Risk Tool for Spent Fuel Dry Storage:

Making it Real

Rod McCullum, NEI

NRC/NEI Performance Margin Workshop

July 28, 2020

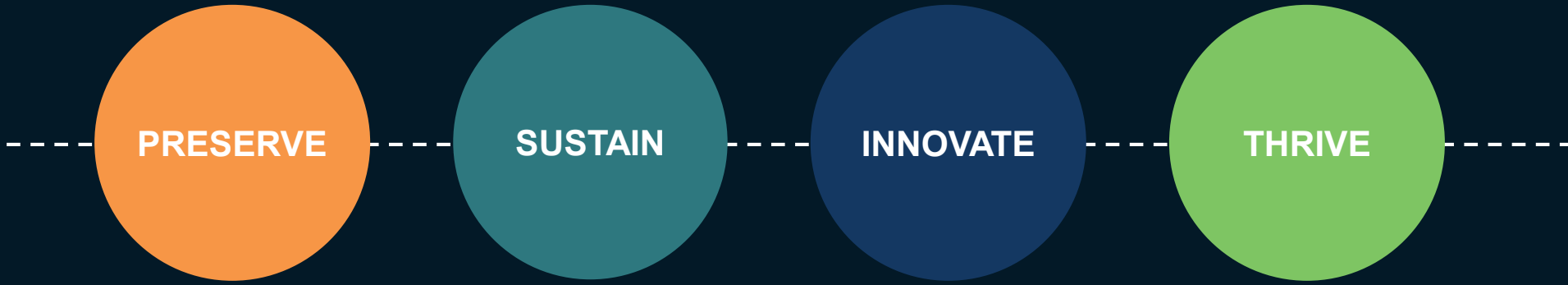
NUCLEAR ENERGY INSTITUTE

Nuclear Energy Institute

- Vision
  - A world powered by clean and reliable energy
- Mission
  - Promote the use and growth of nuclear energy through efficient operations and effective policy

Industry Strategic Focus

National Nuclear Energy Strategy



The imperative of dry storage efficiency - I

Used fuel inventory*

- Approximately 85,000 MTU
- Increases 2 - 2.4k MTU annually

ISFSI** storage

- 143,920 assemblies
- 41,000 MTU (48%)
- 3,283 casks/modules loaded
- 73 Operating dry storage ISFSIs
- Eventual deployment at 76 sites (119 reactors)

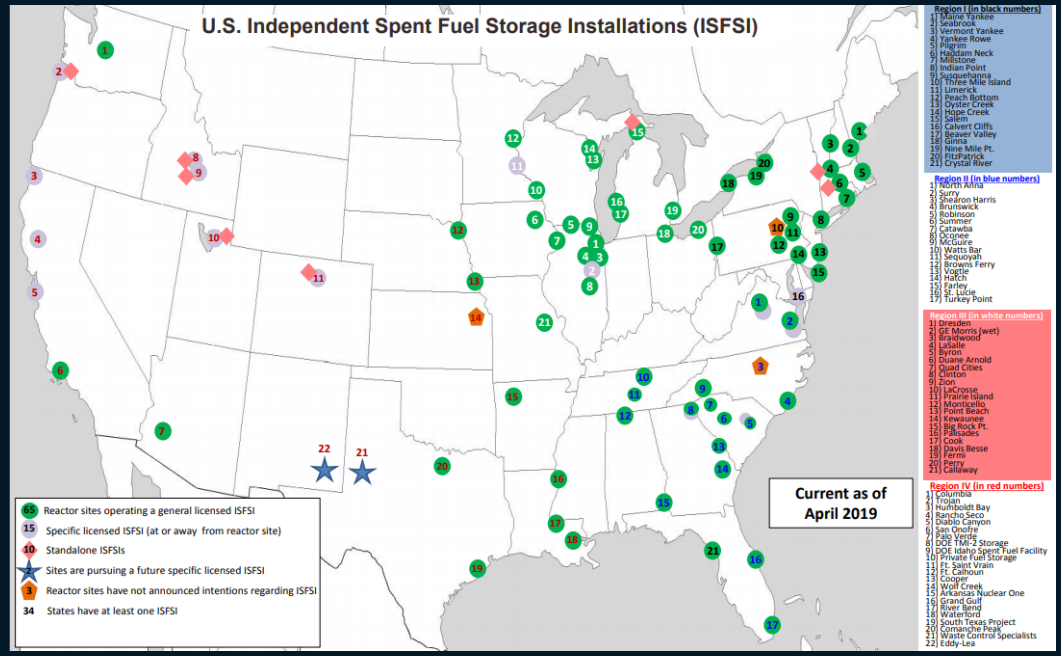
Long term commitment to ISFSIs

- Licenses being extended to 60 years
- Licenses extensions approved at 32 sites

Contents will continue to evolve

Transport to CIS in TX or NM could begin in 2023-2024 Timeframe

Work on permanent repository (Yucca Mtn.) on indefinite hold



*As of June 2020

** ISFSI = Independent Spent Fuel Storage Installation

The imperative of dry storage efficiency - II

Status	Plant	Current Owner	Current NRC Licensee	License/Ownership Transfer
Plants that have completed decommissioning but still have used fuel stored on site	Rancho Seco	SMUD	SMUD	
	Yankee Rowe	Yankee Atomic	Yankee Atomic	
	Maine Yankee			
	Connecticut Yankee			
	Trojan	Portland GE	PGE	
	Big Rock Point	Entergy	Entergy	Pending to Holtec
	Lacrosse	Dairyland Power	Energy Solutions	Pending to Dairyland Power
	Zion 1&2	Exelon	Energy Solutions	Pending to Exelon
Plants* that have permanently shut down and entered decommissioning	Humboldt Bay	Pacific G&E	PG&E	
	San Onofre 1,2,&3	SCE	SCE	
	Crystal River	Duke/ADP	Duke/ADP	Duke plant owner/licensee, ADP spent fuel owner/licensee & plant licensed operator
	Kewaunee	Dominion	Dominion	
	Vermont Yankee	ADP	ADP	ADP purchase from Entergy closed 1/19
	Fort Calhoun	OPPD	OPPD	
	Oyster Creek	Holtec	Holtec	Holtec purchase from Exelon closed 7/19
	Pilgrim	Holtec	Holtec	Holtec purchase from Entergy closed 8/19
	Three Mile Island 1	Exelon	Exelon	
	Three Mile Island 2	FENOC	FENOC	License transfer to Energy Solutions pending
	Indian Point 2	Entergy	Entergy	Pending to Holtec
Plants that have announced intent to enter decommissioning	Duane Arnold	NextEra	NextEra	
	Indian Point 3	Entergy	Entergy	Pending to Holtec
	Palisades	Entergy	Entergy	Pending to Holtec
	Diablo Canyon	Pacific GE	PG&E	

*Does not include shutdown plants that are co-located with an operating reactor (Indian Point 1, Peach Bottom 1, Fermi 1, Dresden 1 & Millstone 1)

Enabling the imperative

- The risk tool presented by NRC on June 23 has the potential to result in *significant improvement* in dry storage licensing efficiency
- Realizing this potential will require:
  - Well defined and actionable Risk Significance Determination Criteria
  - Qualitative Assessment of Risk
  - Consistent Application of these Criteria

NUREG-1536 as Prologue – I

Risk Tool for Spent Fuel Dry Storage Grades

Risk Significance	LAR Review Process	Risk Significance Determination Criteria
Low	Efficient	→ Redundancy of preventive measures or multiple conditions necessary for accident initiation. Failure of redundant systems, or independent concurrent conditions required for accident initiation. → If quantitative data is available: Insignificant increase (by a factor of less than one order of magnitude) of release of radioactive isotopes theoretically possible. → Standard reevaluation process of the system that requires only an adaption of new parameters. → Low chance of making a significant evaluation error during safety evaluations by the licensee and high chance of catching such error by the reviewer. → No direct effect on the current operation procedures.
Medium	In Detail	→ Detection of evaluation error or flaw likely (e.g., due to surveillance). → No immediate danger to public or personnel due to significant safety margins. → If quantitative data is available: Medium increase (by a factor of less than two orders of magnitude) release of radioactive isotopes theoretically possible.
High	Extensive, Thorough, Very Detailed	→ Error in the safety evaluations could directly lead to an accident that includes a release of radioactive material, criticality, or undetected issue, and significantly increased radiation exposure of the public or operating personnel. → No reliable redundancy in the system. → If quantitative data is available: Significant increase (by a factor larger than two orders of magnitude) of release of radioactive isotopes theoretically possible.
See Rationale	Based on Extensive Risk Significance Determination	→ No risk significance estimation possible without consideration of additional factors.

DRAFT

NUREG-1536 Prioritization Process

HIGH priority means the NRC staff review should ensure all items in the applicant's submittal are complete and correct as specified in the review procedure. This represents the most comprehensive review where many of the analytical methods, assumptions, and supporting references are evaluated. The reviewer may need to perform independent confirmatory analysis to validate the results of the safety analysis calculations. It is expected a reviewer would spend approximately 60 percent of his or her review time focused on the high priority review procedures.

MEDIUM priority means the NRC staff should review the applicant's submittal for completeness and correctness in key areas. This represents a review in which key analytical methods, key assumptions, and key supporting references are checked and

5

evaluated. It is expected a reviewer would spend approximately 30 percent of his or her review time focused on the medium priority review procedures.

LOW priority means the NRC staff review should ensure that the applicant's submittal contains all of the requested information. A limited review of selected portions of the application for correctness would be performed. Given its relative significance, the reviewer should generally consider the applicant's analysis to be complete and accurate and forego independent confirmation, unless there is a reason to believe otherwise. However, if a problem is detected, the reviewer must thoroughly evaluate and resolve the issue. It is expected a reviewer would spend approximately 10 percent of his or her review time focused on the low priority areas.

NUREG-1536 as Prologue – II

Proposed Risk Tool

Risk Significance Determination Criteria

→ Redundancy of preventive measures or multiple conditions necessary for accident initiation. Failure of redundant systems, or independent concurrent conditions required for accident initiation.
→ If quantitative data is available: Insignificant increase (by a factor of less than one order of magnitude) of release of radioactive isotopes theoretically possible.
→ Standard reevaluation process of the system that requires only an adaption of new parameters.
→ Low chance of making a significant evaluation error during safety evaluations by the licensee and high chance of catching such error by the reviewer.
→ No direct effect on the current operation procedures.

→ Detection of evaluation error or flaw likely (e.g., due to surveillance).
→ No immediate danger to public or personnel due to significant safety margins.
→ If quantitative data is available: Medium increase (by a factor of less than two orders of magnitude) release of radioactive isotopes theoretically possible.

→ Error in risk safety evaluations could directly lead to an accident that includes a release of radioactive material, criticality, or undetected issue, and significantly increased radiation exposure of the public or operating personnel.
→ No reliable redundancy in the system.
→ If quantitative data is available: Significant increase (by a factor larger than two orders of magnitude) of release of radioactive isotopes theoretically possible.

→ No risk significance estimation possible without consideration of additional factors.

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NUREG-1536 Appendix B

Prioritization Process Checklist

Chapter: Paragraph Number:

STEP	SCORE	COMMENTS
1. Identify the SRP procedure to be prioritized.	N/A	
2. Likelihood that requirement will not be met (Table B-1).		
3. Likelihood that staff reviews will find discrepancy (Table B-2).		
4. LOC if requirement is not met (Table B-3).		
5. Determine combined LOC value (Table B-4).		
6. Determine defense-in-depth value (Table B-5), if applicable.		
7. Determine relative weight of risk and defense-in-depth values determined in (steps 5 and 6 above).		
8. Overall priority (Combine LOC and defense-in-depth values).		

NUREG-1536 as Prologue – III

The Devil is in the…

Table B-1 Likelihood of Applicant's Non-Compliance with the SRP Review Procedure

Likelihood of Not Meeting the Requirements	Description
Very High	**Qualitative:** Likely to occur. **Quantitative:** P > 0.5
High	**Qualitative:** Probably will occur. **Quantitative:** 0.1 < P < 0.5
Medium	**Qualitative:** May occur. **Quantitative:** 0.03 < P < 0.1
Low	**Qualitative:** Unlikely to occur. **Quantitative:** 0.01 < P < 0.03
Very Low	**Qualitative:** Occurrence improbable. **Quantitative:** P < 0.01

P = Probability

Table B-2 Potential "Value Added" Through the NRC Review Process

Likelihood that the NRC Review of a Specific Review Procedure Step Will Identify a Non-Compliance	Description
Very High	**Qualitative:** Likely to occur. **Quantitative:** P > 0.5
High	**Qualitative:** Probably will occur. **Quantitative:** 0.1 < P < 0.5
Medium	**Qualitative:** May occur. **Quantitative:** 0.03 < P < 0.1
Low	**Qualitative:** Unlikely to occur. **Quantitative:** 0.01 < P < 0.03
Very Low	**Qualitative:** Not probable. **Quantitative:** P< 0.01

P = Probability

Table B-3 Potential Impact if the Noncompliance Were to Remain Uncorrected

Increase in Likelihood or Consequence (LOC) if Requirements Remain Unmet	Description
High	**Qualitative:** Likely to occur or significant consequences.
	Quantitative: $>10^{-3}$/yr* or >25 rem to worker or > 1 rem to public.
Medium	**Qualitative:** May occur or moderate consequences.
	Quantitative: $<10^{-3}$/yr but $>10^{-5}$/yr** or 5 -25 rem to worker or 0.1 rem - 1 rem to public.
Low	**Qualitative:** Occurrence improbable or minimal consequences.
	Quantitative: $< 10^{-5}$/yr or less than 10 CFR 20 dose limits for workers and the public.

*** 10^{-3}/yr corresponds to the likelihood of an event that could occur in one or more casks over a 20 year life of 50 casks.**

**** 10^{-5}/yr corresponds to the likelihood of an event that could occur in one or more casks over a 20 year life of 5000 casks (i.e., 50 at each of 100 operating reactors).**

Table B-4 Overall LOC Ranking

Numerical values for Tables B-1, B-2 and B-3 are assigned as follows (note that Table B-3 only assigns values of 1 through 3):

Very High	4
High	3
Medium	2
Low	1
Very Low	0

For each SRP review procedure, the qualitative scores from Tables B-1, B-2 and B-3 are added and a combined qualitative score is determined as follows:

High	9 - 11
Medium	6 -8
Low	1 - 5

NUREG-1536 as Prologue – IV

- Industry has little visibility on how the NUREG-1536 prioritization process has been used by NRC
  - What proportion of reviews were classified as “High”, “Medium”, and “Low”?
  - Was there a measurable difference in the conduct of the review between each category?
  - Is this difference quantifiable in terms of resources applied (NRC and Licensee)?

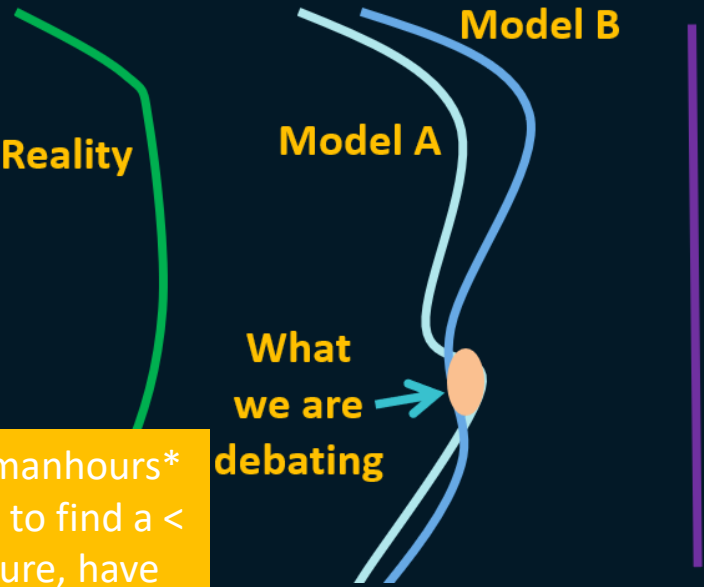
What does this have to do with performance margin?

Management Perspectives

Rod McCullum
NEI Used Fuel Management Conference

May 7, 2019
West Palm Beach FL

Defining Used Fuel Performance Margins



Tuesday am

TRACK 1:
From Science to Implementation: Thermal and Radiation Modeling

Chair
Zita Martin
Tennessee Valley Authority

Speakers
Al Csontos
Electric Power Research Institute

John Scaglione
Oak Ridge National Laboratory

Ricardo Torres
Nuclear Regulatory Commission

Steve Sisley
NAC International

If we are spending 1000 – 2000 manhours* developing more discrete models to find a < 5 degree difference in temperature, have we sufficiently prioritized our efforts?

***based on 1/23 workshop**

…from the 1/23 NEI/NRC Margins Workshop

Cost-Benefit Examples

TN-ORANO

Spent Fuel Performance Margins
Cost-Benefit Overview

- Significant time and computational resources are being engaged in developing mesh sensitivity studies
  - CoC 1042
  - CoC 1029
  - TN-32 HBU
- Temperature difference between meshes

Grid ID	No. of Elements	Temperature (°F)
N0	876,515	712
N1	1,925,705	712
N2	4,196,112	711
N3	9,218,858	709

- Savings of ~1000 hrs for both TN and NRC for every licensing action

Cost-Benefit Examples

GEORGE CARVER, NAC

NAC-STC High-Burnup Fuel Amendment (Cont'd)

- NAC was had no choice but to develop 3 brand new discrete thermal models (utilizing 900K, 3000K, 7200 elements including mesh refinement in axial direction) to support a methodical discretization allowing development of a Grid Convergence Index (GCI)

Model ID	Number of Hexahedral Elements	PCT (°F)	ΔT (°F)
Model No. 1	7,168,000	633	151
Model No. 2	3,024,000	632	151
Model No. 3	896,000	629	151
Base Model	95,672	638	153

- Performance of this work required over 2000 additional man-hours, demonstrated no significant change in PCT and resulted in no changes to the design or loading configuration(s)
- Proximity (~25F) of our calculated PCT, with no credit given for conservatisms in the model, to the PCT limit was used as the basis for requiring the GCI be performed

Where to Next?

- NRC's proposed risk tool has the potential to be an instrument of transformative change, if:
  - It brings real utility to the process originally envisioned in NUREG-1536
  - It is built on a thorough understanding of performance margin
  - It results in a demonstrable and transparent change in how "low" and "medium" priority licensing reviews are conducted

What will “Next” look like to licensees?

- Will we see a difference in review scope?
- Will we see a difference in review duration?
- Will we see a difference in the number/type of RAI’s?
- Will process enable licensees to seek a specific review priority?
  - e.g. be visible during pre-application interactions

What will “Next” look like to NRC?

- Safety focus will enable staff to stay ahead of growing workload associated with spent fuel storage
- Staff resources will be available for full scope of integrated fuel cycle
- NRC processes will be more transparent to stakeholders/public