ATF Fuel Fragmentation, Relocation, and Dispersal Consequences Workshop

July 30, 2025

July 31, 2025

Meeting Logistics

- Meeting visuals and audio are through MS Teams.
- Participants are in listen-only mode until the discussion and public feedback period. During which, we will first allow in-person attendees to participate, then allow remote attendees to un-mute.
  - Remote attendees should utilize the hand raised feature in MS Teams, if possible.
- This is an Observation Meeting. Public participation and comments are sought during specific points during the meeting.
  - NRC will consider the input received but will not prepare written responses.
  - No regulatory decisions will be made during this meeting.
- This meeting is being recorded.

Meeting Purpose

- Provide an update on recent research results regarding FFRD consequences.
- Provide feedback on industry's proposed licensing pathways for power uprates.
- Provide feedback on EPRI's and NEI's proposed white papers on coolability and reporting requirements, respectively.
- Provide an opportunity for members of the public to ask questions of the NRC staff.
- The NRC is not looking for feedback on the Increased Enrichment (IE) Rulemaking.

Proposed Workshop Schedule

- Workshop 1 (May 20-21)
  - Fuel Fragmentation, Relocation, and Dispersal
  - Recriticality
- Workshop 2 (Today)
  - Exemptions
  - Coolability
  - Reporting
- Workshop 3
  - Transition Break Size
- Workshop 4
  - Materials
  - Inspections

Agenda – Day 1

Time	Topic	Speaker
8:00 am	Welcome	NRC
8:05 am	Opening Remarks	NRC, NEI
8:10 am	Advanced Fuels and Power Uprates: Licensing Pathways	NEI, Constellation
8:50 am	NRC Studies on Post-FFRD Consequences	NRC
9:30 am	Rule Exemption Under 10 CFR 50.12	Duke
10:00 am	Plant Hatch Potential Pilot Approach for EPU	Southern
10:30 am	Break	
10:40 am	Assessing Debris Bed Coolability	EPRI
11:00 am	Coolability of Dispersed Fuel	EPRI
11:30 am	LOCA Reporting	NEI, Dominion
12:00 pm	Adjourn	NRC

Topic times are estimated based on the participation level and presentation length.

Agenda – Day 2

Time	Topic	Speaker
9:00 am	Welcome	NRC
9:05 am	Discussion	
10:30 am	Break	
10:40 am	Discussion	
11:45 am	Public Comment Period	
11:55 am	Closing Remarks	NRC, NEI
12:00 pm	Adjourn	NRC

Topic times are estimated based on the participation level and presentation length.

Opening Remarks

ADVANCED FUELS & POWER UPRATES: LICENSING PATHWAYS

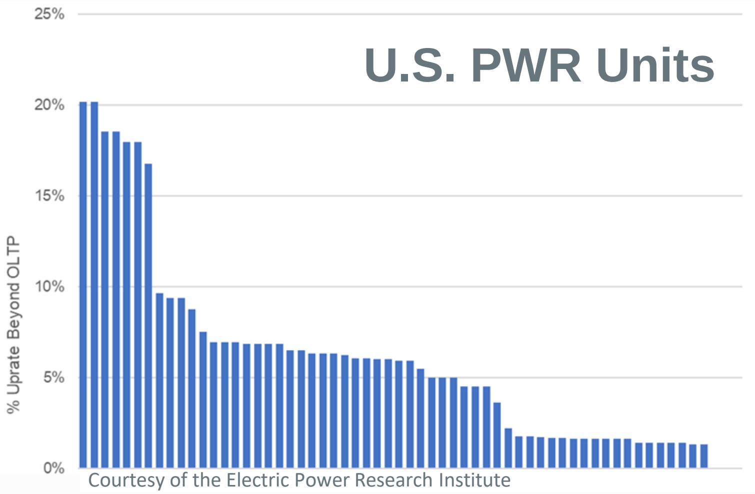
Al Csontos
Director, Fuels
Baris Sarikaya
Principal Engineer, Constellation

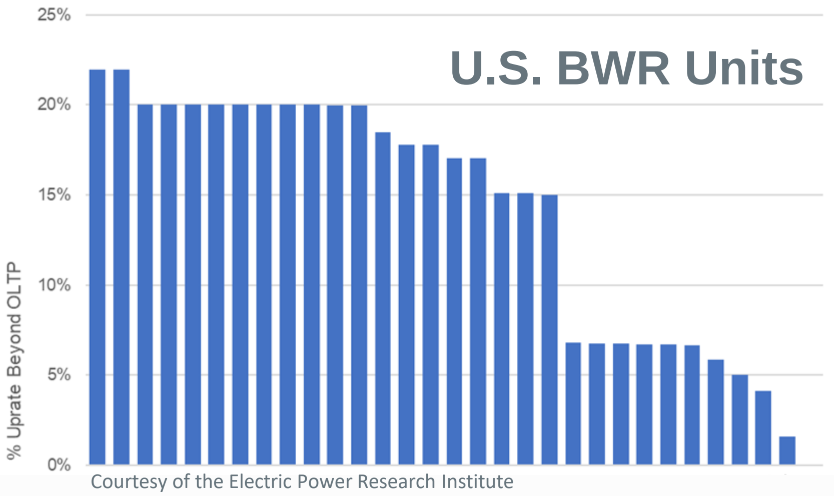
July 30, 2025

NEI NUCLEAR ENERGY INSTITUTE

Power Uprates: Background

- NRC approved over 170 power uprates
- Nearly all U.S. plants have uprated
- Swedish units uprated to beyond 125% of the Original Licensed Thermal Power

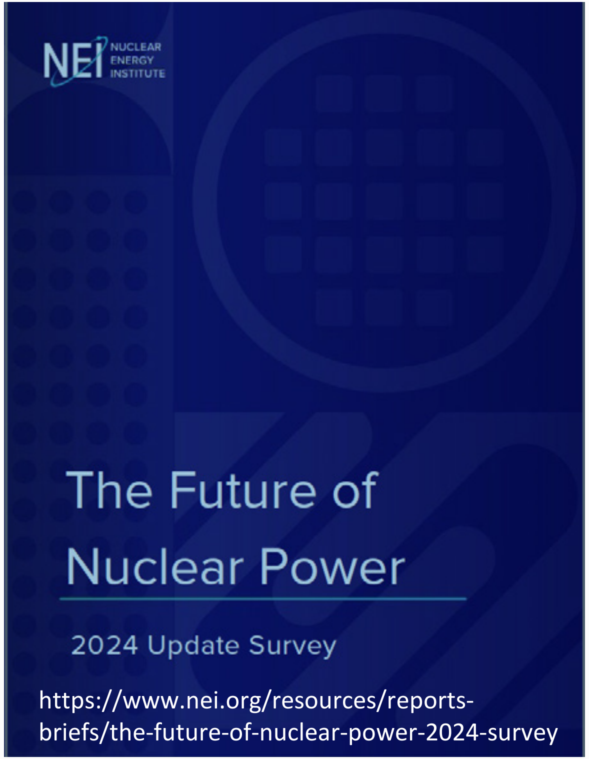




- Opportunities exist for additional uprates
- Domestic/international precedent >120%
- EO direction for larger uprates sooner
- OB3 tax credits incentivize uprates

Power Uprates: Current Aspirations

- Tax credits and EOs incentivize new clean energy production (uprates and restarts)
- 2024 NEI Future of Nuclear Power Survey:
  - **>70% of sites** have a level of interest/planning for one or more power uprates with a combined capacity **increase of 3 GWe**
  - **Nearly 50%** of sites have varying interest/plans for one or more of the enabling changes (ATF/ LEU+, Extended Fuel Cycles, and/or RI LOCA)
- NRC/Industry workshops in line with intent of ADVANCE Act and Executive Orders



Executive Orders (EO) Impacting Uprates

- Reinvigorating the Nuclear Industrial Base:
  - Funding for Restart, Completion, Uprate, or Construction
  - Expedite and promote production and operation of nuclear energy
  - DOE facilitate 5 GWe additional capacity through uprates by 2030
  - Expanding the Nuclear Energy Workforce
- Ordering the Reform of the NRC:
  - Decrease regulatory barriers, fixed licensing deadlines, limits on credible risks, wholesale revision of NRC regulations by 2026, etc.
  - To meet the 5 GWe by 2030 goal, licensing efficiencies needed

Nuclear Provisions in the OB3 Act

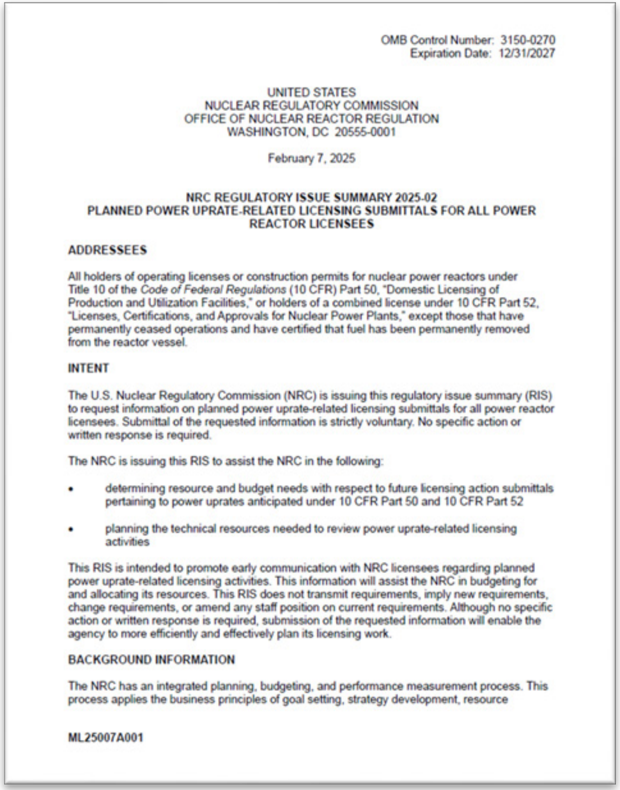
- The One Big Beautiful Bill Act (OB3):
  - Tax credits for nuclear generation similar with additional bonus:
    - Zero-Emission Nuclear Production Credit - 45U
    - Clean Electricity Production Credit - 45Y
    - Clean Electricity Investment Credit - 48E
  - Added path to qualify for the 10% energy community bonus (45Y)
  - Full tax credits only if BOC before 2034 (45Y/48E)
- Incentivize additional capacity through nuclear generation:
  - Power uprates, plant restarts, and new builds

Flexibility for Power Uprates - 45Y/48E

- Treasury regulations provide only limited methods to determine capacity for purposes of calculating tax credit value for uprates
- **OB3 expands flexibility**, allowing capacity increases to be measured in any reasonable manner, including:
  - Interconnection agreements or other filings with FERC, **NRC**, or similar entities
  - Reports by an independent professional engineer
  - RTO/ISO reports showing capacity increase
  - Any other method provided by the Treasury Secretary

NRC Regulatory Issue Summary

- NRC Regulatory Issue Summary 2025-02: Planned Power Uprate Licensing Submittals
  - Determining and planning for NRC resource and budget needs to power uprate submittals
- RIS intent to promote early communication on power uprate-related licensing activities
- Utility voluntary responses complete:
  - Proprietary responses included along with publicly available information (next slide)
- NEI generic response submitted as well



OMB Control Number: 3150-0270
Expiration Date: 12/31/2027

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

February 7, 2025

NRC REGULATORY ISSUE SUMMARY 2025-02
PLANNED POWER UPRATE-RELATED LICENSING SUBMITTALS FOR ALL POWER REACTOR LICENSEES

ADDRESSEES

All holders of operating licenses or construction permits for nuclear power reactors under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," or holders of a combined license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," except those that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to request information on planned power uprate-related licensing submittals for all power reactor licensees. Submittal of the requested information is strictly voluntary. No specific action or written response is required.

The NRC is issuing this RIS to assist the NRC in the following:

- determining resource and budget needs with respect to future licensing action submittals pertaining to power uprates anticipated under 10 CFR Part 50 and 10 CFR Part 52
- planning the technical resources needed to review power uprate-related licensing activities

This RIS is intended to promote early communication with NRC licensees regarding planned power uprate-related licensing activities. This information will assist the NRC in budgeting for and allocating its resources. This RIS does not transmit requirements, imply new requirements, change requirements, or amend any staff position on current requirements. Although no specific action or written response is required, submission of the requested information will enable the agency to more efficiently and effectively plan its licensing work.

BACKGROUND INFORMATION

The NRC has an integrated planning, budgeting, and performance measurement process. This process applies the business principles of goal setting, strategy development, resource

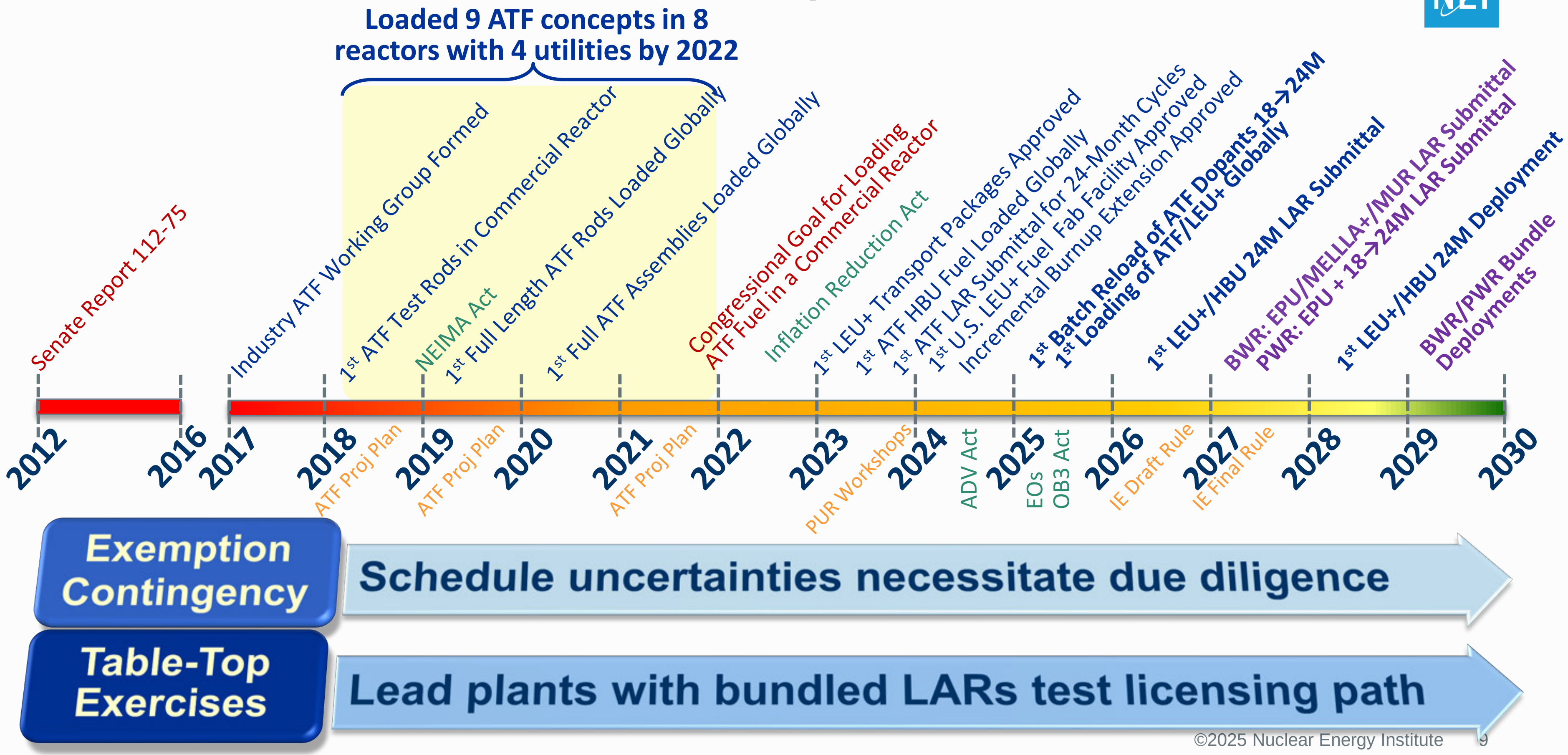
ML25007A001

Advanced Fuels/Uprates – Public Info.

# of Reactors	Name of Plant	Descritption of LAR	Projected Submittal date*	Projected Completion date	Power Ascension Date with PUR/Fuel Cycle Changes	Additional details and comments
1	Dominion – Millstone U3	24-Month Cycles	Q2-4 2026	Q4 2027	Q2 2028	(1) Address SFP storage requirements; (2) 50.68 Exemption; (3) Update dose analyses for LEU+/HBU with potential 50.67 exemption; (4) Address COLR method changes (internal and fuel vendor methods) to support LEU+/HBU
1	Wolf Creek	MUR using LEFM's	Q4 2026		Q3 2028	
2	Duke - Brunswick U1 & U2	MUR	Q1 2027	Q4 2027	U1 Q1 2028 U2 Q1 2029	
2	Southern Co. - Hatch U1 & U2	Extended Power Uprate	Q2 2027		U2 Q1 2029 U1 Q1 2030	MELLLA+ in Q2 2027
2	PSEG - Salem U1 & U2	Stretch Power Uprate with MUR	Q2 2027	Q4 2028	U1 Q4 2029 U2 Q2 2029	(1) Implement FSLOCA Methodology; (2) RG 1.236 Ejected Rod Analysis; (3) Adopt Gap Release Fractions from RG 1.183 R1; (4) Use ADOPT Fuel Pellet Type; (5) Non-LOCA PAD5 Fuel Rod Code; (6) DVR Based MUR
2	Duke- McGuire U1 & U2	Extended Power Uprate	Q2 2027	Q4 2028	U1 Q4 2029 U2 Q4 2030	(1) Address updates to Duke Energy in-house methodologies and (2) transition to increased enrichment, high burnup fuel
1	Energy Northwest- Columbia Generating Station	Extended Power Uprate	Q2 2028	Q4 2030	Q2 2031	Combined LAR application for EPU and MELLLA+
1	Duke - Catawba U1	Extended Power Uprate	Q2 2028	Q4 2029	U1 Q2 2031	(1) Address updates to Duke Energy in-house methodologies and (2) transition to increased enrichment, high burnup fuel.
2	Southern Co. - Farley U1 & U2	Extended Power Uprate	Q3 2028		U2 Q2 2031 U1 Q4 2031	(1) AST RG 1.183 Rev 1 in Q3 2026; (2) SFP Criticality Analysis in Q2 2027; (3) Other Fuel/Methodology Updates in Q4 2029; (4) 24-mo fuel cycle in Q1 2032
2	Southern Co. - Vogtle U1 & U2	Extended Power Uprate	Q4 2028		U1 Q4 2030 U2 Q2 2031	(1) AST RG 1.183 Rev 1 in Q2 2025; (2) SFP Criticality Analysis in Q2 2026; (3) Other Fuel/Methodology Updates in Q2 2027; (4) 4 RCCAs and 24-month fuel cycle in Q2 2030

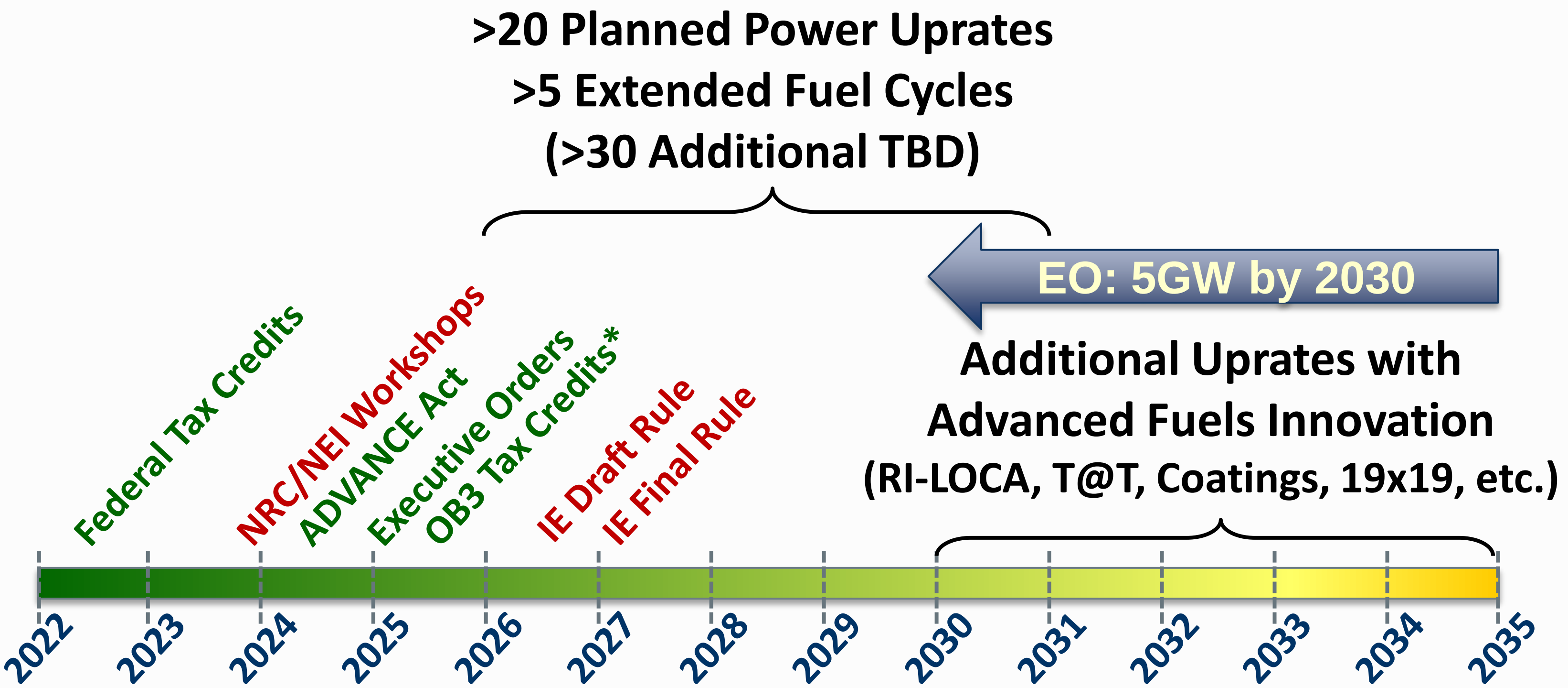
* Submittal dates/strategy subject to change

Overall Advanced Fuels/Uprates Milestones



Uprates and Advanced Fuels Synergy

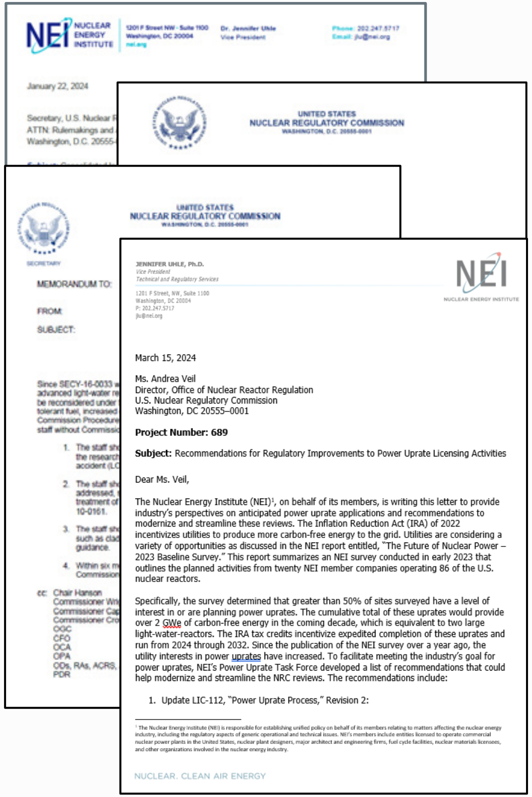
NEI



* Begin construction by the end of 2033

Power Uprate Regulatory Improvements

- NEI recommendations for modern efficient reviews
- Updated NRC uprate review timeliness targets:
  - MUR: 9➡6 m, SPU: 12➡9 m, and EPU: 18➡12 m
- NRC/NEI Uprate Review Efficiency Workshops:
  - Flexibility for sequential, combined concurrent reviews
    - PWR: Uprates with 24M cycles (LEU+/HBU)
    - BWR: EPU + MELLLA+ + MUR
  - NRC graded approach guidance:
    - Binning of technical issues (L/M/H)
  - NEI/EPRI AI Power Uprate Licensing Round Robin



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March 15, 2024

Ms. Andrea Veil
Director, Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

Project Number: 689

Subject: Recommendations for Regulatory Improvements to Power Uprate Licensing Activities

Dear Ms. Veil,

The Nuclear Energy Institute (NEI)[1], on behalf of its members, is writing this letter to provide industry's perspectives on anticipated power uprate applications and recommendations to modernize and streamline these reviews. The Inflation Reduction Act (IRA) of 2022 incentivizes utilities to produce more carbon-free energy to the grid. Utilities are considering a variety of opportunities as discussed in the NEI report entitled, "The Future of Nuclear Power – 2023 Baseline Survey." This report summarizes an NEI survey conducted in early 2023 that outlines the planned activities from twenty NEI member companies operating 86 of the U.S. nuclear reactors.

Specifically, the survey determined that greater than 50% of sites surveyed have a level of interest in or are planning power uprates. The cumulative total of these uprates would provide over 2 GWe of carbon-free energy in the coming decade, which is equivalent to two large light-water-reactors. The IRA tax credits incentivize expedited completion of these uprates and run from 2024 through 2032. Since the publication of the NEI survey over a year ago, the utility interests in power uprates have increased. To facilitate meeting the industry's goal for power uprates, NEI's Power Uprate Task Force developed a list of recommendations that could help modernize and streamline the NRC reviews. The recommendations include:

1. Update LIC-112, "Power Uprate Process," Revision 2:

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PWR Bundling Example

Uprates and Advanced Fuels Transition

- Combined license applications for plant specific aims:
  - ATF/LEU+/HBU to achieve uprates and/or 24-month fuel cycles (PWR)
- Analytical synergy for combined review efficiencies:

Power Uprates

- Chapter 15 Analysis:
  - AOOs/LOCA/ATWS/SBO/Dose
  - Stability (BWR)
  - SG tube rupture (PWR)
  - Locked rotor (PWR), etc…
- Chapter 4 / 6
- Fuel Pool Storage

Similar

Advanced Fuel Transition

- Chapter 15 Analysis:
  - AOOs/LOCA/ATWS/SBO/Dose
  - Stability (BWR)
  - SG tube rupture (PWR)
  - Locked rotor (PWR), etc…
- Chapter 4 / 6
- Fuel Pool Storage

Improved licensing efficiencies with reduced iterative & duplicative reviews

BWR Bundling Example

Analytical and Review Efficiencies for Power Uprate Submittals

Baris Sarikaya
Principal Engineer, Constellation

July 30-31, 2025

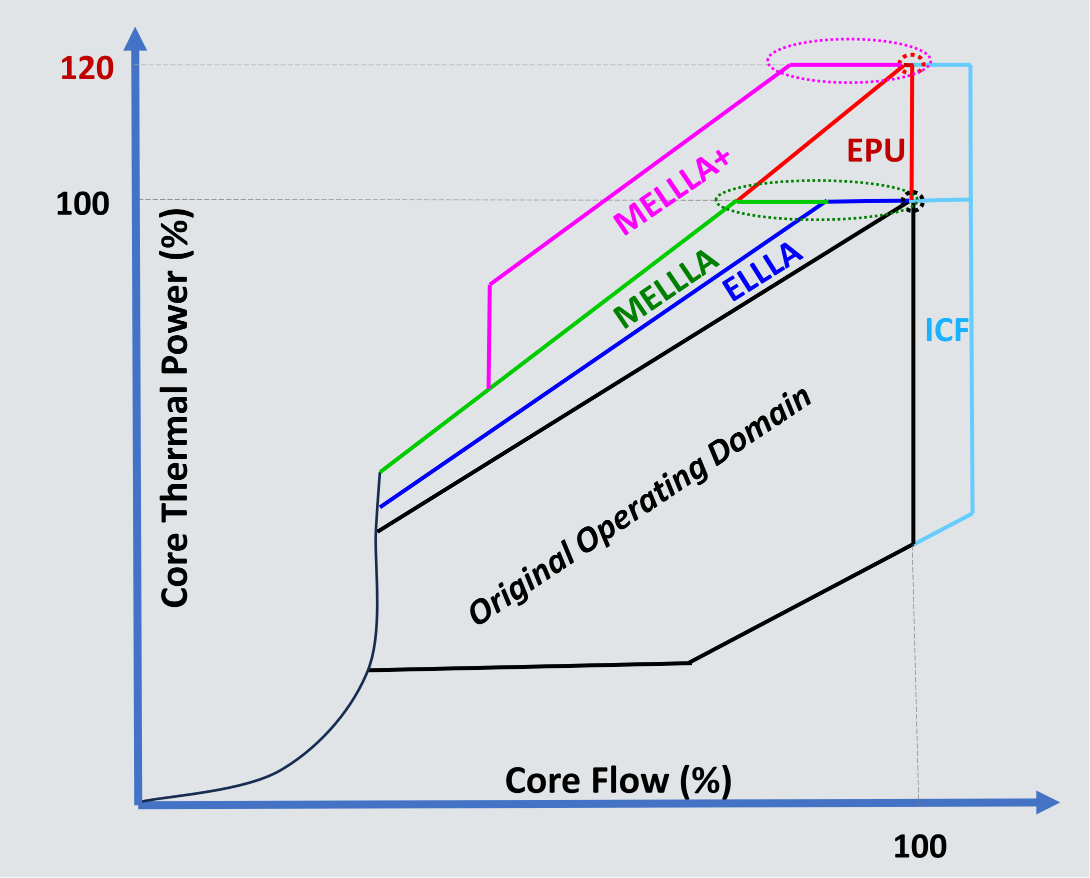
NUCLEAR ENERGY INSTITUTE

Combined License Applications

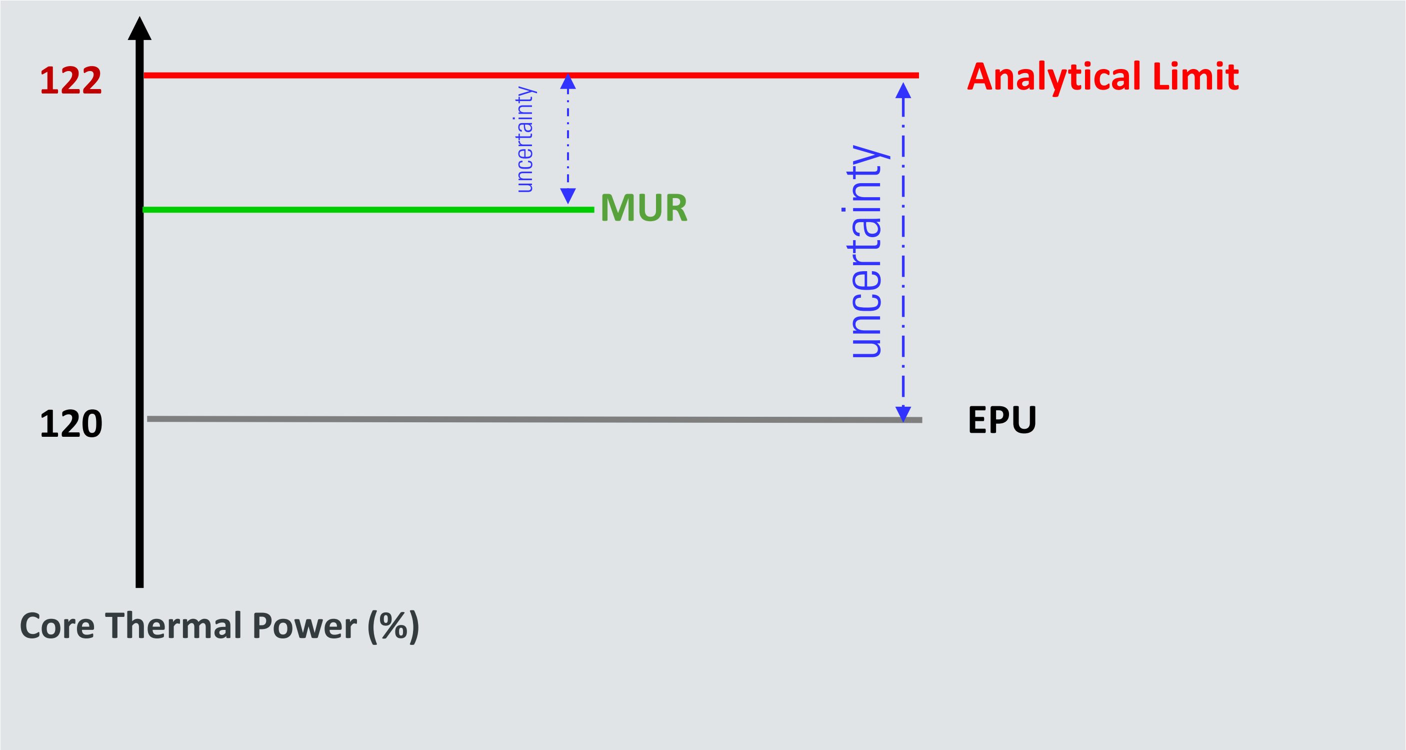
- EPU & MELLLA+ Case Study → Implementation Example

	Nine Mile Unit 2	Peach Bottom
EPU	31	23
MELLLA+	22	18
MUR		9
Review Time (months)	53	50
Implementation Time (months)	76	62

BWR Operating Domain – MELLLA+



BWR Operating Domain - MUR



Combined License Applications

EPU & MELLLA+ Case Study → Why EPU & MELLLA+

Combined Applications

- Previous example: > 72 months with 3 submittals in series
- Combined Application: < 18 months with 3 submittals combined.

Review Time (months)	Nine Mile-2	Peach Bottom
EPU	31	23
MELLLA+	22	18
MUR		9
Review Time (m)	53	50
Implementation Time (m)	76	62

Review time (months)	Combined Application Review
EPU	
MELLLA+	
MUR	
Total (m)	12 - 18

FFRD

- BWRs do **not** need high burnup / increased enrichment for Power Uprates
  - Stay within the current **62 GWd/MTU** limit
  - FFRD is not a concern for BWR Power Uprates (**burnup ≤ 62 GWd/MTU**)

- Currently, **risk-informed LOCA** implementation is very difficult for BWRs
  - TBS determination
    - TBS determination is very difficult for BWRs
  - TBS applicability
    - About half of the BWR fleet is Small Break Limited
    - Power Uprates will increase the number of SB Limited BWRs
    - Risk-informed LOCA is not applicable to SB Limited BWRs

Need for Risk Informed-TBS

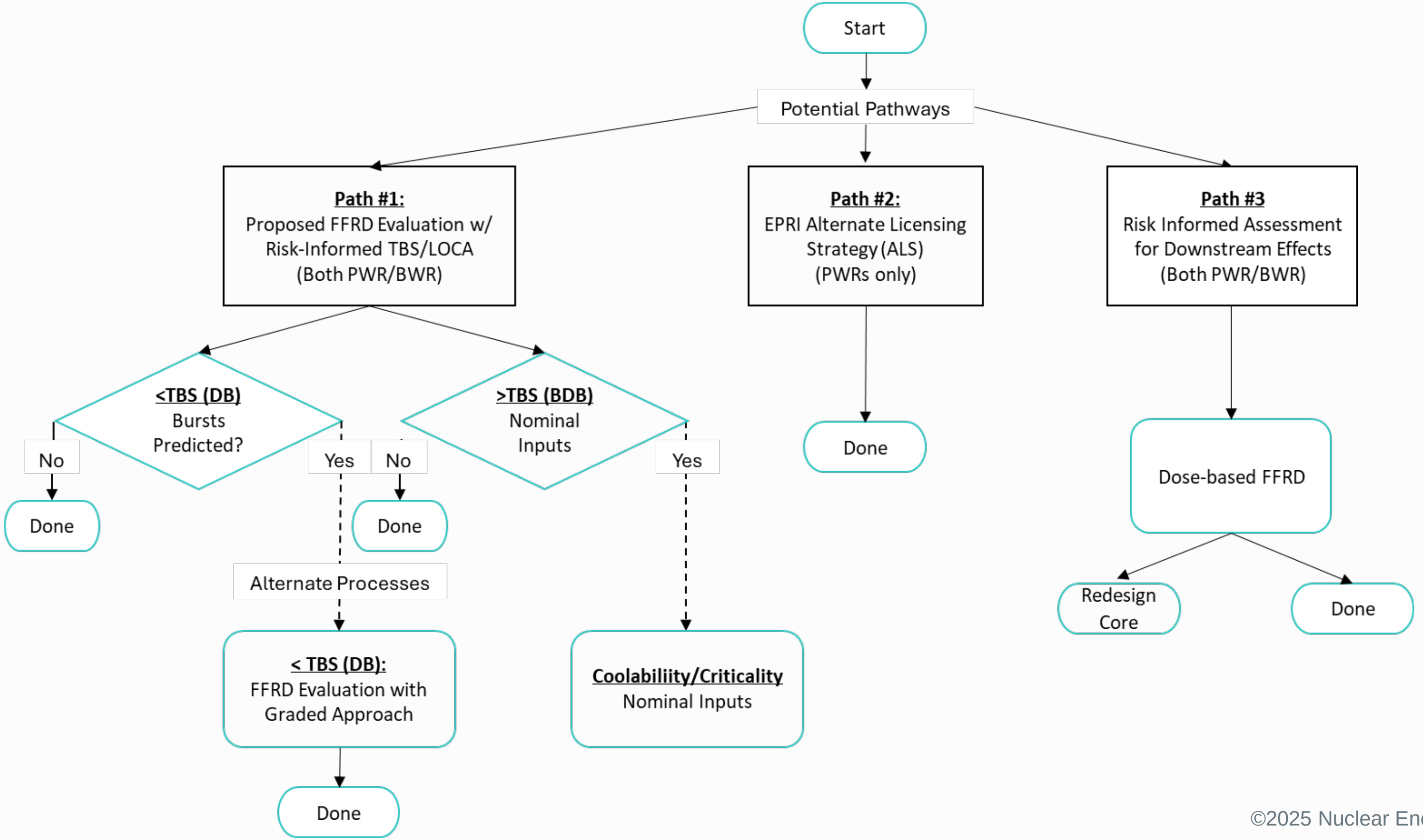
1. **RI-TBS** enables BWRs (and PWRs) a path for RI-LOCA adoption:
   - RI-TBS also helps address FFRD for burnup beyond 62 GWd/MTU
2. **For uprates, expectations for addressing FFRD burnup limits?**
3. **FFRD could** be an unresolved issue **non-ALS PWRs**
4. **RG 1.183 R2:**
   - Need to address FFRD?

RI TBS helps address all these issues

Risk Informed-TBS Implementation

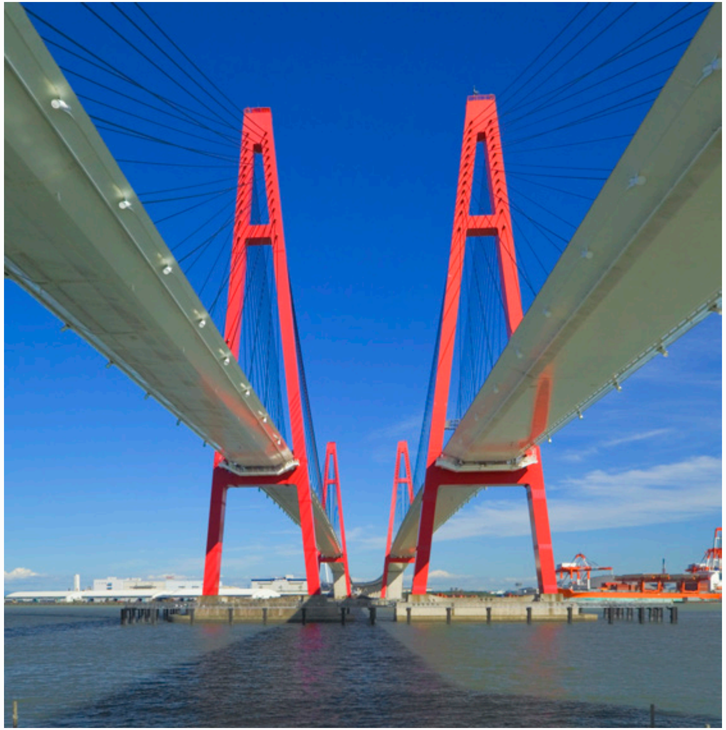
1. **Flexible** language for **RI-TBS** implementation enables BWRs (and PWRs) a path for addressing FFRD:
   - NRC adoption of Industry's RI-TBS white paper
   - RI-TBS topical report submission at a later date
2. **However,** if **FFRD Burnup limits change** or **RG 1.183 R2 requires addressing FFRD:**
   - RI-TBS solution will be needed

Flexible Pathways



Path Forward

- Industry plans for >3GWe power uprates
- EO: Facilitate 5GWe with uprates by 2030
- Regulatory predictability and stability key to meet bundled LAR review timeliness
- Due diligence for exemption path for early adopters and potential schedule delays
- Table-top exercises for a lead BWR and PWR to test bundled LAR licensing path
- Increased market confidence:
    - Meeting costs and schedules
    - Meeting NRC review timeliness goals



Questions?

Questions

NRC Studies on Post-FFRD Consequences

Fuel Fragmentation, Relocation, and Dispersal (FFRD) Workshop

July 30, 2025

Scott Krepel

Branch Chief, Nuclear Methods & Fuel Analysis (NRR/DSS/SFNB)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Credit where credit is due…

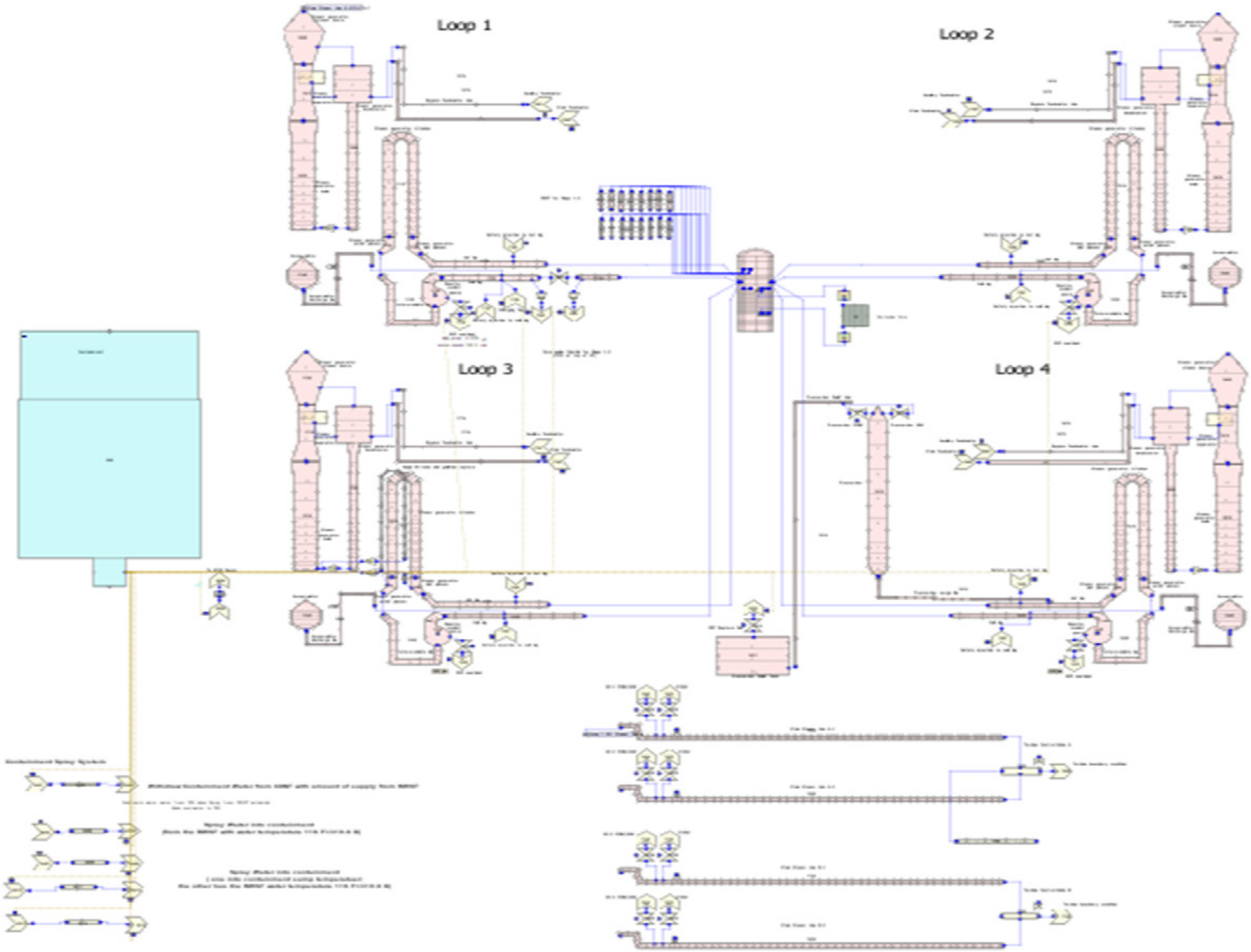
This presentation is based on analytical work done by the Office of Nuclear Regulatory Research:

- James Corson, RES/DSA/FSCB
- Joseph Staudenmeier, RES/DSA/CRAB-I

Post-FFRD Consequences Overview

- Thermal hydraulics (T-H) model & core model
- Typical licensing assumptions vs best estimate
- Recap – fuel dispersal estimates
- Fuel dispersal modeling
- Post-FFRD core coolability results
- Summary

TRACE model



Core Design Model

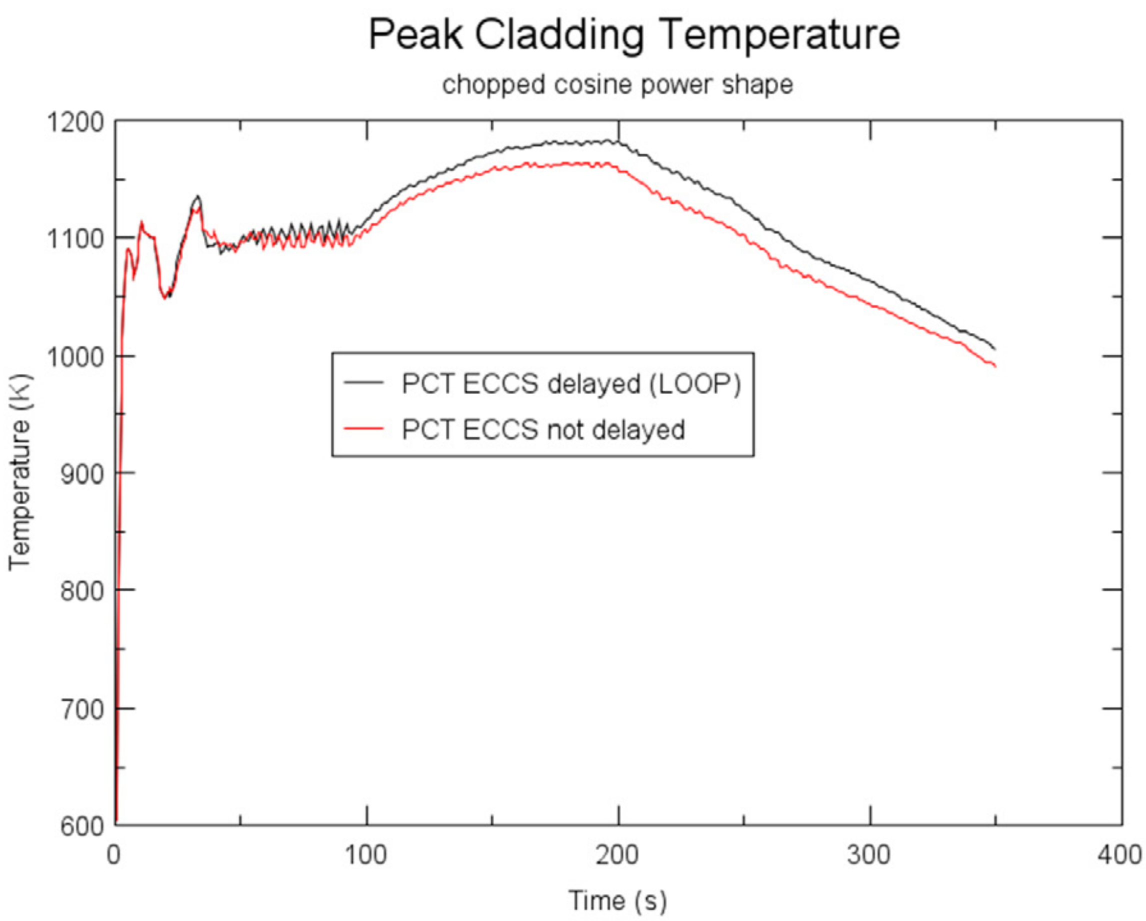
	H	G	F	E	D	C	B	A
8	5.95 200	H-6	5.95 200	N-4	F-4	B-8	5.95 200	K-6
9	F-8	5.95 200|24	J-9	5.95 200|24	F-2	5.95 200	5.95 200|20	N-9
10	5.95 200	M-10	5.95 200	E-7	5.95 200|24	B-5	5.95 104	P-12
11	D-3	5.95 200|24	G-5	D-13	G-2	5.95 200	6.20 200|8	J-4
12	D-10	P-10	5.95 200|24	P-9	C-13	5.95 200	N-5	
13	H-14	5.95 200	L-14	5.95 200	5.95 200	6.60 156	R-9	
14	5.95 200	5.95 200|20	5.95 104	6.20 200|8	L-3	G-1		
15	F-6	J-13	D-2	M-4				

6.20 200|8	Enrichment IFBA|WABA
H-6	Previous Cycle Location

From ORNL/TM-2020/1700, "Full Core LOCA Safety Analysis for a PWR Containing High Burnup Fuel," Oak Ridge National Laboratory, 2020.

Current Licensing vs Best Estimate

- LOOP vs non-LOOP



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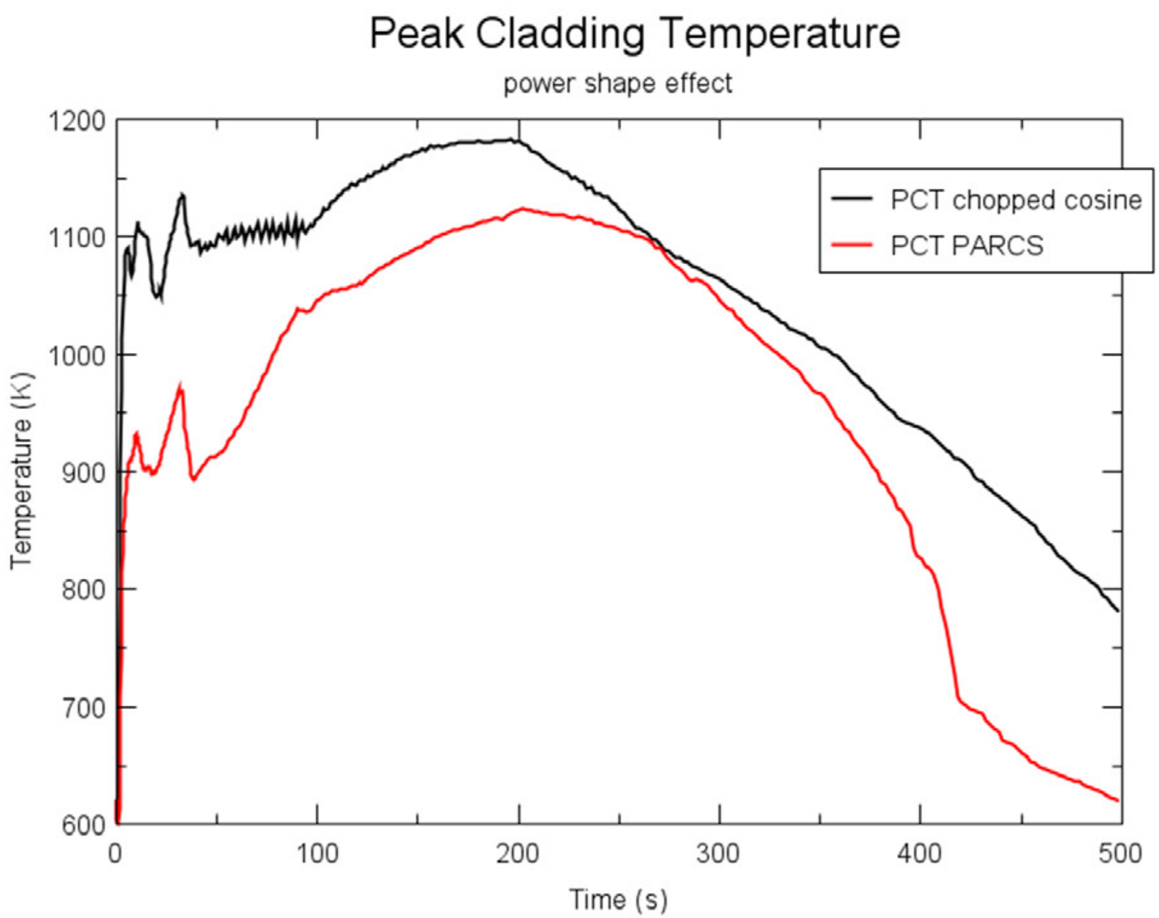
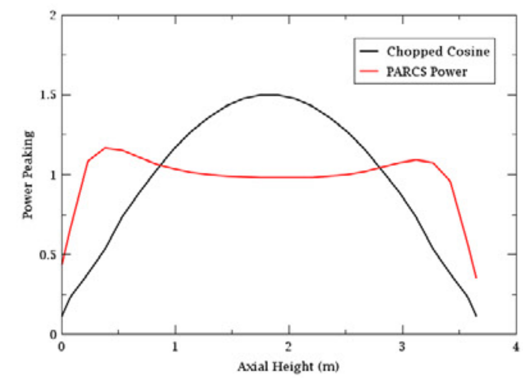
Current Licensing vs Best Estimate

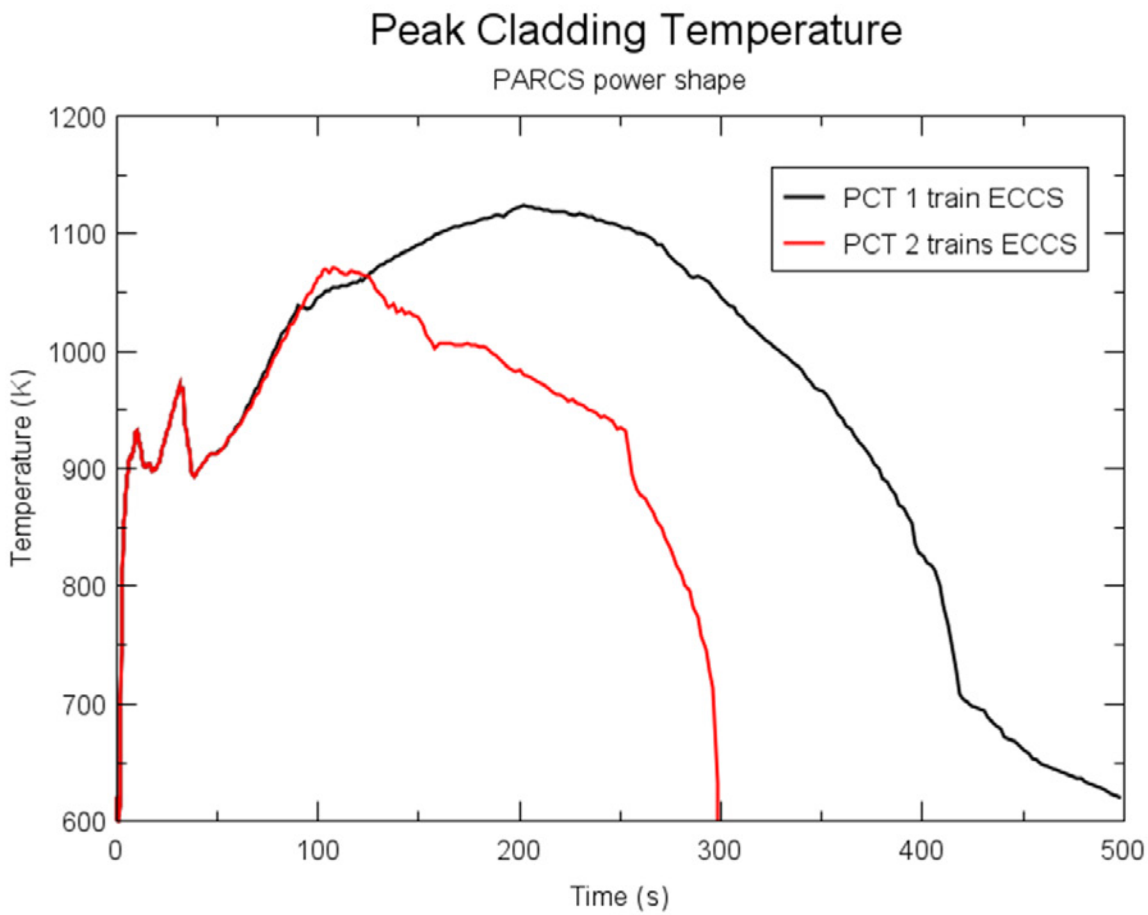
- Chopped cosine vs double-peak from PARCS





Current Licensing vs Best Estimate

- ECCS availability (1 train vs 2 trains)



Fuel Dispersal Estimates

	PARCS Power, Offsite Power Available, 2 ECCS Trains	PARCS Power, Offsite Power Available	PARCS Power, Offsite Power Unavailable	Chopped Cosine, Offsite Power Available	Chopped Cosine, Offsite Power Unavailable
FAST Peak Cladding Temperature (°C)	774	816	834	852	863
Burst Rods (% of total)	25	49	55	44	49
Second Cycle Burst Rods (% of total)	24	50	58	38	41
Dispersed Mass (RIL Model C) (kg UO_2)	1300	2000	2100	3400	3700
Dispersed Mass (RIL Model A) (kg UO_2)	700	940	980	2300	2500
Dispersed Mass (RIL Model A, single grid span) (kg UO_2)	380	530	540	1400	1500

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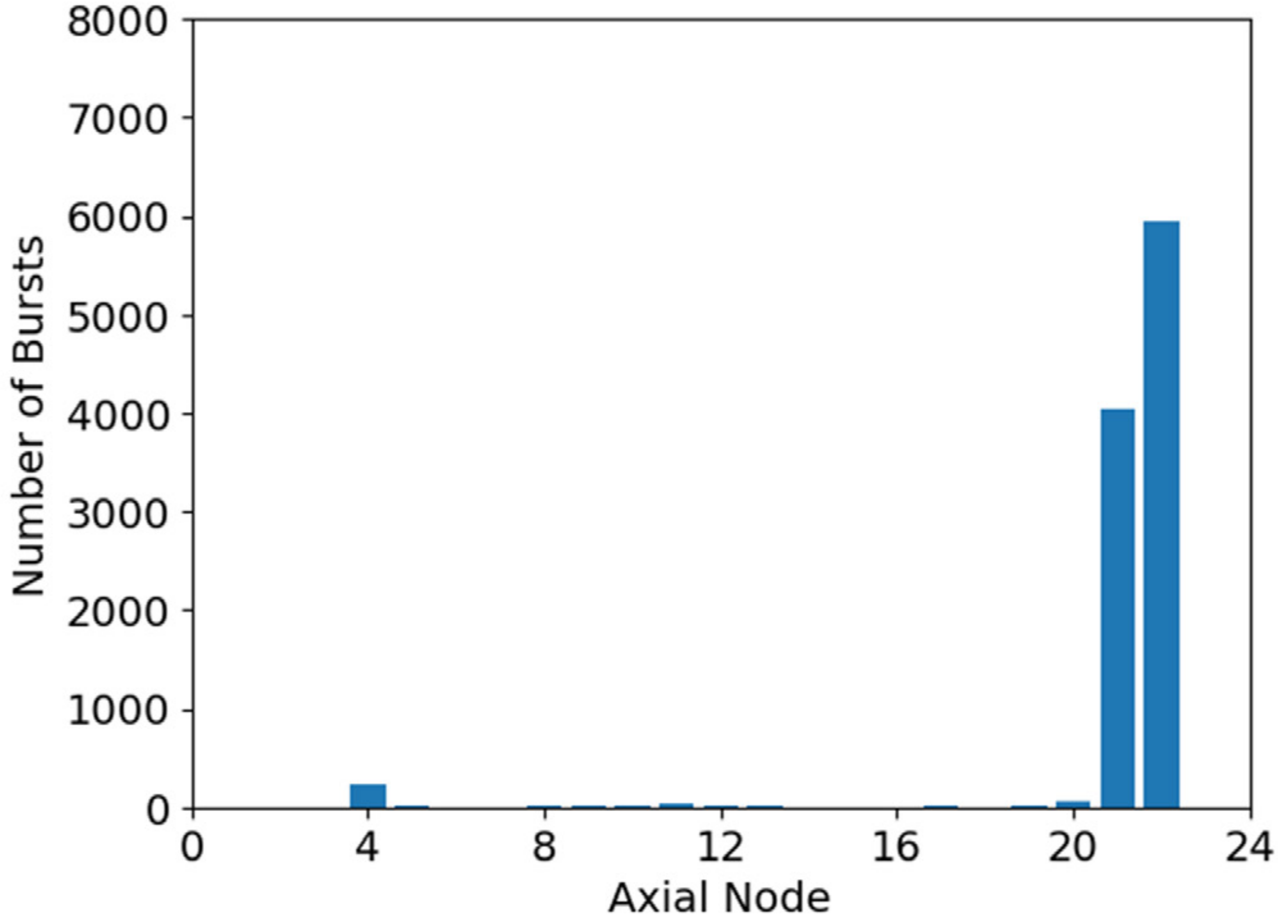
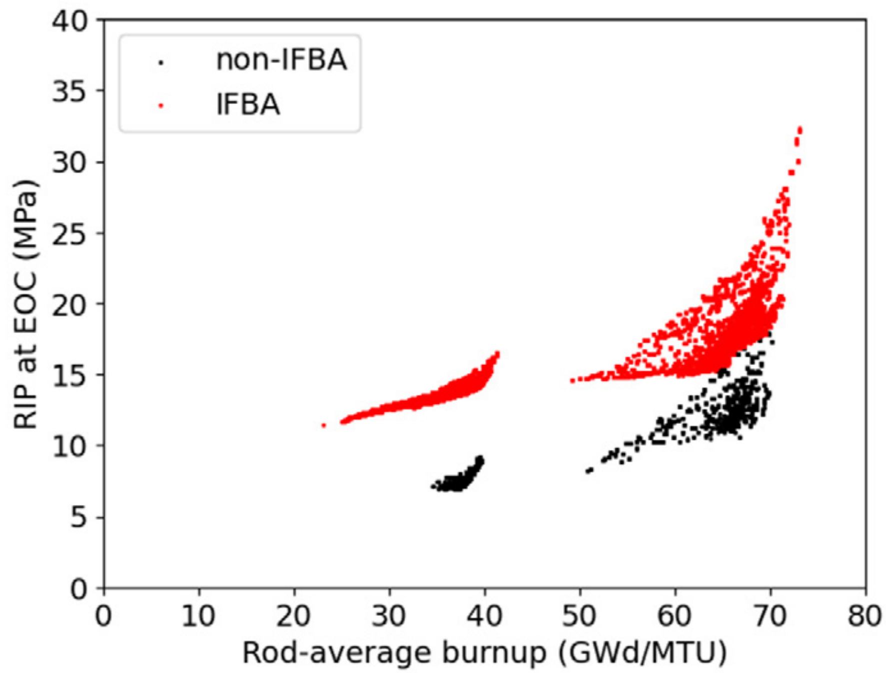
Fuel Dispersal Estimates

- Axial locations of bursts

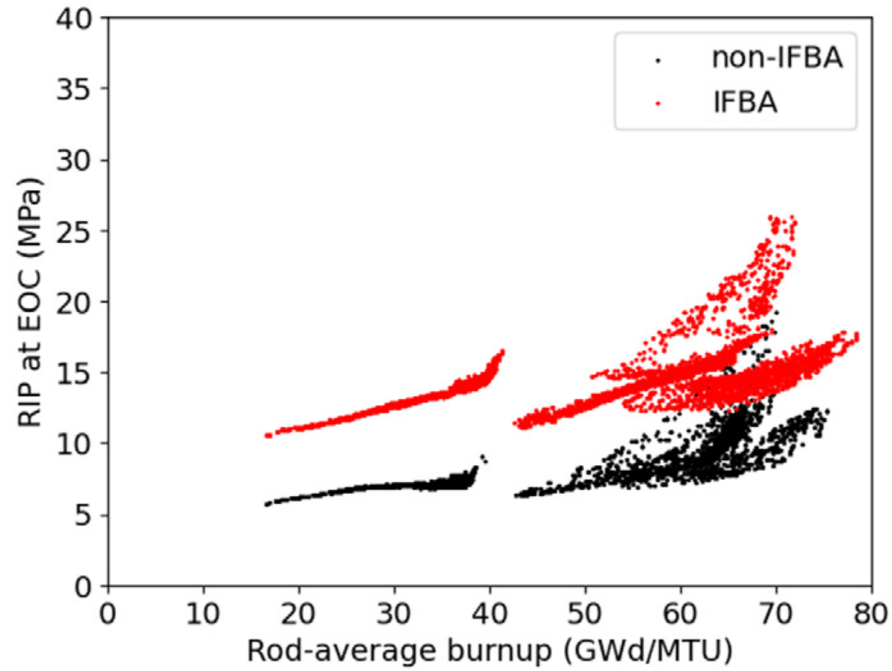


Fuel Dispersal Estimates

- IFBA vs non-IFBA rods



Burst rods



Intact rods

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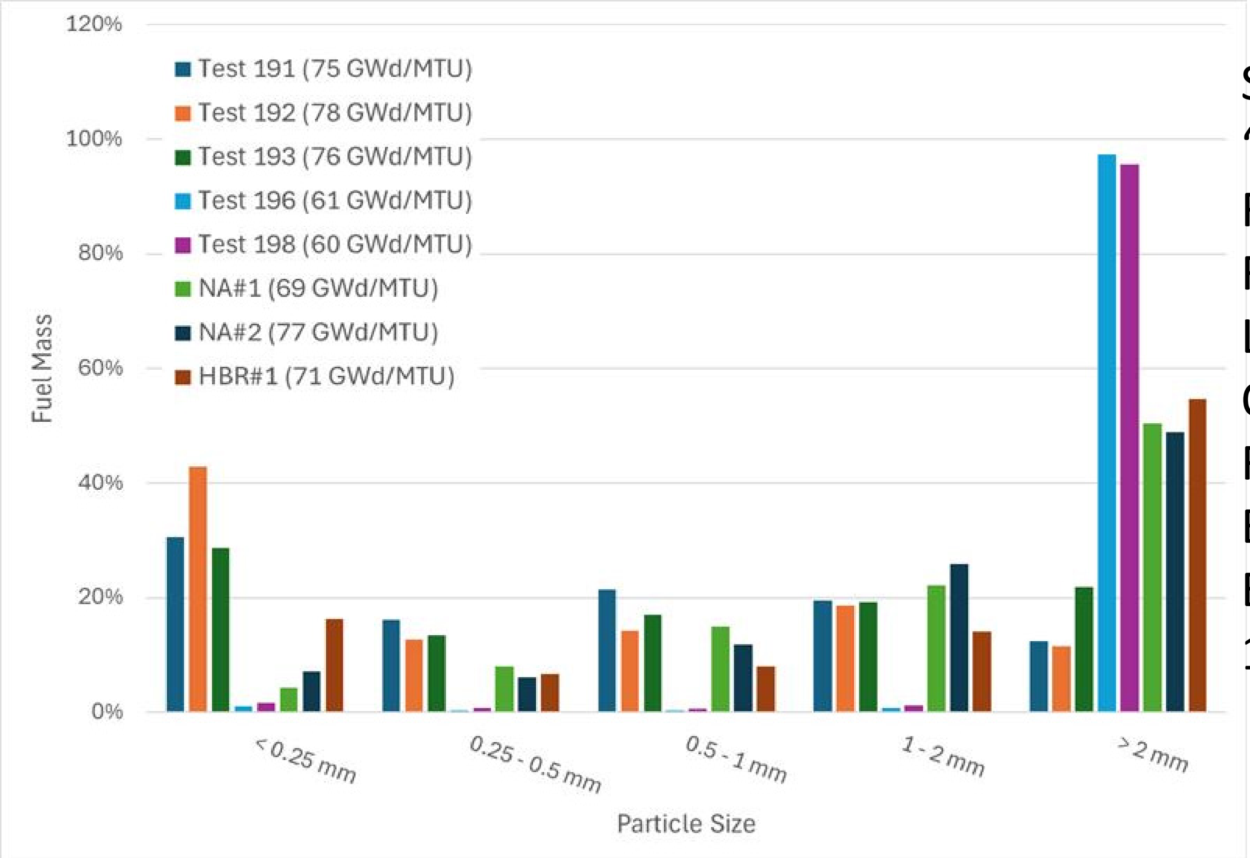
Fuel Dispersal Modeling

- Conservatively assumed all dispersed fuel forms a uniform bed on the spacer grid immediately below the axial span where most bursts occur



Studsvik data from NUREG-2160, "Post-test Examination Results From Integral, High-Burnup, Fueled Tests at Studsvik Nuclear Laboratory," August 2013
ORNL data from "Integral LOCA Fragmentation test on high-Burnup fuel, Nuclear Engineering & Design 367, (2020), 110811, ISSN 0029-5493

Fuel Dispersal Modeling

- Dispersed fuel grouped into 4 simplified dispersed-fuel beds at different axial locations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
15					13	14	15	16	17	18	19							
14			25	26	27	28	29	30	31	32	33	34	35					
13		39	40	41	42	43	44	45	46	47	48	49	50	51				14.61 kg @ 10 ft
12		55	56	57	58	59	60	61	62	63	64	65	66	67				5.9 kg @ 10 ft
11	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85			.85 kg @ 6 ft
10	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102			33.18 kg @ 4 ft
9	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119			
8	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136			
7	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153			
6	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170			
5	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187			
4		191	192	193	194	195	196	197	198	199	200	201	202	203				
3		207	208	209	210	211	212	213	214	215	216	217	218	219				
2			223	224	225	226	227	228	229	230	231	232	233					
1					239	240	241	242	243	244	245							

Fuel Dispersal Modeling

- Dispersed fuel beds modeled as 1-D hydraulic components (VALVEs) that partially close at times of bursts, as follows:
  - Lower core bursts occur at ~30 sec
  - Upper core bursts occur at ~100 sec
- Partially closed valve flow area scaled to achieve loss coefficient consistent with particle sizes of 4 mm and a porosity of 0.4 (Ergun equation)
- Does not explicitly account for de-entrainment of water droplets in flow hitting debris bed
- Earlier sensitivity studies showed heat deposition from debris bed into fluid most likely has little impact on PCT
- Local dispersal estimates bounded; global dispersal overestimated by 100+ kg

Core Design Model

<table>
<tr><th></th><th>H</th><th>G</th><th>F</th><th>E</th><th>D</th><th>C</th><th>B</th><th>A</th></tr>
<tr><td>8</td><td>5.95
200</td><td>H-6</td><td>5.95
200</td><td>N-4</td><td>F-4</td><td>B-8</td><td>5.95
200</td><td>K-6</td></tr>
<tr><td>9</td><td>F-8</td><td>5.95
200|24</td><td>J-9</td><td>5.95
200|24</td><td>F-2</td><td>5.95
200</td><td>5.95
200|20</td><td>N-9</td></tr>
<tr><td>10</td><td>5.95
200</td><td>M-10</td><td>5.95
200</td><td>E-7</td><td>5.95
200|24</td><td>B-5</td><td>5.95
104</td><td>P-12</td></tr>
<tr><td>11</td><td>D-3</td><td>5.95
200|24</td><td>G-5</td><td>D-13</td><td>G-2</td><td>5.95
200</td><td>6.20
200|8</td><td>J-4</td></tr>
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200|24</td><td>P-9</td><td>C-13</td><td>5.95
200</td><td>N-5</td><td></td></tr>
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200</td><td>L-14</td><td>5.95
200</td><td>5.95
200</td><td>6.60
156</td><td>R-9</td><td></td></tr>
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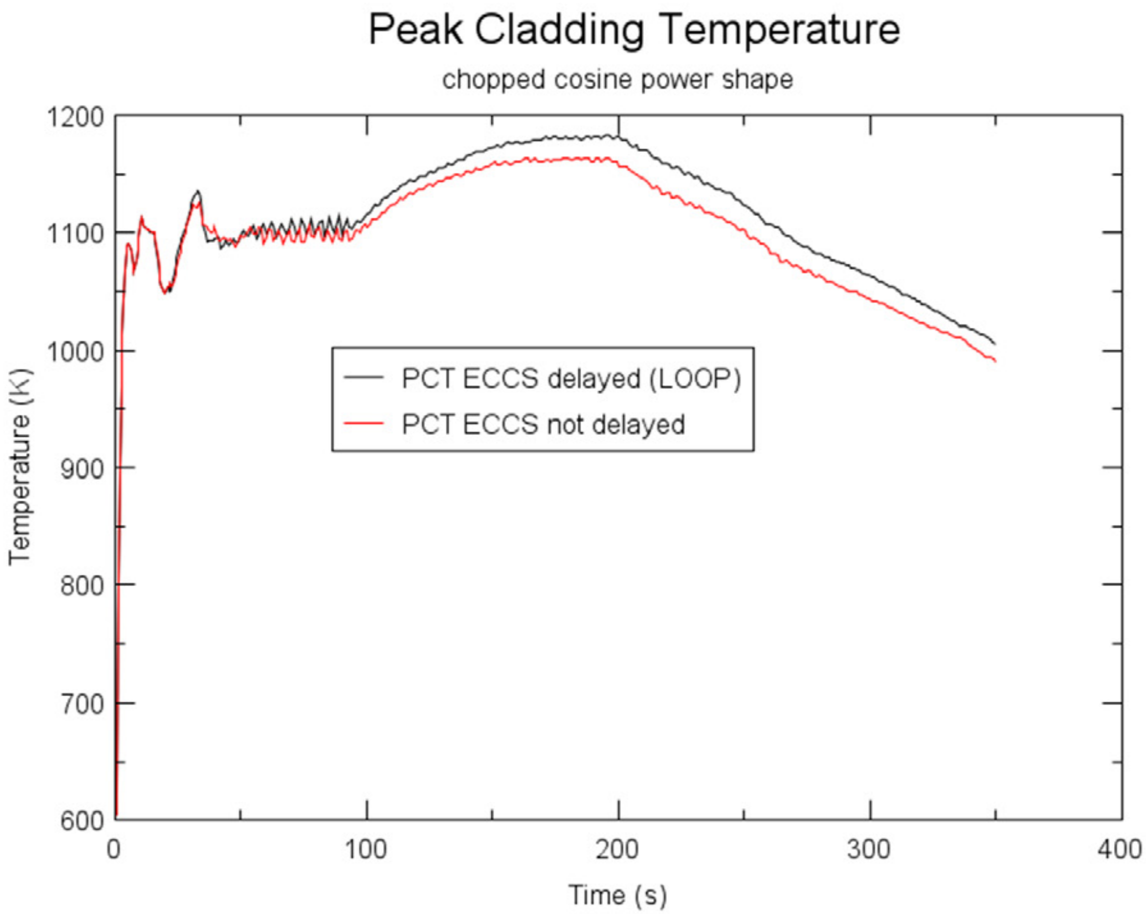
200</td><td>5.95
200|20</td><td>5.95
104</td><td>6.20
200|8</td><td>L-3</td><td>G-1</td><td></td><td></td></tr>
<tr><td>15</td><td>F-6</td><td>J-13</td><td>D-2</td><td>M-4</td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>6.20
200|8</td><td>Enrichment
IFBA|WABA</td></tr>
<tr><td>H-6</td><td>Previous Cycle
Location</td></tr>
</table>

From ORNL/TM-2020/1700, “Full Core LOCA Safety Analysis for a PWR Containing High Burnup Fuel,” Oak Ridge National Laboratory, 2020.

Current Licensing vs Best Estimate

- LOOP vs non-LOOP



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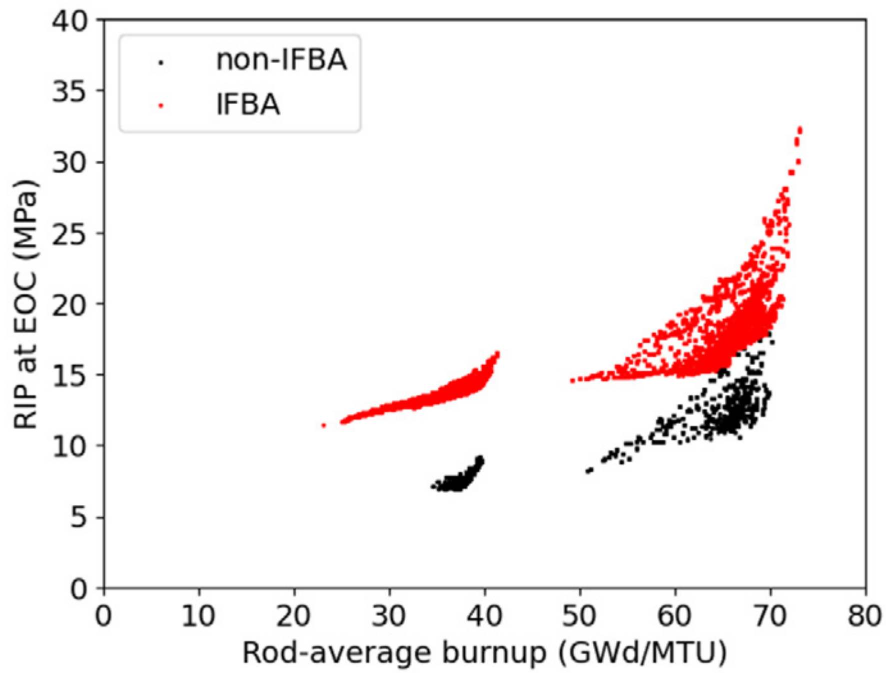
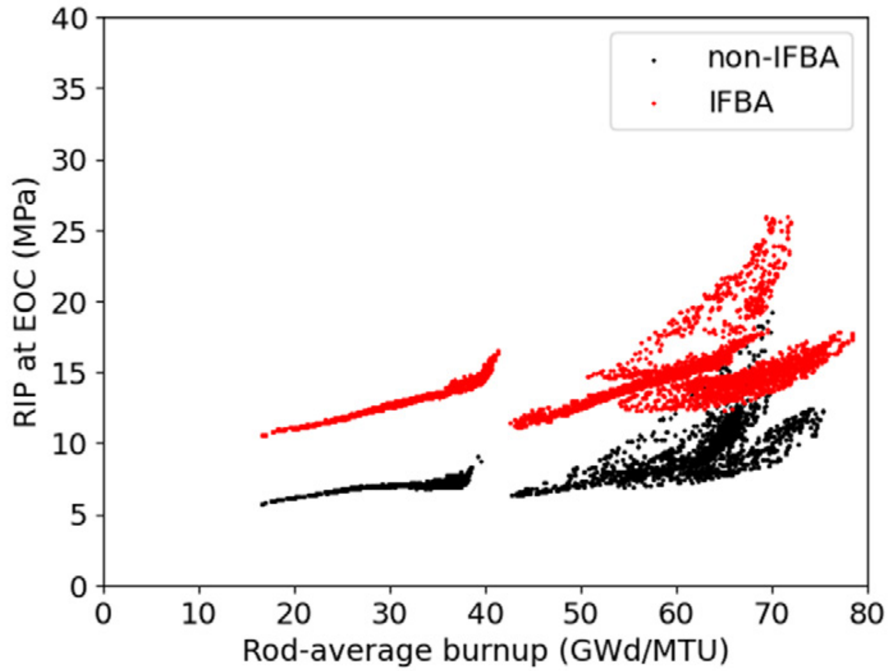
Fuel Dispersal Estimates

- IFBA vs non-IFBA rods



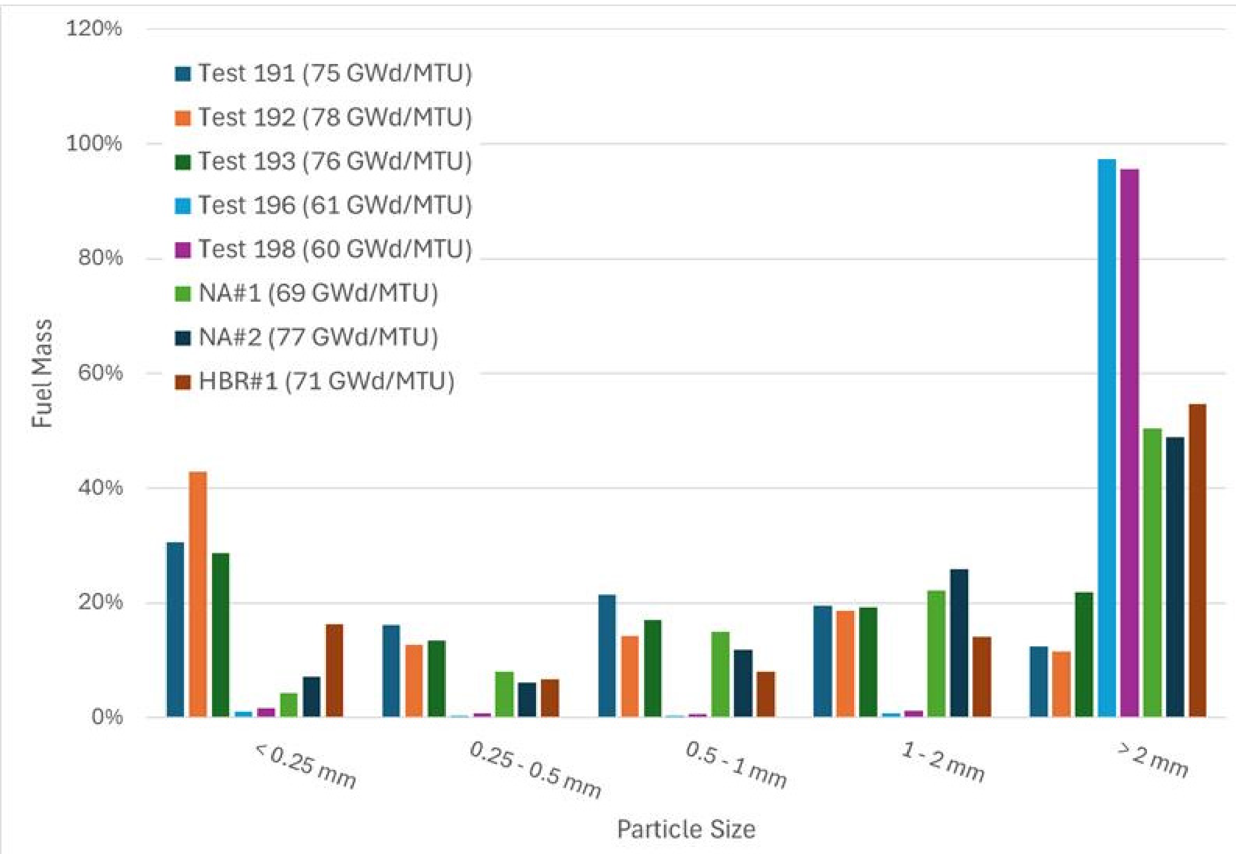
Burst rods



Intact rods

Fuel Dispersal Modeling

- Conservatively assumed all dispersed fuel forms a uniform bed on the spacer grid immediately below the axial span where most bursts occur



Studsvik data from NUREG-2160, "Post-test Examination Results From Integral, High-Burnup, Fueled Tests at Studsvik Nuclear Laboratory," August 2013
ORNL data from "Integral LOCA Fragmentation test on high-Burnup fuel, Nuclear Engineering & Design 367, (2020), 110811, ISSN 0029-5493

Fuel Dispersal Modeling

- Dispersed fuel grouped into 4 simplified dispersed-fuel beds at different axial locations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
15					13	14	15	16	17	18	19						
14			25	26	27	28	29	30	31	32	33	34	35				
13		39	40	41	42	43	44	45	46	47	48	49	50	51			14.61 kg @ 10 ft
12		55	56	57	58	59	60	61	62	63	64	65	66	67			5.9 kg @ 10 ft
11	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85		.85 kg @ 6 ft
10	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102		33.18 kg @ 4 ft
9	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119		
8	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136		
7	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153		
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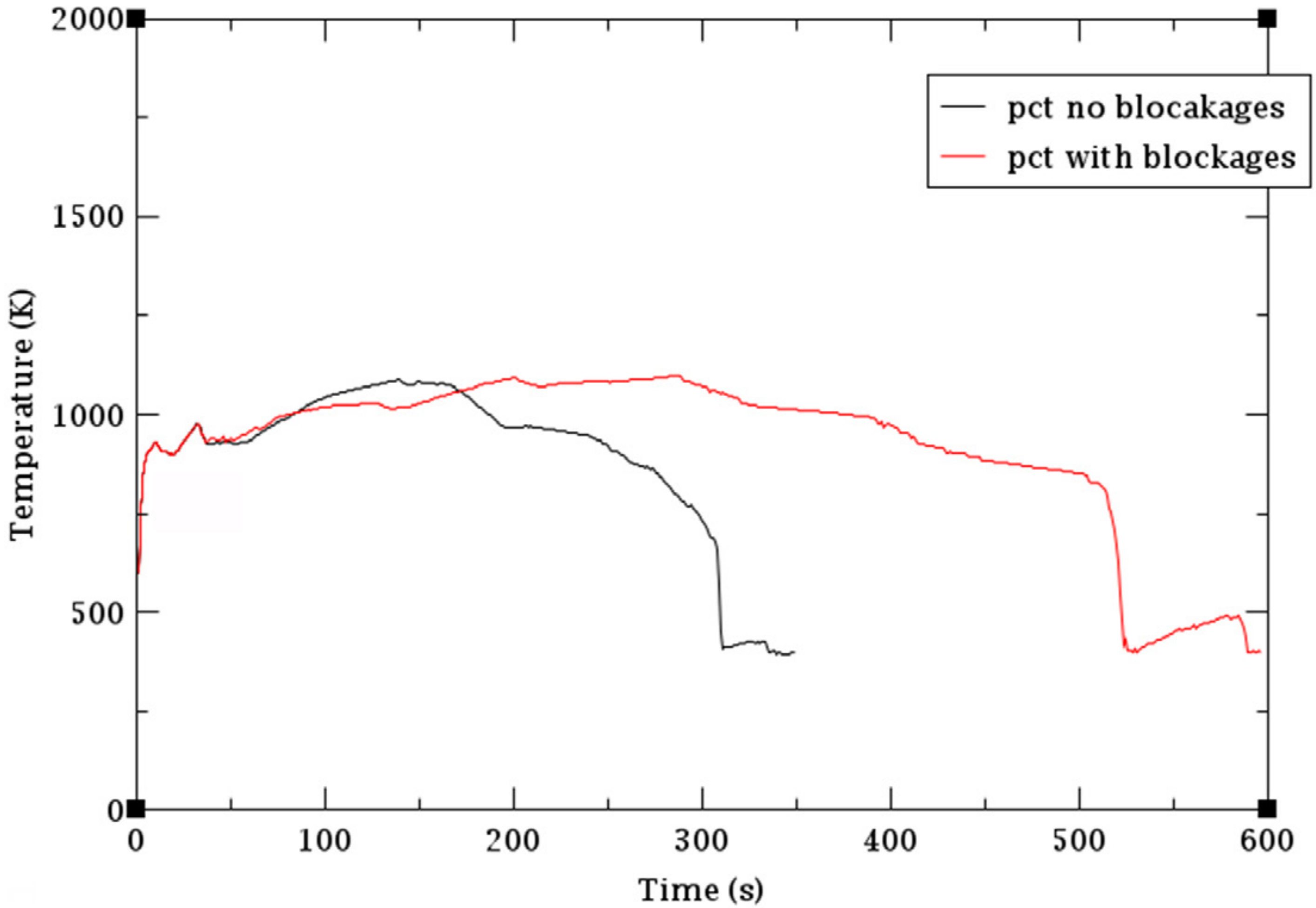
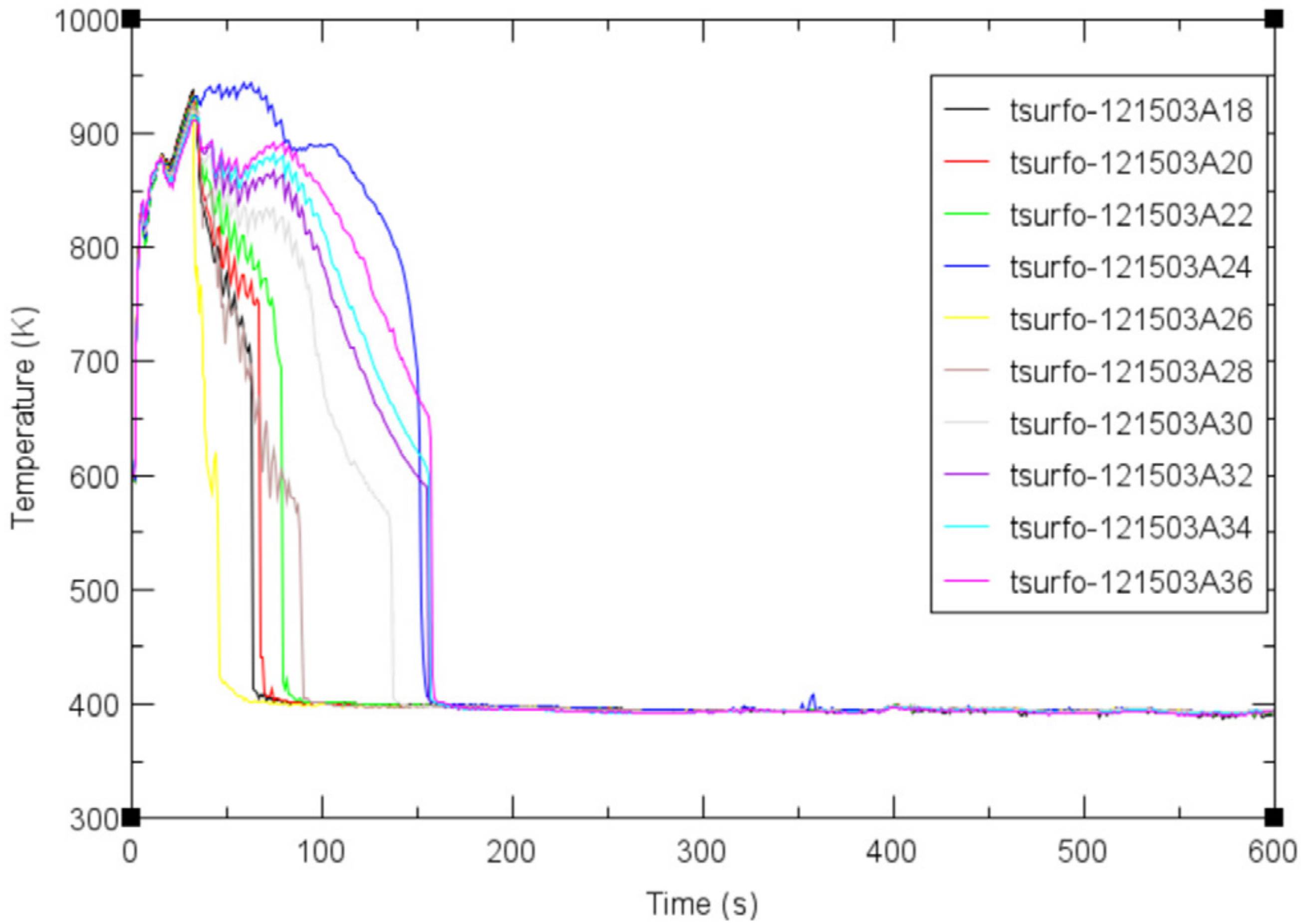
- Earlier sensitivity studies showed heat deposition from debris bed into fluid most likely has little impact on PCT
- Local dispersal estimates bounded; global dispersal overestimated by 100+ kg

Top Line PCT Results



Detailed Inspection of Results

- Lower elevation blockages don't impact top line PCT



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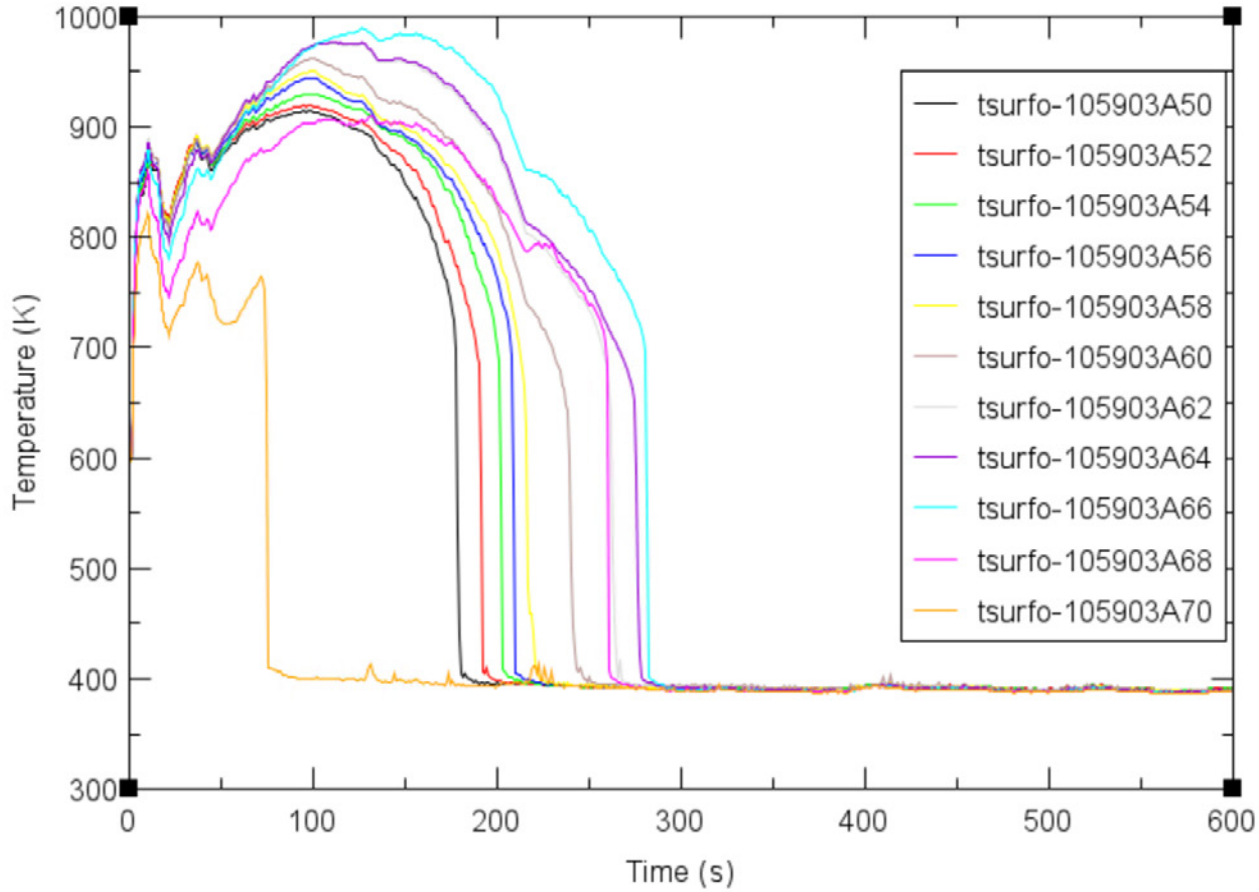
Detailed Inspection of Results

- Blockages in adjacent fuel assemblies do not have a significant effect on PCT for highest power fuel



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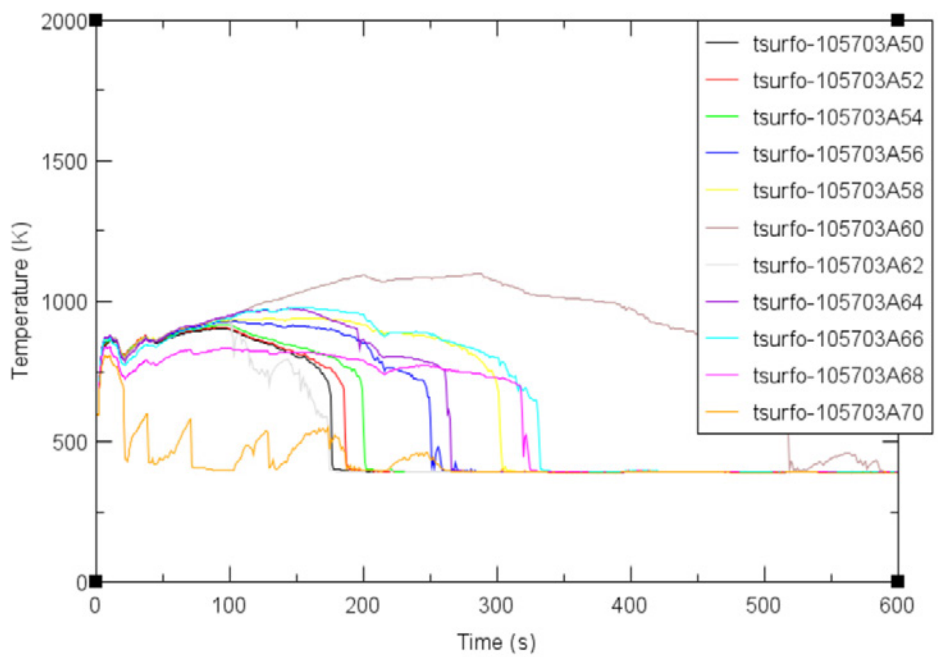
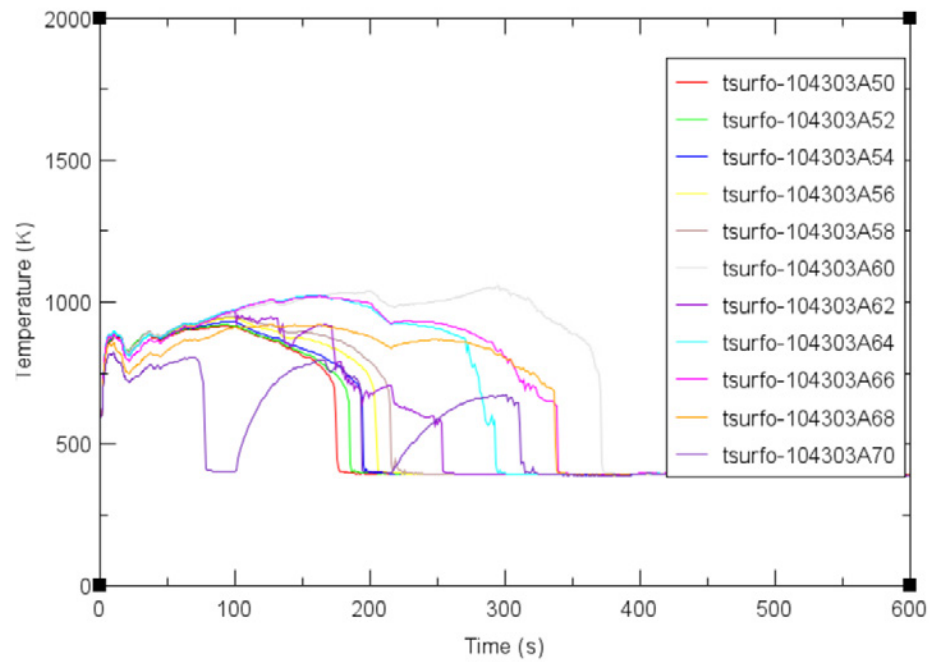
Detailed Inspection of Results

- Extended PCT trend (200-500 sec) driven by cladding node immediately above blockage



Location 04-12



Location 06-13

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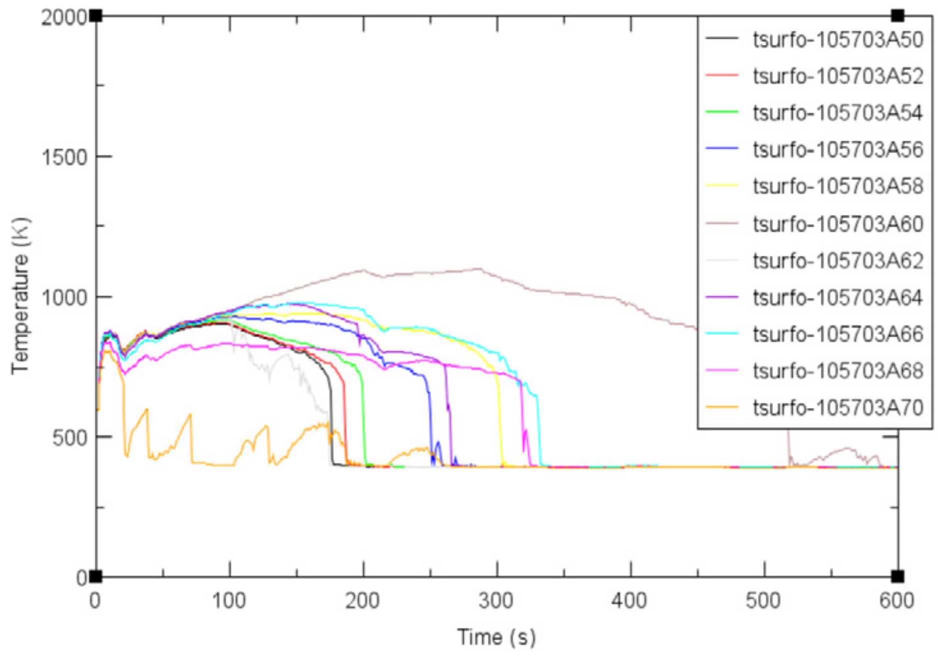
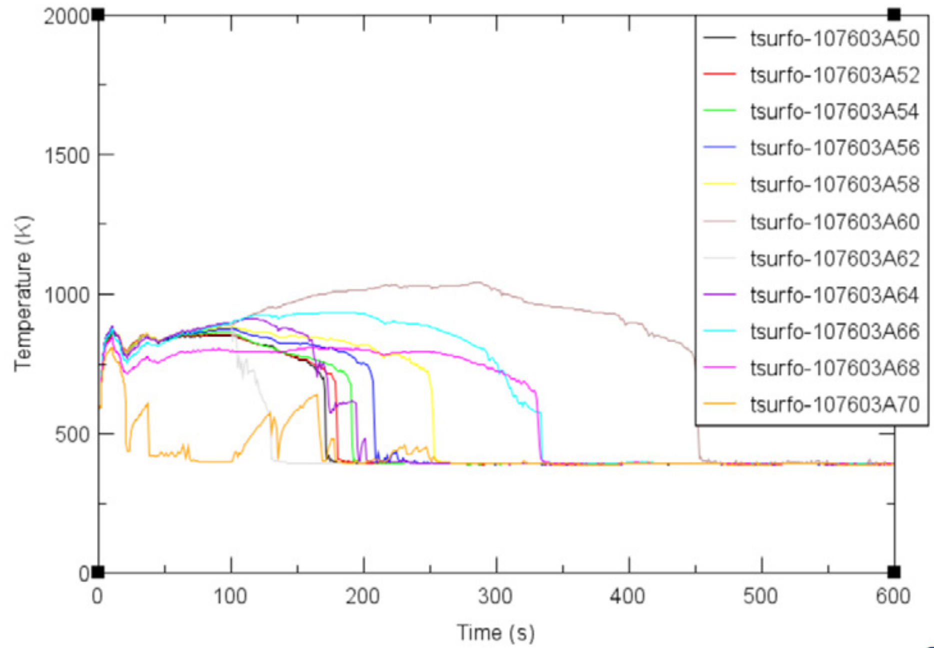
Detailed Inspection of Results

- PCT results relatively insensitive to assembly/rod power level



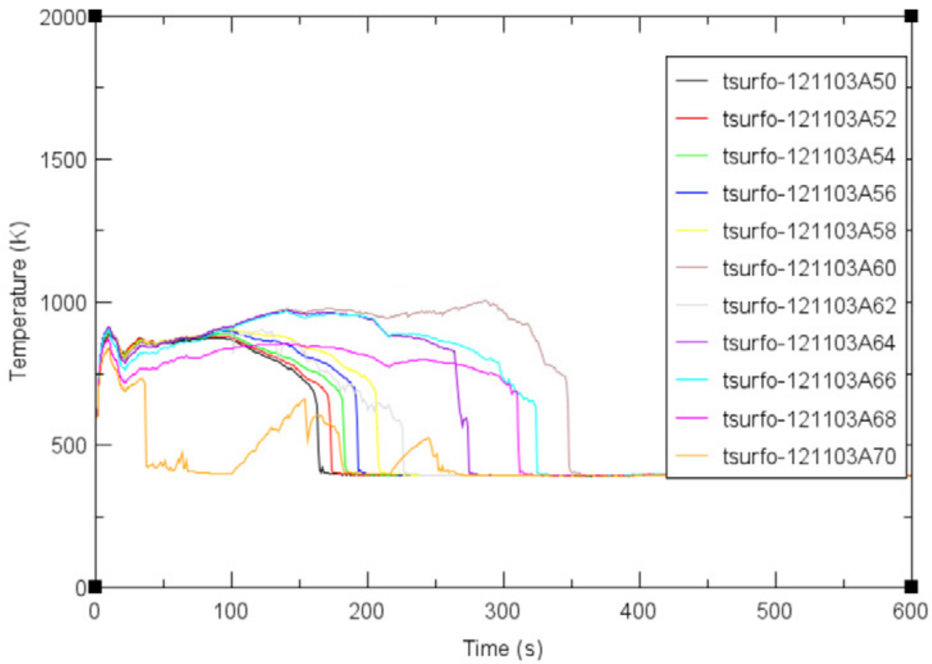
Location 04-12



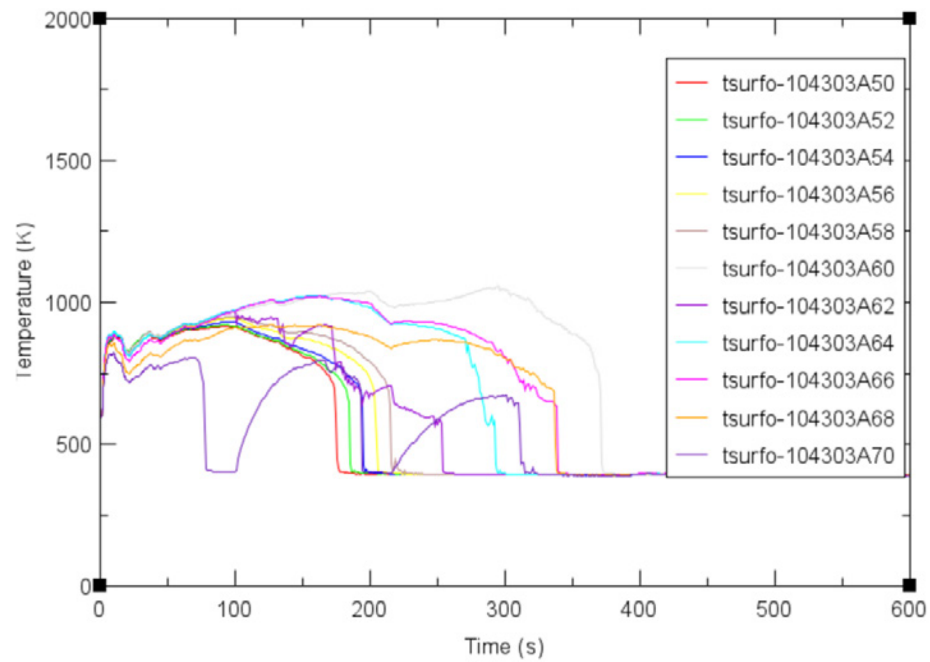
Location 06-11

Detailed Inspection of Results

- PCT trend similar for 14.61 kg simulated blockage vs 5.9 kg simulated blockage



Location 06-03



Location 06-13

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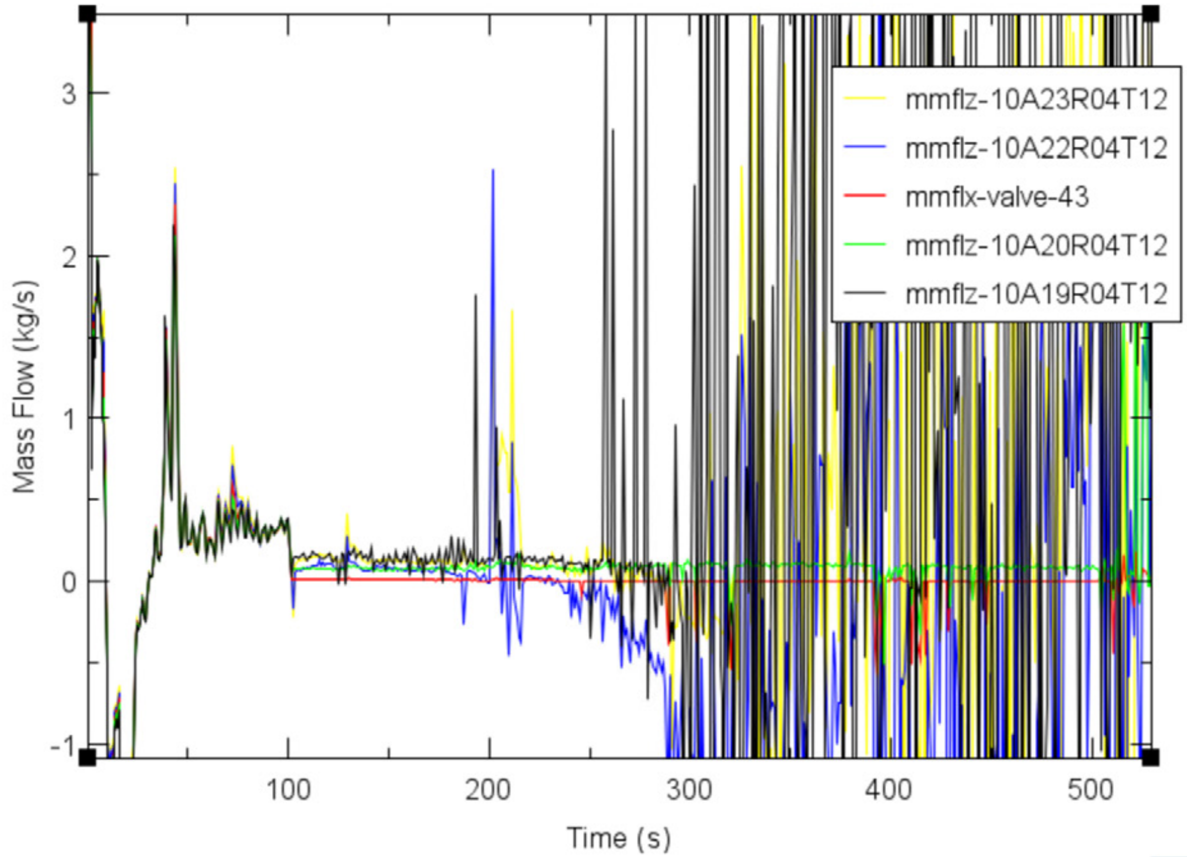
Detailed Inspection of Results

- Axial flow suggests significant reduction in flow leading to stagnant region immediately above blockage



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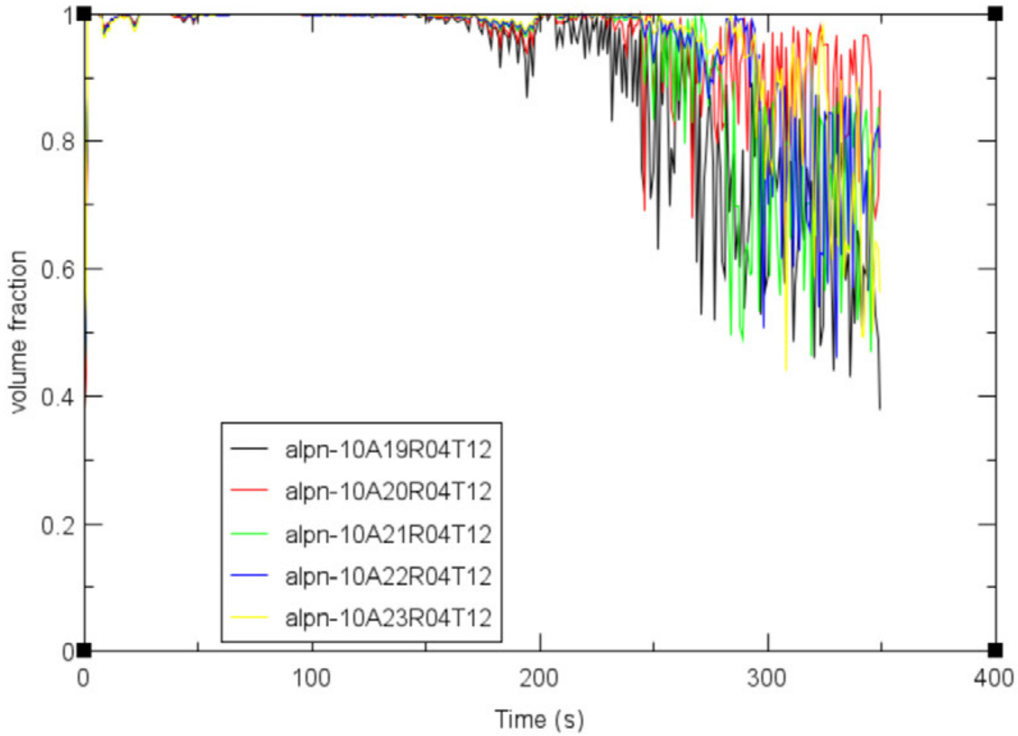
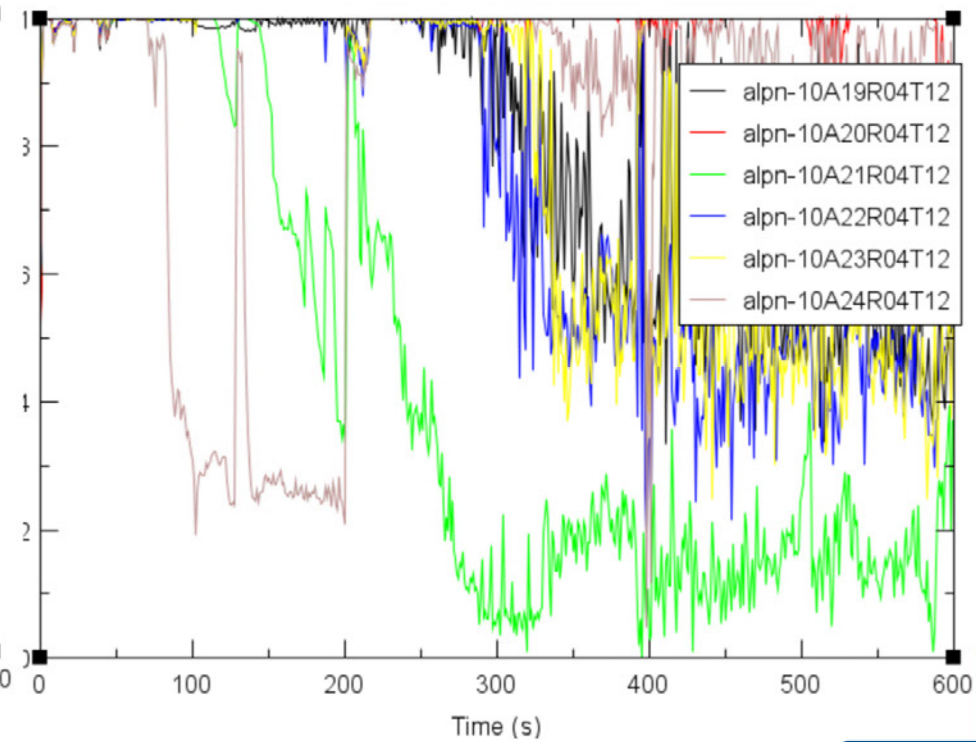
Detailed Inspection of Results

- Somewhat unusual axial void fraction distribution surrounding blockage



No blockage



Blockage

Summary

- Some modeling conservatisms:
  - All debris assumed to form a uniform debris bed on grid immediately below cladding failure
  - Dispersed fuel modeled slightly higher than estimates
- Some caveats:
  - Effects of de-entrainment of water droplets in debris bed not accounted for
  - Two-sided heating of cladding due to fuel inside and outside not addressed
  - Uncertainty exists with respect to some of the relevant phenomenology
- Some speculation:
  - 1-D junction with flow area adjusted to achieve a target loss coefficient may not be the best representation
  - The assumption of a uniform debris bed may be extremely conservative relative to reality

Summary

- TRACE has been benchmarked extensively, but it is not validated for licensing purposes
- The calculations performed represent best estimate conditions with some modeling conservatisms
- Report on results is draft and subject to change
- However, this information could be used by NRC staff with other information as part of an integrated risk evaluation

Rule Exemption Under 10 CFR 50.12

July 30, 2025

Tara Matheny - Duke Energy
Stan Hayes – Duke Energy
Dennis Earp – Duke Energy

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Background

- Duke Energy is pursuing power uprates and fuel cycle extensions for multiple plants with implementations starting in spring of 2029
  - Regulatory predictability and certainty is needed to ensure these projects can be executed efficiently and predictably.
- Duke Energy would like to see the rulemaking approved and issued by 1st Quarter of 2027
  - The company continues to actively participate in industry whitepaper preparation and NRC workshops
- Duke Energy is exploring an option for exemption under 10 CFR 50.12
  - *10 CFR 50.12(a)(2)(ii) Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule*

Opportunities to Reduce Regulatory Uncertainty

- Continued workshop discussions
- Pre-submittal Meetings
  - Licensee specific discussion to ensure understanding and expectations
- Tabletop Exercise
  - Discuss the proposed licensing process
  - First of a kind application
  - Licensing efficiency
  - Alignment early in the process

Tabletop Exercise

- Proposed tabletop exercise with NRC in September after the completion of the FFRD workshops
- Explore connections between vendor topicals and Duke Energy submittals
  - Efficiency improvements
  - Using NRC-approved methodologies
- Step through all associated aspects of the proposed exemption(s)
  - Transportation Package
  - Receipt Process at Utility Site
  - Spent Fuel Pool and New Fuel Storage Pool Licensing
  - Updates to the Licensing Basis
    - Alternate Licensing Strategy (ALS)
    - Reg Guide 1.183 Rev 2 and 10 CFR 50.67 Accident Source Term

Exemptions and Timeline

- Expected timeline for exemption submittal
  - Detailed submittal information provided in future tabletop exercise
  - Fuel cladding exemption request for 10 CFR 50.46
    - August 15, 2025
  - SFP Criticality LAR submittal
    - June 2026
    - Could include 10 CFR 50.68 exemption for greater than 5 wt% U-235
    - Pre-submittal meeting August 11, 2025
    - Pending approval of the Studsvik Supplement

Implementation of Alternative Licensing Strategy (ALS)

- Regulatory clarity and predictability on implementation of ALS
  - ALS is not part of the current rule considerations and a policy determination is needed to include ALS
    - Option 1- Policy Clarification
    - Option 2- Policy Exemption
    - Option 3- Policy Revision
  - Policy clarification is the preferred path for implementation
- ECCS design is not changing and cannot change without NRC approval
- Additional discussion proposed in future tabletop exercise

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Plant Hatch Potential Pilot Approach for EPU

T. Kindred, P.E.
Consulting Engineer
Nuclear Fuels and Safety Analysis

Southern Nuclear

Plant Hatch Potential Pilot Approach for EPU

EPU

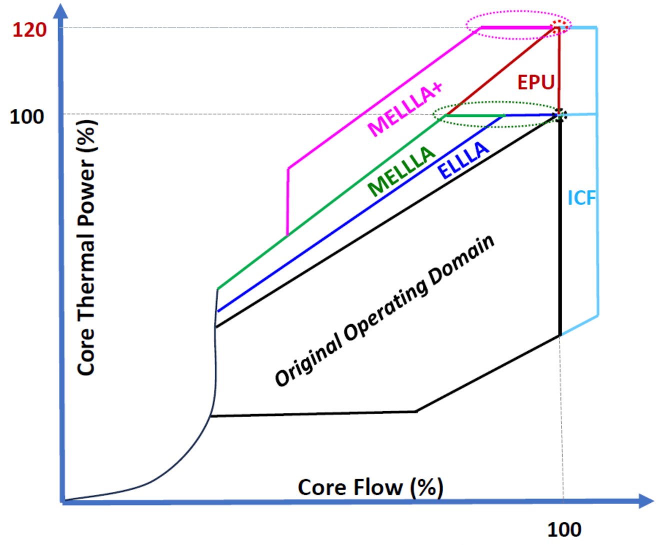
- To Meet Increasing Power Demands in Georgia with Reliable Clean Energy
- Proposed increase to licensed power level from 2804 MWth to 2960 MWt, which is an increase of 5.6% from CLTP or 121.5% of the OLTP.

MELLLA+

- To Improve Operating Flexibility at Extended Power Uprate Levels
- Allow operations in the MELLLA+ domain to provide maximum operations flexibility. At 121.5% OLTP, MELLLA+ will allow a core flow window range similar to the currently licensed MELLLA domain.

Combined LAR to Support Efficient Licensing Strategy

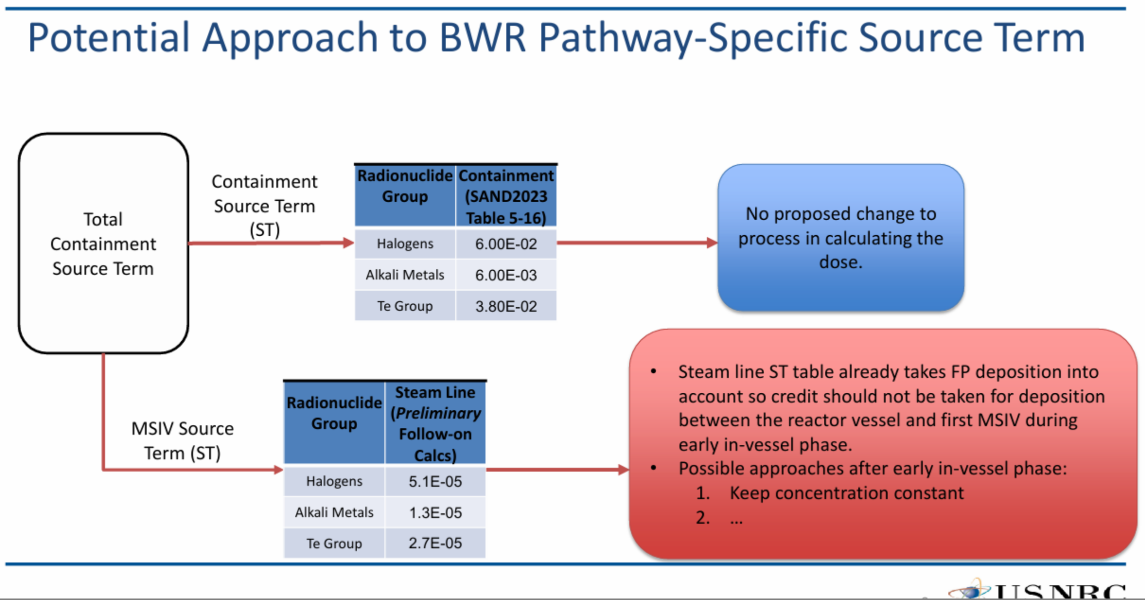
- To Gain <u>Efficiency</u> in the Development, Review, and Implementation of the LAR



Plant Hatch Potential Pilot Approach for EPU

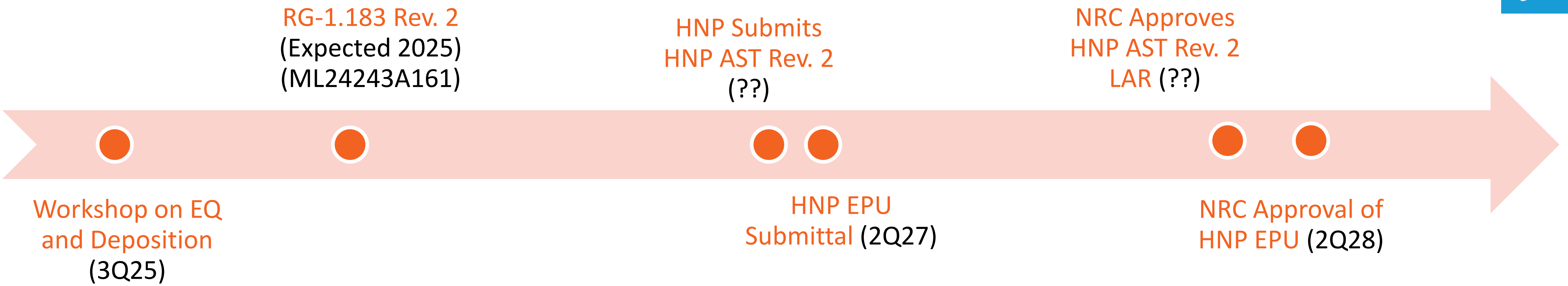
Regulatory Guide 1.183 Rev. 2

- The second revision of the Alternative Source Term Regulatory Guide is essential to facilitate uprate initiatives for Boiling Water Reactors (BWRs).
  - It addresses a long-standing industry need for modeling aerosol scrubbing within the suppression pool, a need recognized as far back as 30 years ago in NUREG-1465 (pg. 19).
  - This guide offers crucial direction on pathway-specific source terms for BWRs.
  - Enables modeling of existing BWR safety systems
- Assuming no rule change, necessary exemptions for the implementation of RG-1.183 Rev. 2 include:
  - §50.67 associated with control room dose criteria.
  - No increase in licensed burnup or enrichment would be requested to support EPU
  - Additional uprates (beyond currently planned) will require



NRC provided significant effort and needed advances in dose consequence analysis guidance (ML24005A102, ML24066A177, ML24304A864) planned for Rev. 2. Utilities seeking uprates for BWRs would benefit from the improved realism of the dose methods communicated in Rev. 2

Plant Hatch Potential Pilot Approach for EPU



Discussion Topics

- During HBU workshop (September 2024, ML24243A161) it was communicated RG-1.183 Rev. 2 was expected in 2025.
  - Requires rule change to §50.67 for GDC 19
- If RG-1.183 Rev. 2 is not released in 2025 industry sees two options:
  - Option 1: Submit for Rev. 2 approval w/exemptions as part of the EPU LAR
  - Option 2: Submit coincident with EPU using available draft guidance, but runs the risk of linked submittals (RG-1.183 Rev. 2 LAR may not be finished before EPU LAR is submitted)
- Industry would like to discuss these options with considerations for
  - Potential for increased complexity of combined (EPU, AST Rev. 2) submittals
  - Potential for increased complexity of linked submittals (LIC-109 implications)
  - Potential for increased regulatory uncertainty associated with utilizing draft guidance

Southern Nuclear

Break

Assessing Debris Bed Coolability

Application of CORQUENCH - Defense-in-depth analysis

Matt Nudi, Risk & Safety Management
EPRI

NRC Public Workshop
July 30, 2025

Background

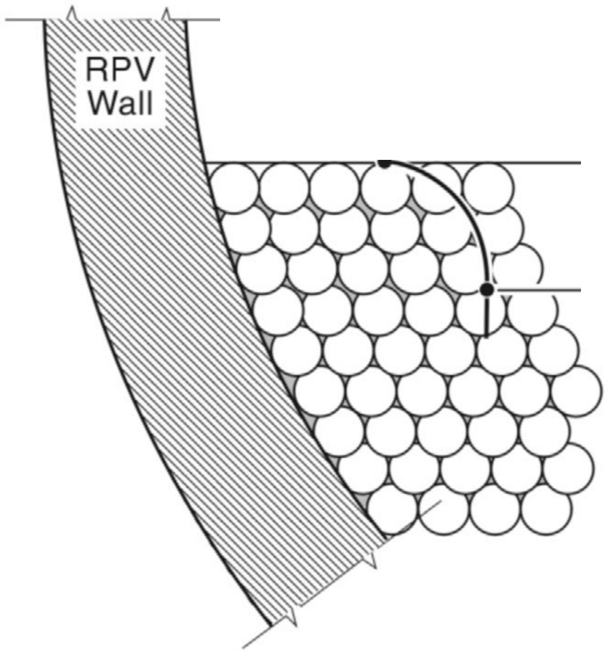
- Work is being developed to assess the ability to cool postulated debris beds resulting from FFRD phenomena
  - This is one element of several **EPRI/industry efforts** intending to demonstrate that FFRD is **prevented** (i.e., ALS), or can be **risk-informed** to more appropriately characterized its likelihood, consequence (i.e., RI-TBS)
- Coolability research intends to provide defense-in-depth analysis, while also fitting into the characterization of the importance of FFRD
  - It will leverage decades of lessons learned from severe accident analysis and state-of-the-art modeling tools

- **Key question**:
  - What is the significance of FFRD for severe accident progression with respect to maintaining a coolable condition for in-vessel & ex-vessel debris beds?

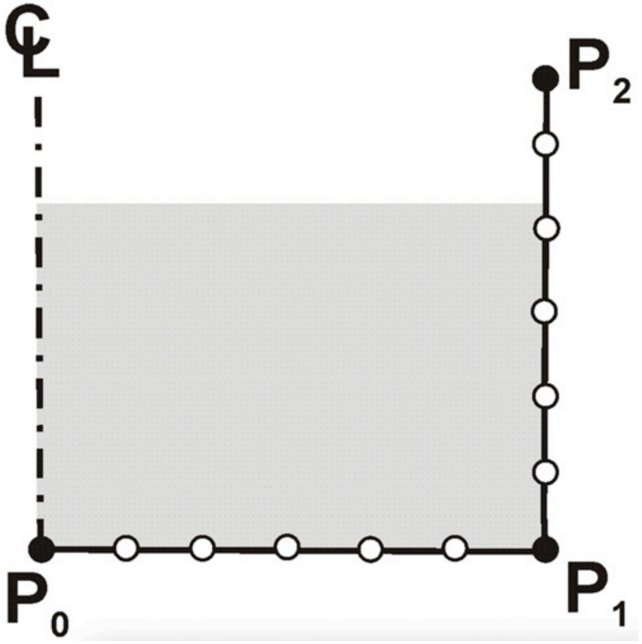
Scope of Analysis

Will evaluate one in-vessel and one ex-vessel debris bed configuration

In-Vessel Configuration in Lower Head

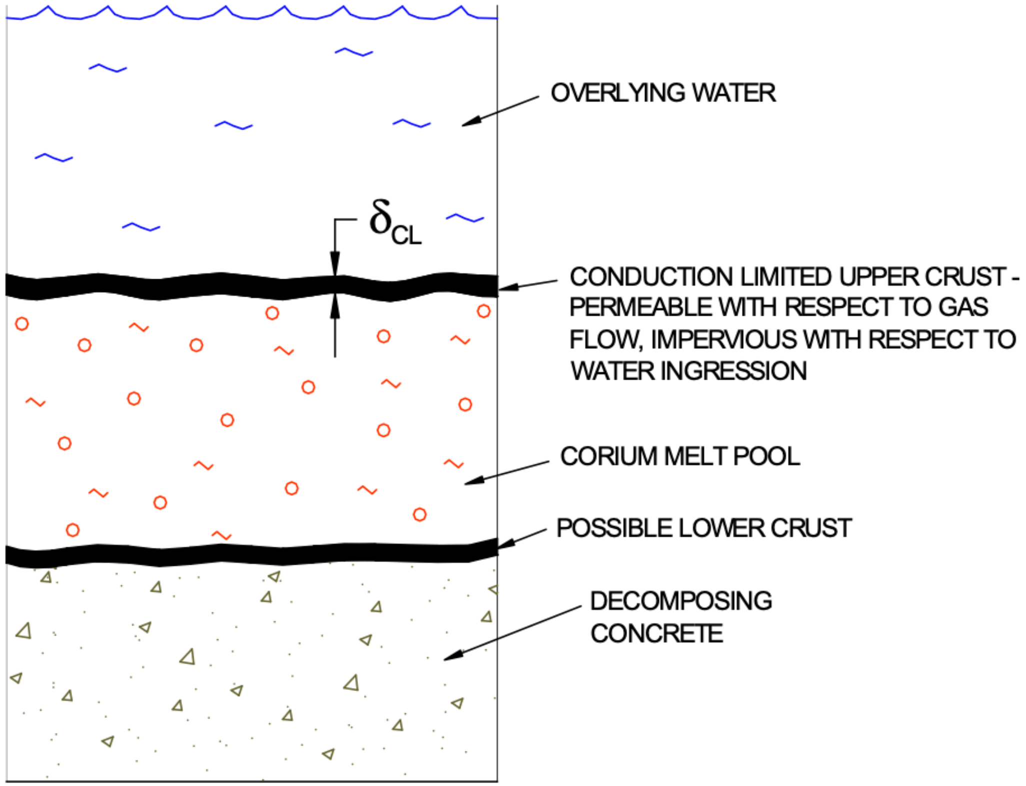


Ex-Vessel Configuration in Containment Sump



CORQUENCH Overview

- Under development by Argonne National Laboratories since 1990’s
  - Originally supporting MACE and OECD/MCCI programs
  - More recently - expanded validation through ROSAU program
- Traditionally focused on ex-vessel scenarios including MCCI
  - Mechanistically calculates water ingress and ultimate ability to cool severe accident debris beds
- Code contains **fundamental elements** needed to assess coolability of potential debris beds resulting from FFRD phenomena

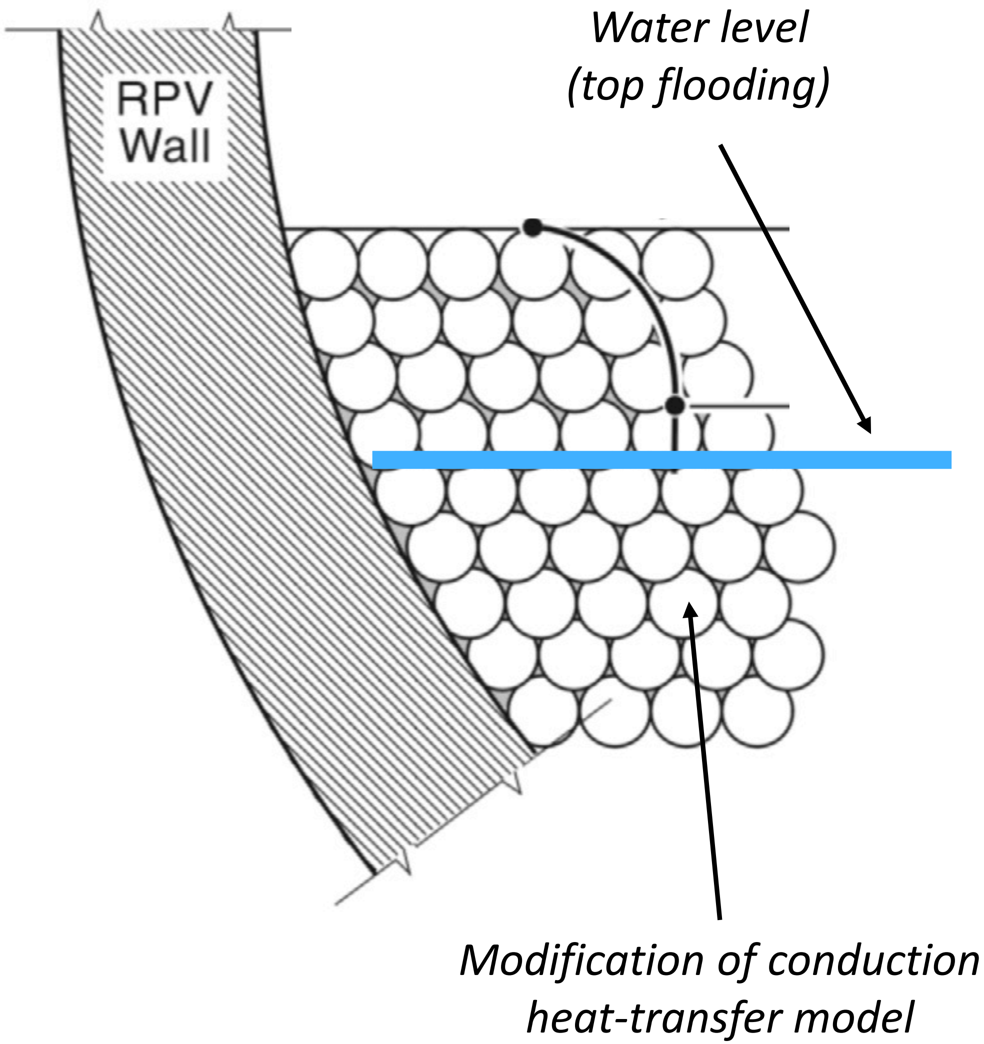


Ref: Figure 1-1a from https://publications.anl.gov/anlpubs/2018/10/146345.pdf

CORQUENCH well qualified to assess FFRD debris bed coolability

Minor modifications to CORQUENCH for FFRD application

- Ability to start calculations with fuel debris in a fully solidified state
- Current modeling assumes only conduction heat transfer in lower debris bed region
  - Where water not yet present from top flooding
- Potential enhancement may consider addition of convective cooling due to steam flow



Boundary Conditions

- Key assumptions
  - Fragment particle size distribution
  - Porosity and packing within debris bed
  - Fuel mass released
  - Decay heat input
  - Injection water subcooling
- Inputs will be aligned with in-core coolability assumptions
- Will require some judgment regarding in-vessel and ex-vessel debris bed conditions
  - Sensitivity analysis will be used to assess **impact of key assumptions** on ability to demonstrate coolability

Schedule & Conclusions

- EPRI coolability research will evaluate both in-core & debris bed conditions
- Schedule
  - Framework development – July/August 2025
  - Model development – August/September 2025
  - Analytical results – October/November 2025
    - Results to be discussed in subsequent NRC workshops
  - White paper – **Early 2026**

Technical work will be published in EPRI White Paper – Early 2026

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Coolability of Dispersed Fuel

Framework for Analytical Approach

Kurshad Muftuoglu
Fuel Reliability Program, EPRI

NRC Public Workshop
July 30-31, 2025

Outline

- Core coolability
  - Scope
    - Impact of FFRD on PCT and Oxidation
    - Coolability of accumulated fuel fragments at spacer location
  - Background
    - NUREG/CR-7307 observations
  - Analysis Framework
    - Assumptions and other considerations

Core Coolability

- For core coolability, the analysis examines the potential for dispersed fuel fragments to accumulate at spacer grid locations, where they may obstruct coolant flow and act as localized heat sources.
- The study aims to assess whether the combination of both the dispersed fuel fragments and those retained within the rod can be adequately cooled during a LOCA, thereby maintaining core integrity and ensuring continued safety margins.

Discussion Points from NUREG/CR-7307 (Dispersal PIRT)

- Initially porous fuel debris beds allow for cooling.

- Fuel rods above a blockage caused by fuel debris would be expected to be cooled.

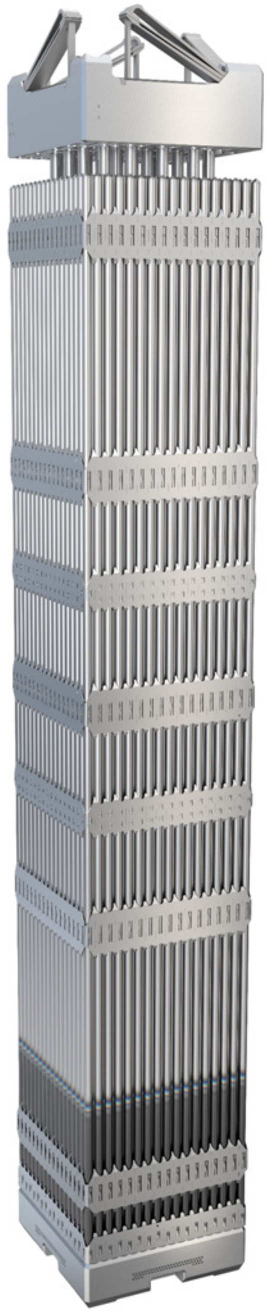
- With respect to coolable geometry during an FFRD LOCA, the impact of debris beds around spacer grids needs to be evaluated.

Core Coolability Analysis Framework

- Starting with an approved BELOCA EM modified for high burnup modeling
  - Code modification is necessary to model the accumulation of fuel fragments at the spacer location.
  - Simplifying assumptions and boundary conditions as input will be utilized.
- Evaluations to be performed for a prototypical Large-Break LOCA scenario, which is already conservative, with realistic/reasonable assumptions for FFRD phenomena.

Key Assumptions and Modeling Approach

- Fuel mass release
  - Burnup and temperature threshold is to be considered along with the radial temperature distribution of the high-burnup fuel.
  - For high burnup assembly, the fuel prone to dispersal is mainly in the ballooned region and between the burst location and the upper spacer grid.
  - After burst, it is assumed to be collected at the lower spacer grid.
  - No lateral redistribution of fragments is assumed.



Key Assumptions and Modeling Approach

- Porosity and packing of accumulated fuel can be treated as a sensitivity.
- Proposed packing fractions 50%, 70%, 90%, covering a range that extends from reasonably realistic to conservative.
- Resistance to flow and heat loading would be adjusted accordingly.
- Heat load of the accumulated fuel fragments will consider the additional decay heat contribution at the nodal location.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LOCA Reporting Workshop

Al Csontos – NEI
Brian Mount – PWROG/Dominion

July 30, 2025

NEI NUCLEAR ENERGY INSTITUTE

Background/Objectives of the Workshops

- Industry appreciates the opportunity to hold open and transparent dialogue with staff at these public workshops
- Applications for uprates, extended cycle lengths and/or advanced fuels incoming
- Aligning requirements to minimize administrative burden while improving overall efficiency for both industry and regulator without a reduction in safety
- Workshops align with the intent of the ADVANCE Act for the development of modern, risk-informed, and efficient processes to ensure safety while minimizing burden

Drivers for Modernization

- NEIMA (Nuclear Energy Innovation and Modernization Act)
  - Requires use of risk-informed and performance-based techniques within the existing regulatory framework
- ADVANCED Act (Accelerating Deployment of Versatile, Advanced Nuclear Clean Energy Act)
  - Promotes streamlined licensing and regulatory modernization
  - Emphasizes the need for efficient communication and data sharing between the NRC and stakeholders
- Executive Orders
  - Emphasizes need for efficient regulatory processes
  - Promote regulatory process improvements

Historical Perspective

- Reporting requirements were formalized on September 16, 1988, § 50.46 of 10 CFR Part 50 is amended [53 FR 35996]
  - Significant changes, defined as those having an absolute magnitude of 50ºF, must be reported in 30 days …. reanalysis

  “The NRC considers a major error or change in any direction a cause for concern because it raises potential questions about the adequacy of the evaluation model as a whole.”

  - All PCT changes must be reported annually

  “While errors or changes which result in changes in calculated peak clad temperatures of less than 50ºF are not considered to be of immediate concern, the NRC requires cognizance of such changes or corrections since they constitute a deviation from what previously has been reviewed and accepted.”

- At the time (1988), available computer resources limited the robustness of LOCA EMs contributing to uncertainty in the ability of the EMs to be able to estimate the impact of changes

Purpose vs. Current Practices

- Inferred Purpose
  - Maintain confidence in evaluation models
  - Licensing basis must reflect current state of the plant and account for known phenomena and uncertainty (for realistic evaluation models)
  - Simplify communication and create consistency
  - NRC feedback
- Current use is highly subject to interpretation
  - Inconsistent application of reporting requirements
  - Overly burdensome
    - Majority of reporting are <10ºF for changes such as code maintenance
    - Not risk-informed

Review of Annual Reporting of Changes

- In 2014, Industry presented the results of a survey of 50.46 reports and demonstrated that for more than a 950 estimates the majority of errors results in an estimated ΔPCT of zero degree Fahrenheit
- New survey performed to evaluate reporting trend since 2014
- Since 2014, more than 1200 estimates were reviewed and found that the majority of estimates continue to be a ΔPCT of zero degree Fahrenheit

ΔPCT	2014 (ML14175A162)	Since 2014
x < 0°F	11%	6%
x = 0°F	59%	82%
x > 0°F	30%	12%

Assessment Annual Report Trends

- Improvements in Estimation
    - Considerable improvement in LOCA state-of-knowledge
    - Considerable improvement in modeling capability
    - Considerable improvement in computing resources
- How does staff use reporting letters currently?
    - Does magnitude or plant licensing basis affect usage?
    - Please provide examples [i.e., Annual ECCS Safety Assessment (ML25043A133)]

LOCA analysis capability has increased significantly, as well as the knowledge and capability to evaluate changes or errors commensurate with their potential significance, such that high fidelity of the EMs is maintained.

Modernization of Reporting Requirements

- Industry recognizes NRC desire to maintain knowledge of evaluation model, but requirements should
  - Align with NRC usage
  - Avoid redundancy or conflicting regulatory requirements
    - 10 CFR 50.72 and 10 CFR 50.73 requires reporting of unanalyzed conditions that degrade plant safety (e.g., Event Notifications 50639, 50640, and 50641)
    - 10 CFR Part 21 requires reporting of errors in analyses that result in substantial safety hazard
  - Should be commensurate with risk significance
- LOCA EM errors are typically recorded corrective action programs
  - Resident inspectors have access to a plant Corrective Action systems
  - Improved telecommunications increase accessibility of licensee corrective action programs

Modernization of Reporting Requirements

- Industry believes this can be accomplished via annual reports of PCT changes
  - No need for
    - “Significance” – Redundant; Alternatively, should be risk based
    - “Reanalysis” – Estimates are better informed
  - Adequacy of current tools eliminates need for reanalysis schedule
    - Modern evaluation techniques often capture current plant state and account for uncertainty of non-trivial errors/changes
  - Satisfies NRC cognizance of changes or corrections from year to year.
  - Does everyone need to report on an annual basis, or could it be required once a licensee reached a specific PCT value (i.e., 2000F)?

Other Reporting Topics

Al Csontos – NEI
Thomas Kindred – Southern

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Robustness on the Use of Risk Insights, Technical Quality, Configuration Control

- Robust use and implementation of PRA insights and risk-informed decision-making for over 20+ years through verified and approved programs/submittals in multiple applications with increased degree of quality expectation and level of detail (e.g., Risk Informed Completion Times, 50.69 Risk Informed Categorization of SSCs, Surveillance Frequency Control Program, Reactor Oversight, Plan Licensing Basis Changes, Maintenance Rule)
- Specific Requirements:
  - RG-1.200 Rev. 3 Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities
    - Application specific requirements (e.g. RG-1.174)
  - PRA Change program requirements covered in ASME/ANS PRA Standard (ASME/ANS RA-S-1.1) – approved standard per regulatory review
    - RG-1.200 Rev. 3 communicates PRA upgrade frequencies (4 years)
    - Each application has its own application on quality and configuration control
    - NEI 17-07 for quality standards pertaining to PRA Peer Reviews
    - Utility specific procedures, guides, job aids for quality and configuration control

The current guidance, metrics, and expectations regarding PRA Technical Adequacy, meeting the principles of risk-informed decision making is more than sufficient for the use of such tools, to the extent that significant additional guidance and over-conservatisms are not warranted nor should they prevent the realistic use of risk information to inform changes in regulation (as expected from the Commission PRA Policy Statement)

Discussion Period

Break

Discussion Period

Public Comment Period

Closing Remarks

Adjourn