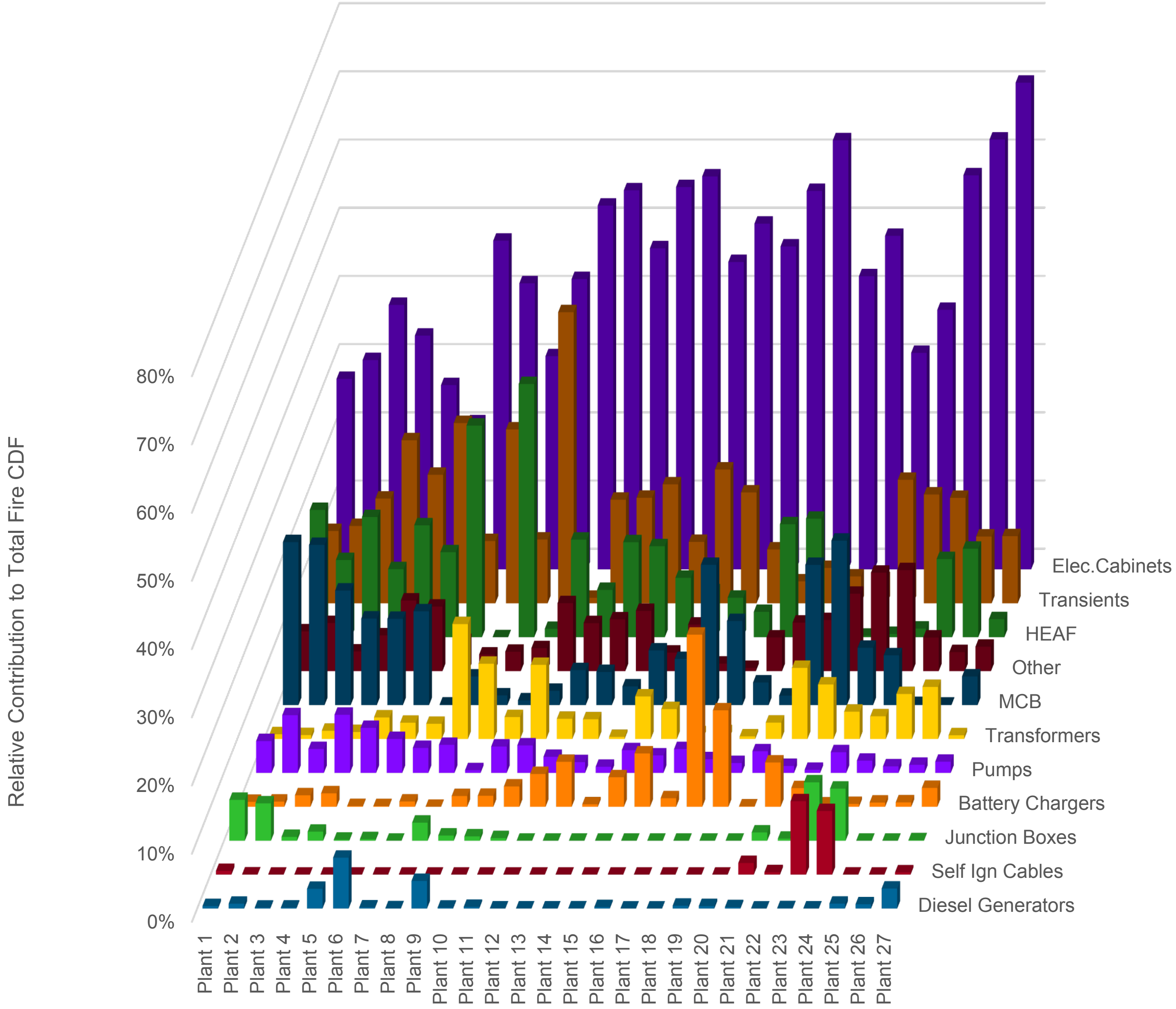
- Originally constructed in 2010 to identify risk drivers
  - Electrical cabinet fires important for all plants sampled
  - Remaining drivers important on a plant specific basis
- Skyline re-created to understand current FPRA results and identify top FPRA contributors
  - Obtained FPRA results from nearly 30 plants (BWRs and PWR)
    - Included NFPA 805 and non-NFPA 805 plants
- Follow on investigation to identify
  - Analytical drivers to calculated risk
  - Departures from operational experience
  - Research to achieve realism

Are the current fire PRA methods in line with operating experience? Does the application of current fire PRA methods and data impact our understanding of the plant risk due to fire?

Process to Derive Research Plan

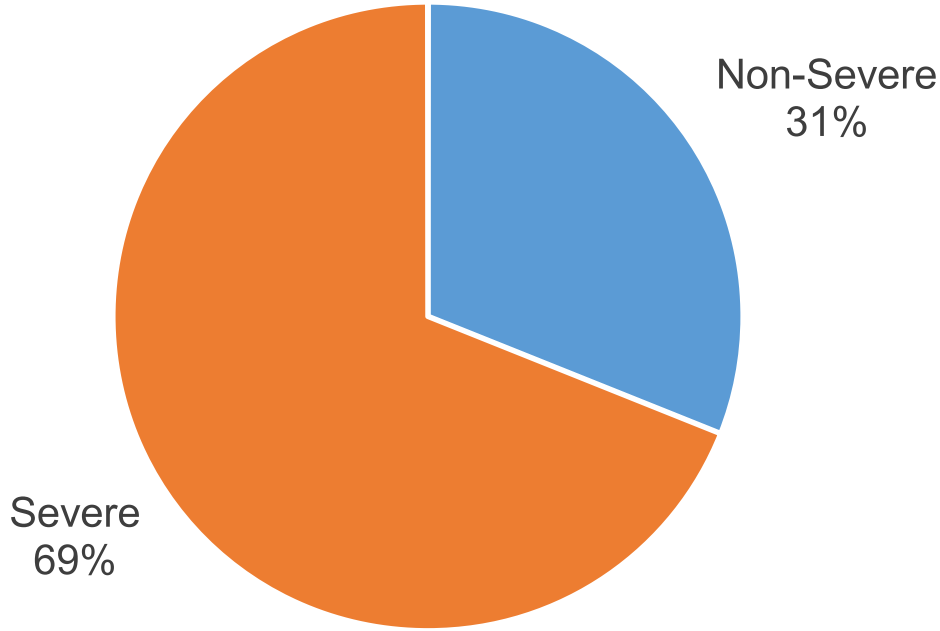


Key Contributors to Fire PRA Results



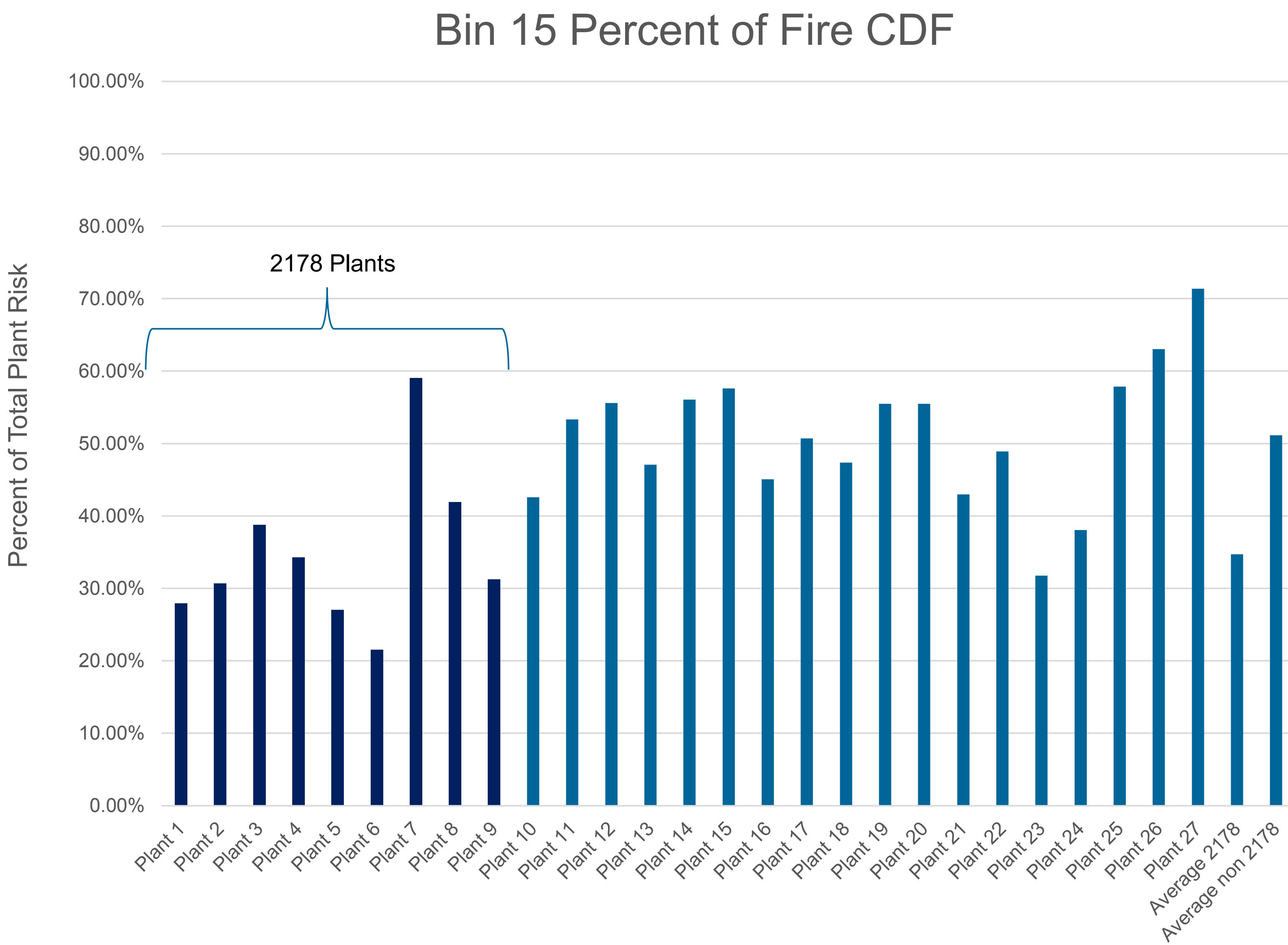
Cabinet Fires: Severe vs Non-Severe Events

- Severe fire = fires that cause damage to external targets (regardless of calculated CCDP)



- Based on FPRA results, the rate of severe fires is calculated as:
  - 2.5 fires per year for the industry, and
  - Over a 10 year period, 25 fires
- This is contrary to the insights from the updated FEDB where most fires are quickly suppressed / confined to the object of origin

Impact of Recent Research



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Insights from Skyline

- Calculated risk from electrical cabinets is important at <u>all</u> plants
  - Assumptions of fire growth outside panels
  - No credit for personnel detection
  - No credit pre-growth phase (when appropriate)
  - Conservatisms on cable tray ignition and propagation
- Transients and HEAFs are also important, but to a lesser degree
  - Transients: No distinction between transient combustibles and transient ignition sources
  - Transients: All transients are treated equal
  - HEAF: No credit for protection schemes
  - HEAF: Difference in frequencies between 1E and non 1E equipment
  - HEAF: One of the few ignition sources that actually generates damage outside the ignition source
- In roughly half of the results, the main control board is important
  - OPEX suggests fires are limited to the source ignition (panel subcomponents)
  - No good model for fire spread and identification of target sets (very conservative target mapping)
- Other ignition source bins can be important, but very plant-specific

Comparison with Operating Experience

- Reviewed data in SECY 14-0107 Accident Sequence Precursor Data (2004-2013)
  - 7 events with CCDPs > 1E-4/yr
    - 2 involving fire
      - Robinson (2010), estimated CCDP = 4E-4
      - Fort Calhoun (2011), estimated CCDP => 1E-4

- Extrapolating the FPRA results for the US industry over the same time period would have estimated:
  - ~15 events with CCDPs > 1E-4
  - ~5 events with CCDPs > 1E-3

Research Focus for 2017-2019

- Moving from screening level → detailed assessment of the key drivers for FPRAs
  - Electrical cabinets
  - Transients
  - HEAFs
  - Main control board
- Realistic modeling of fire scenario progression focusing on insights from skyline chart

Proposed Research Path Forward

- Delta: OPEX suggests that a large majority of fires do not generate damage outside the ignition source
  - Main focus on electrical cabinets, given insights from Skyline chart
- Gaps:
  - Methodology does not acknowledge the different fire growth progressions
  - The current treatment of characterizing each fire parameter independently coupled with aggressive fire growth results in a large percentage of severe fires
- Research to address gaps:
  - 1a. Develop technical basis for treating *potentially challenging (PC)* and *challenging* (CH) fires differently
  - 1b. Develop fire progression event tree to support fire quantification based on the characteristics and attributes of different ignition sources

Proposed Research Path Forward (continued)

- Delta: OPEX suggest that plant personnel routinely detect and suppress fires before growth or propagation
- Gap:
  - Personnel suppression credit only applied for continuously occupied rooms (MCR) and continuous fire watch (hotwork)
  - OPEX suggest that personnel detection and suppression is present in a wide range of ignition sources
- Research to address gap:
  - 2. Develop methods and data to credit *plant personnel suppression* more realistically in the fire scenario progression
  - Requires a realistic treatment of fire growth/progression of different ignition sources

Proposed Research Path Forward (continued)

- Delta: Fire PRAs assume every fire leads to a plant trip, when in actuality it is dependent on the ignition source and severity of fire*
- Gap:
  - Fire PRA analyses make an implicit assumption that every fire leads to a plant trip
- Research to address gap:
  - 3. Develop guidance for applying a conditional probability of plant trip following a fire event

*NEI Fire PRA Roadmap (2010), 1 in 8 fires resulted in a reactor trip or significant power reduction

Proposed Research Path Forward (continued)

- Delta: OPEX suggests that not all HEAFs present the same damage profile
- Gap: Current guidance treat all HEAF similarly (e.g., same frequency, scenario progression, and damage profile)
- Research to close gap:
  - 4. Accurately reflect HEAF ignition trends and properly account for the plant impact due to HEAF
    - Update frequencies to reflect split between safety and non-safety equipment
    - Update consequence model to account for the circuit protection effectiveness and other factors that may affect the duration of a HEAF event

Proposed Research Path Forward (continued)

- Delta:
  - OPEX suggests that majority of transient fire events are transient ignition sources that do not propagate through transient combustibles
  - OPEX indicates that a number of transient fires are small ignition sources that are not capable of growth or propagation
- Gap: Most general transient fires are treated with the same fire scenario progression
  - No consideration between transient ignition source and transient combustibles
  - No consideration of different types of transients ignition source or combustibles in different plant locations
- Research to close gap:
  - 5. Develop a more detailed characterization of transient fires on a plant area basis
    - Enhance methodology and provided additional heat release rates

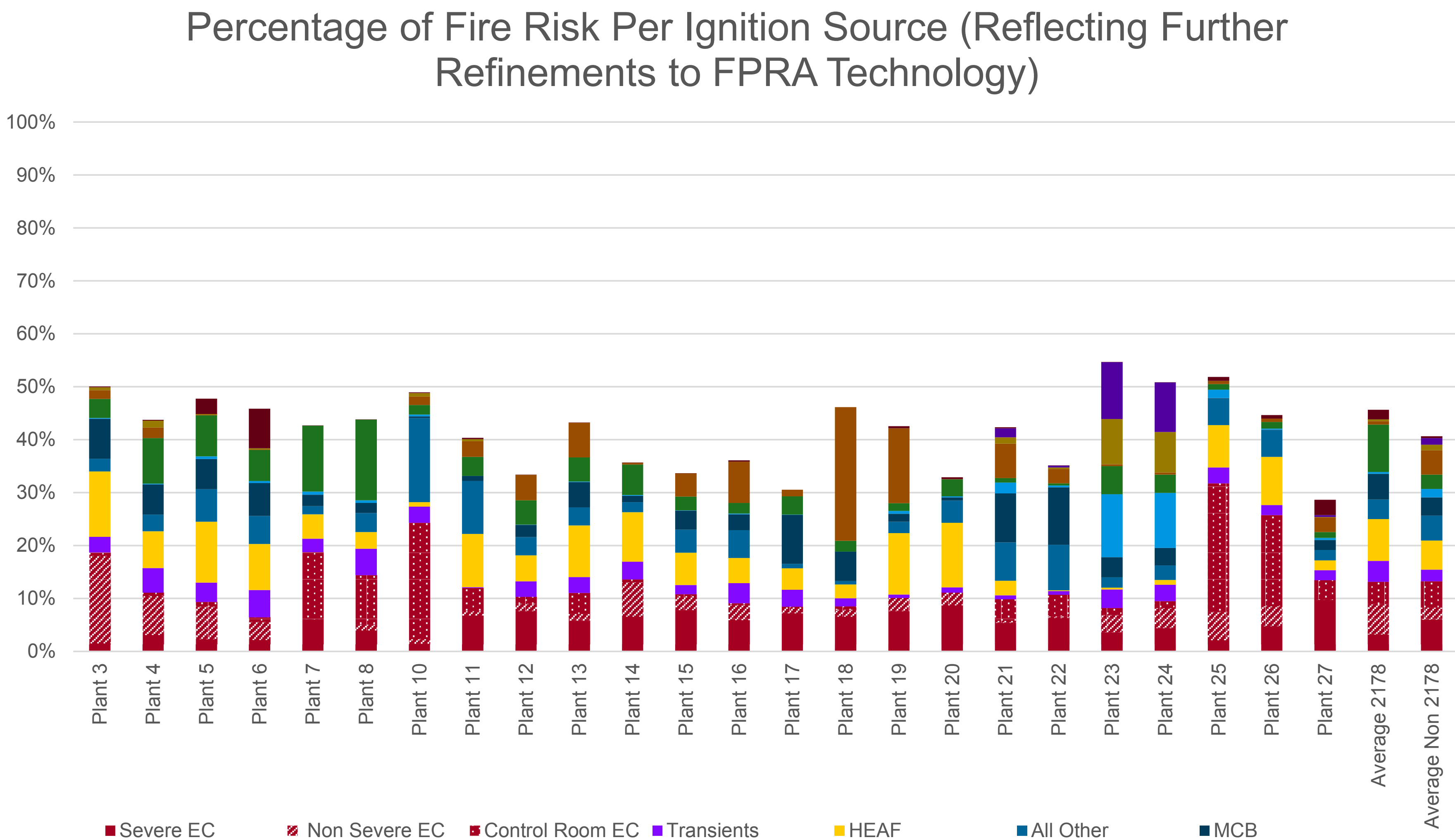
Proposed Research Path Forward (continued)

- Delta: OPEX suggests that control room fires have not propagated outside the sub-component level ignition source given rapid intervention by operators
- Gap: Damage profile is conservative given difficulty of identifying targets within the main control board.
- Research to close gap:
  - 6. Revise fire growth/spread model for the main control board (MCB)
    - OPEX suggests that fires are limited to the ignited components inside the MCB with no propagation.
      - Develop heat release rate profile specific to the MCB
      - Remove conservatism in existing approach
      - Properly apportion generic frequencies throughout the board

Sensitivity Studies vs. Current Resolution Path

- In progress research or current FAQs
  - Cabinet to cabinet propagation
  - Obstructed radiation
  - Radiation ZOI
  - Cable tray ignition at 500°C (FAQ 16-011)
  - Transient combustibles within a PAU (FAQ 14-007)
  - Incipient Detection (FAQ 17-012)
  - HEAF NSP (FAQ 17-013)
- Others
  - Reduce NSP floor from 1E-3 to 1E-5
  - Cable fire spread
- Research plan
  - Revised fire growth curves (1a, 1b, 2, 5, and 6)
  - Updated EC NSP curve (1a, 1b, and 2)
  - HEAF event propagation beyond ZOI (4)
  - Transient fire characterization (5)

Future Skyline



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Key Takeaways

- Skyline exercise in early 2017 provided a "reset" used to re-calibrate the path forward for fire PRA research
- The results from Fire PRAs are not reflective of the operating experience
  - Screening level analysis and methodology assumptions may be inappropriately biasing our understanding of fire risk contributors
- Skyline results and comparison with OPEX provides motivation to continue working to refine fire PRA methodology
- Research is especially critical in the following areas:
  - Electrical cabinets
  - Transients
  - HEAFs
  - Main control board

Together…Shaping the Future of Electricity

NRC Draft Fire Research Plan FY 2018 – FY 2022

Mark Henry Salley, P.E.
Branch Chief, Fire & External Hazards Analysis Branch
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Oct 5, 2017

Purpose

- Share NRC Draft Fire Research Plan
  - Solicit Comments & Discussion
    - Are we doing the right research?
    - Are the tasks properly prioritized?
  - Explore Opportunities for Joint Research
    - EPRI
    - NIST & Other Federal
    - International
      - OECD/NEA
      - Japan S/NRA/R

Background

- March 22, 1975, Browns Ferry Fire
  - Near-miss accident/Wake-up call
  - NRC active Fire Research Program
    - NUREG/BR-0364 "A Short History of Fire Safety Research Sponsored by NRC 1975-2008"
- Safety
  - Fire is a significant risk-driver at many NPPs
  - Focus on the important issues

Context

- 5 Year Plan: FY 2018 – FY 2022
- Use as a Catalogue:
  - Best Estimate of Current and Near Term Future Research Needs
  - Attempt to be Foreword Looking
  - Understand not all Tasks will be funded/worked
  - Work with other NRC Offices and Stakeholders
  - Revision/Update can be performed as warranted

Current Tasks (1-2)

- Task 1: NUREG/CR-7150 Joint Assessment of Cable Damage and Quantification of Effects from FIRE
  - Partnered with EPRI
  - Volume 1 & 2 issued, Volume 3 in Publication
    - Volume 1 needs revised to incorporate information learned in Volume 2 & 3
- Task 2: Small Scale Instrument Circuit Testing
  - Testing performed by Sandia with support from EPRI
  - NUREG/CR is Complete and in Publishing

Current Tasks (3 - 4)

- Task 3: NRC Post-Fire Safe-Shutdown Inspector Training
  - Training Modules are Complete
    - Brookhaven, Sandia & RIII support
    - Self Paced Computer Based Training
    - Finalize NUREG-1778 Handbook
- Task 4: Electrical Cable Coatings
  - Testing performed by Sandia & NIST
    - Reports Drafted
    - Open Question on RII "Off Color" Coating

Current Tasks (5 - 8)

- Task 5: Obstructed Plume ZOI
  - Partnered with EPRI & NIST
  - CFD Modeling exercise
- Task 6: Electric Pump & Motor HRR
  - Partnered with EPRI & NIST
  - Develop more realistic HRR
- Task 7: Cabinet to Cabinet Propagation
  - Partnered with EPRI & NIST
  - Develop more realistic analysis methods
- Task 8: Transient Fire HRR
  - Partnered with EPRI & NIST
  - Develop more realistic HRR

Current Tasks (9)

- Task 9: High Energy Arcing Faults (HEAF)
  - Partnered with OECD/NEA, S/NRA/R, & NIST
    - Currently 8 member Countries
  - Phase 1 Testing Complete
    - International Report Issued
    - Information Notice 2017-04 Issued
    - Aluminum HEAF entered into Generic Issue Program
  - NRC Proposing Phase 2 Testing OECD/NEA
    - US Industry invited to join program
    - Test Plan issued for Public Comment

Current Tasks (10 - 13)

- Task 10: MCR Abandonment HRA
  - Partnered with EPRI
  - Qualitative Analysis Complete Published
  - Quantitative Analysis in process
    - Need Pilot Sites
- Task 11: Vetting Panels
- Task 12: FAQ Support
- Task 13: Fire PRA Training
  - Partnered with EPRI
  - 12 Years
  - Strong Attendance

Current Tasks (14 - 16)

- Task 14: Fire Growth Methodology Revision
  - Partnered with EPRI, NIST, Sandia
  - Develop realistic growth profiles
- Task 15: Refine Bin 15 Electrical Cabinets
  - Partner with EPRI
  - Improved realism fire ignition frequency
  - Improved realism non-suppression probabilities
- Task 16: PRISME III
  - Partnered with OECD/NEA
  - Improved realism fire dynamics
  - Improve Fire Model V&V

Potential Tasks for Discussion

- Very Early Warning Fire Detection Systems
  - Is there any remaining work?
    - Testing?
    - Operating Experience?
    - HRA?
- Instrument Circuits Spurious Operation
- In Cabinet Spurious Operation
- Digital I&C
- Knowledge Management
- Other NRC – Industry Needs?