Probabilistic Risk Assessment Input to Decommissioning Requirements

NRC/Industry/Public Workshop

Risk-Informed Basis for Decommissioning Exemption Guidance

July 15-16, 1999

Gaithersburg, MD

NEI

9/14

C4429901-3909-1

MAJOR TOPICS OF DICUSSION

- Purpose
- Previous Probabilistic Analysis
- Consistency of Analysis Assumptions
- Decision Criteria
  - Success Criteria
  - End States
- Realism of Accident Sequences
  - Initiating Event Frequency
  - Operating Crew Response
  - Time to Complete Actions
- Dominant Contributors: Avoid False Resource Allocations
- Risk Insights

PURPOSE

Risk-informed regulation uses PRA input to optimize the allocation of limited resources

As stated in Section 3.0 of DRAFT STAFF REPORT

"to reduce unnecessary conservatisms associated with current regulatory requirements and staff practices."

PREVIOUS PROBABILISTIC ANALYSIS

Two dominant contributors have been previously identified:

- Seismic induced failure of SFP causing loss of inventory
- CASK drop causing loss of inventory (before A-36)
- Resolution of A-36 eliminated Cask Drop as dominant consideration (NUREG-1353)

IDENTIFICATION OF ACCIDENTS

Accident Type	Comparison of Risk Contributors in NRC Studies Identified (I)/Risk Significant (RS)						
	Decommissioning Plant		Operating Plant				
	DRAFT NUREG	NUREG/CR 6451[3] (12 days after shutdown)	NUREG 1275, Vol 12	NUREG 5176	NUREG 1353	INEL 96-334	NUREG/CR 4982 & 5281[4]
Seismic Induced SFP Failure	I/RS	I/RS	--	I/RS	I/RS	I/RS	I/RS
CASK Drop Accident	I/RS	I/	I/	I/	I/	--	I/[5]
Loss of Inventory	I/RS	I/	I/	--	I/	I/RS	I/
Loss of SFP Cooling	I/	I/RS	I/[1]	I/[2]	I/	I/	I/
LOOP	I/RS	--	--	--	--	I/RS	I/RS
Aircraft Impact	I/	--	--	--	--	--	I/
Tornado Missile	I/	I/	--	--	I/	--	I/
LOCA		--	--	--	--	I/	
Turbine Missile	NA	NA	--	--	--	--	I/

RS – Risk Significant is arbitrarily defined in this table as >1E-6/yr fuel uncovery.

(1) "loss of cooling poses less hazard than loss of inventory because loss of cooling does not pose the immediate threat of uncovering the fuel." No fuel damage is probable until the fuel is uncovered.

(2) The consequences of the cooling and make-up water system failure on the spent fuel pool system were assessed by performing a thermal analysis. It was concluded that the fuel assembly uncovery would occur only after 3 to 7 days from the time of failure of the cooling and make-up water systems; this response time is considered to be sufficiently long for any recovery action.

(3) Same as NUREG-1353.

(4) Value impact analysis indicated no modifications were cost beneficial.

(5) Not risk significant after A-36 resolution.

Drain Pool and Clad Fire (Per SFP-Year)

	NUREG-1353 (1)	DRAFT NUREG (2)
Seismic	1.8E-6	2.0E-6
Cask Drop	3.1E-8	2.5E-6
Loop	—	2.7E-6
LOI	3E-8 1.2E-8	2.9E-6
Fire	—	8.6E-7
Aircraft	6E-9	4E-8
Tornado	—	5.6E-7
TOTAL	1.9E-6	1.2E-5

(1) Best Estimate
(2) Upper Bound

NEI

CONSISTENCY OF ANALYSIS ASSUMPTIONS

- Provide well recognized measure of risk

<u>or</u>

- Establish a new criteria that can be related to the NRC safety goals

END STATE CONSISTENCY

- Clear Technical Basis for evaluating severe accidents in spent fuel pools
  - Deterministic Analysis
  - Probabilistic
- Probabilistic Analysis is characterized by Best Estimate and include uncertainties.

RISK MEASURES/ END STATES

The DRAFT NUREG presents estimates that are very difficult for decision makers to incorporate in planning because:

- They are upper bounds without uncertainty characterization
- They are not tied to a surrogate risk measure
- They are a different measure than used in most PRA evaluations

CONNECTION BETWEEN DETERMINISTIC & PROBABILISTIC ANLYSES

- Previously probabilistic analysis had identified loss of pool water as a dominant risk contributor
- Deterministic calculations therefore assumed those conditions
- The DRAFT NUREG is postulating new scenarios for which comparable consequence analysis has not been performed

CONSISTENCY OF ANALYSIS ASSUMPTIONS

Disconnect Between

Deterministic Assessment

(Loss of ALL Water in the Fuel Pool)

AND

Probabilistic Analysis

(Boil Down of Inventory to Top of Fuel)

These two entirely different configurations are treated together in the sequence frequency evaluation.

CONSISTENCY OF END STATES

The problem with measuring the risk is seen in the variations in end states chosen in analysis:

really for operating plant

Study	End State
INEL 96-0334	Near Boiling Frequency
DRAFT REPORT	Frequency of Fuel Uncovery

These two conditions represent different challenges and do not represent comparable end states yet the data and times are treated in a similar manner.

FLAW IN ANALYSIS

- INCONSISTENCY OF END STATES CREATES CONFUSION REGARDING THE SEVERITY OF ACCIDENTS
- BECAUSE THE FREQUENCIES FOR THESE SEQUENCES ARE SO LOW(NEW REQUANTIFICATION)-- THE FLAW DOES NOT ADVERSELY IMPACT DECISION MAKING

BEST ESTIMATE ACCIDENT SEQUENCE FREQUENCIES

Risk informed regulation depends on the ability to characterize on a best estimate basis the accident scenarios that may contribute to risk. This best estimate characterization can then be used to prioritize resource allocation.

The use of upper bound or worst case assumptions to demonstrate the "importance" of an issue is counter productive to the risk informed process.

ELIMINATE CONSERVATIVE BIAS

Conservatisms when included make the results unable to be compared on a level playing field

Ensure the analysis is realistic, not upper bound or "worst case"

Avoid Conservative Bias

Result--contributors can be compared and fairly addressed

CONSERVATISMS NOTED IN THE DRAFT NUREG ANALYSIS

- HEPs
- LOOP Initiators
- AC Recovery Probabilities
- Diesel Fire Pump Reliability (i.e., diesel & electric)
- Time to Boil
- Time to Uncover
- No consideration of Boil Down Time from TAF
- Temperature of Zr Ignition

HRA FROM INEL 96-0334

- A simple approach
- Established in a draft report
- Peer Review by experts such as
  - Alan Swain
  - Gareth Parry

  Are not cited to support use of the DRAFT methodology
- Described as: relatively quick, if sometimes conservative, estimates of HEPs
  - not sensitive to detailed characteristics of available operating procedures
- Time windows are those for a full core off load -- i.e., very conservative

HRA

For the most part, the DRAFT NUREG HEPs are characteristic of operating crew actions that are required to be completed over relatively short time frames (e.g., 30 min.) and do not reflect the potential for:

- self checking
- second crew member check
- additional shift attention in recovery
- additional cues causing increased attention
- design simplicity--plant not operating
- long reaction times available
- management oversight

HRA

- Provide realistic evaluation of operating crew response
- Provide HEP estimates consistent with existing data and methodologies
- Ensure proper weight is given to performance shaping factors
  - Complexity
  - Time Available
  - Available management oversight
  - Shift changeover

KEY HEPs EXPECTED

from Swain Handbook

<u>Shift Change</u>	0.5/shift	EPRI TR 100259
not much credit given to shift changeover in draft rept.	0.1/day	Handbook Table 20-22
	1.5E-5/ 5 days	Handbook Table 20-22
Annunciation Response	1E-4Lvl	Handbook Table 20-23
	1E-4 Rad	
	1E-4 Temp	
Diagnosis by Control Room Personnel (1 day)	1E-5	Handbook Table 20-3
	1E-6	IEEE
		EPRI ORE

HEP Examples from NRC Staff Draft

Operating Crew Action	HEP	Time Available Hours	Shifts
Recognition of Loss of Cooling (Alarm)	3E-3	120	15
Recognition of Loss of Cooling (Walkdown)	1E-2	120	15
Restart SFP Cooling	3.5E-3	120	15
Start Diesel Fire Pump	1E-2 2E2	120 112	15 14
Align Offsite Resources	1E-2	120	15

HEP CONSISTENCY WITH PRA VALUES

Action	Time Available	Time of Action	HEP
ATWS Level Control	15 min	2 min	1E-2
ECCS System Initiation	30 min	1 min	1E-3
RHR Initiation	20 hrs	4 min	1E-6

LOWEST COMBINED HEP: LOSS OF COOLING EVENT

The most straightforward operating crew response is to the loss of cooling event.

The characteristics of the event scenario are:

- Sequential alarms NOT closely spaced for
  - Level
  - Temperature
  - Radiation
- Camera observation (if applicable)
- Shift walkdown of area

  6 to 12 shifts ~ 0.05 to 0.02
- Substantial time for recognition, recovery, repair, or use of offsite resources -- >190 hours

LOOP - HEP

LOOP is similar to loss of cooling and has equivalent HEPs.

In fact, with a LOOP event, the crew knows that the SFP will heat up and resources must be used to restore the SFP cooling. The HEPs could be considered even lower because the stress level may be optimized -- not routine, but not immediate life threatening.

HRA SUMMARY

Draft NRC analysis is inconsistent with past PRA practices regarding HEP best estimate quantification

Long duration of events is not explicitly incorporated in the quantification

Reductions of factors of 10 to 1000 in HEPs are consistent with current practice

Swain acknowledges that some HEPs are so low as not to be needed to consider further

Present analysis provides biased insight that would mislead decision makers

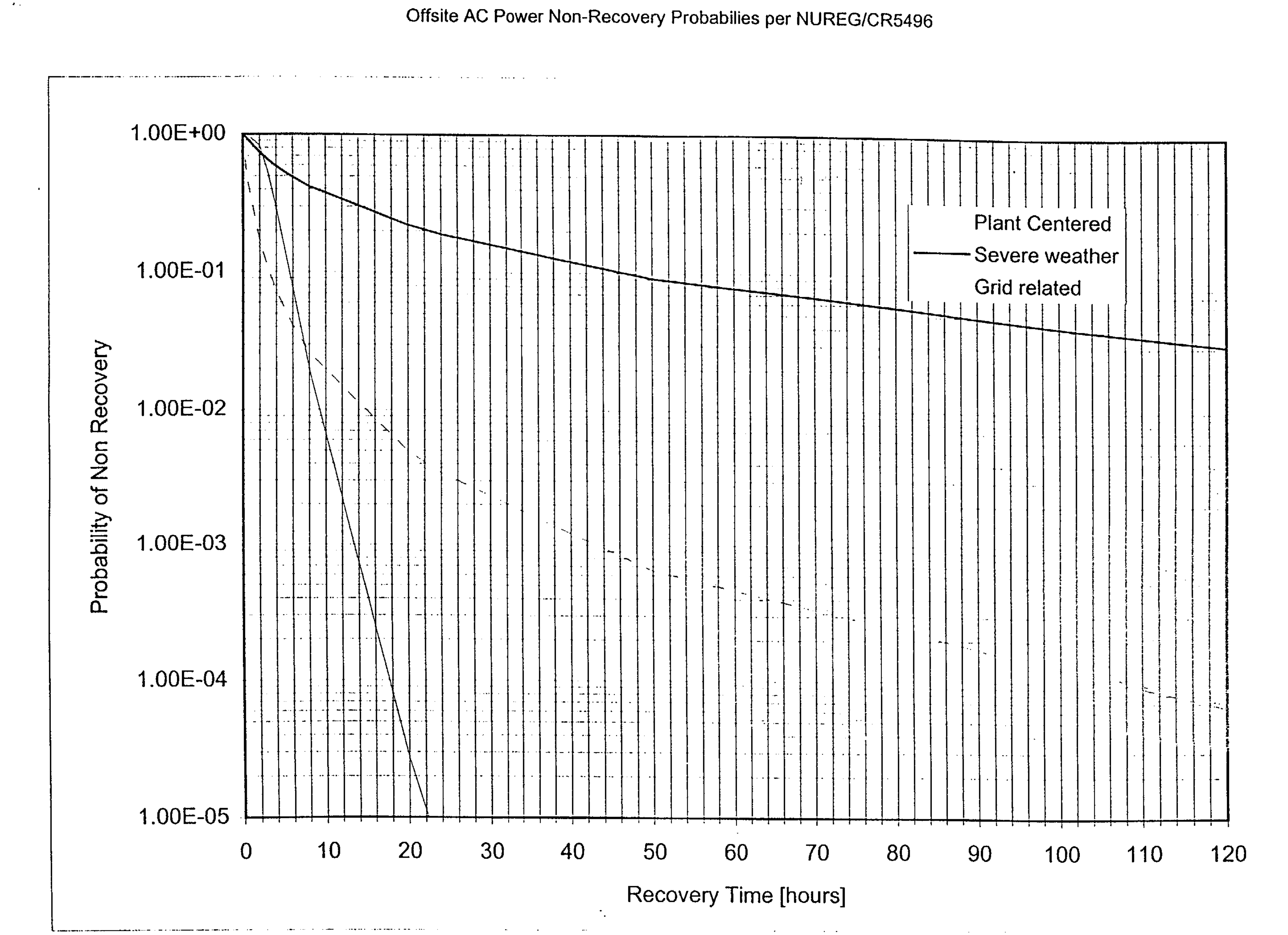
HEPs dominate many of the accident sequences and need to be addressed appropriately

CONSERVATIVE BIAS EXAMPLES

Plant Centered LOOP Analysis	DRAFT NUREG	DATA NUREG/ CR-5496
LOOP Frequency (/yr)	0.08	.04
AC Recovery 127 hrs	1E-3	6E-5
Total FFU (/yr)	1.3E-6	1.2E-8

may not

2-3 incoming line
priority to restore
power



Offsite AC Power Non-Recovery Probabilies per NUREG/CR5496
Probability of Non Recovery
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
0
10
20
30
40
50
60
70
80
90
100
110
120
Recovery Time [hours]
Plant Centered
Severe weather
Grid related

CASK DROP

NUREG -1353 = 3.1E-8/YR

NRC DRAFT = 2.5E-6

The two orders of magnitude change in perceived frequency appears to be strictly a conservative bias introduced

Table 3.3-3

DIESEL DRIVEN PUMP FAILURE PROBABILITIES

	Data Source	
	DRAFT NUREG	ALWR (EPRI)
FTS (/demand)		2.0E-2
FTR (/hr)		1.0E-3
24 Hr Mission		2.4E-2
TOTAL	0.18	4.5E-2

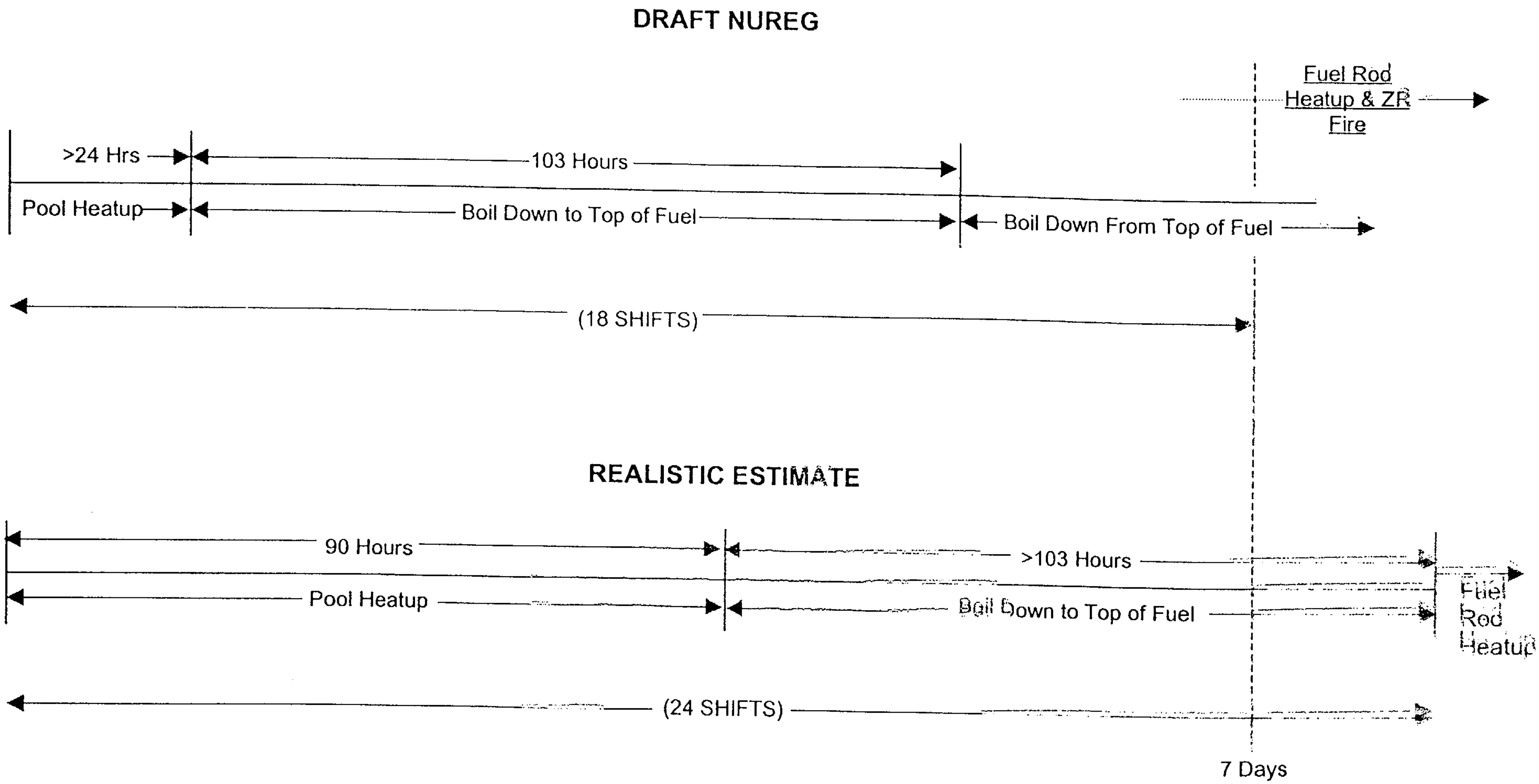


Figure 3.3-1 Comparison of Spent Fuel Time Line for Loss of Cooling Events

Table 3.3-2(a)

COMPARISON OF TIME TO BOIL IN OPERATING PLANTS SPENT FUEL POOLS -- NORMAL LEVEL (~1 YEAR AFTER LAST FUEL TRANSFER)

	X	Y	Z
Static Fuel Pool Load (P_{FP}) BTU/hr[1]	2.9E-6	2.4E-6	2.5E-6
Single Fuel Pool Volume (Gallons)	~360,000	~280,000	~233,000
Time to Boil Eqn (from 120°F)[1]	2.75E-8/P_{FP}	2.14E-8/P_{FP}	1.78E-8/P_{FP}
Time to Boil (Hrs)	94.8	89.2	71.2

(1) Based on plant measurements.
(2) Only considers heat capacity of water.

Table 3.3-2(b)

COMPARISON OF TIME TO BOIL IN OPERATING PLANTS SPENT FUEL POOLS – LEVEL AT BOTTOM OF TRANSFER CANAL (~1 YEAR AFTER LAST FUEL TRANSFER)

	X	Y	Z
Spent Fuel Pool Load (P_{FP}) BTU/hr[1]	2.9E-6	2.4E-6	2.5E-6
Estimated Single Fuel Pool Volume (Gallons) at Bottom of Transfer Canal	~180,000	~140,000	~120,000
Time to Boil Eqn (from 120°F)[1],[2]	1.38E-8/P_{FP}	1.07E-8/P_{FP}	0.92E-8/P_{FP}
Time to Boil (Hrs)	47.6	44.6	36.8

(1) Based on plant measurements.
(2) Only considers heat capacity of water.

CONSERVATISMS

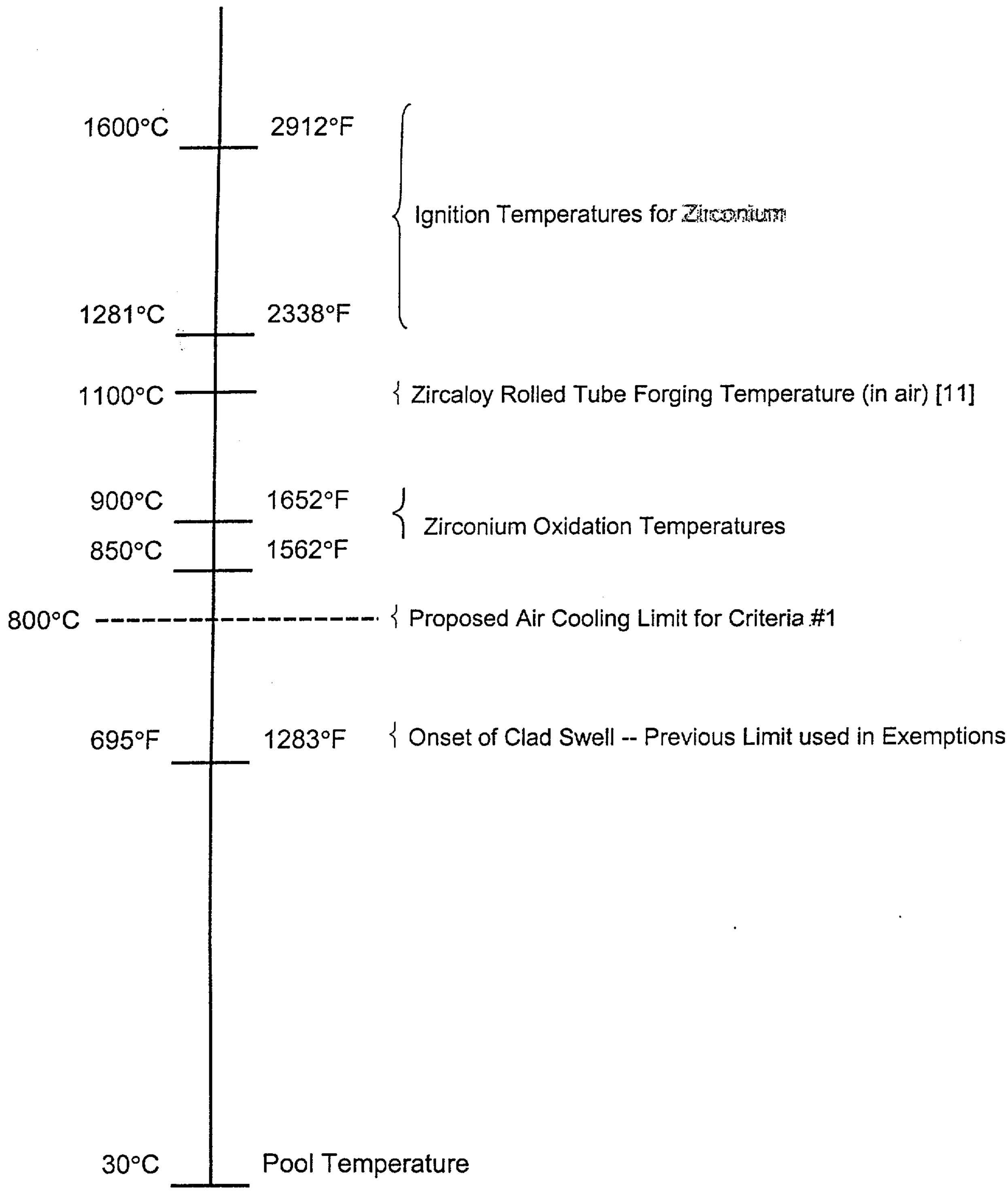
Ignition Temperature (Section 2.1.1)

> "The oxidation temperature reported by SNL was the onset of oxidation, but not the temperature at which rapid, runaway oxidation or ignition occurs"

Nevertheless 800°C is used despite references indicating that Zircaloy ignition is >1600°C.

Table 2.1-1

KEY TEMPERATURES IN THE ASSESSMENT OF
ZIRCONIUM IGNITION & RUNAWAY OXIDATION

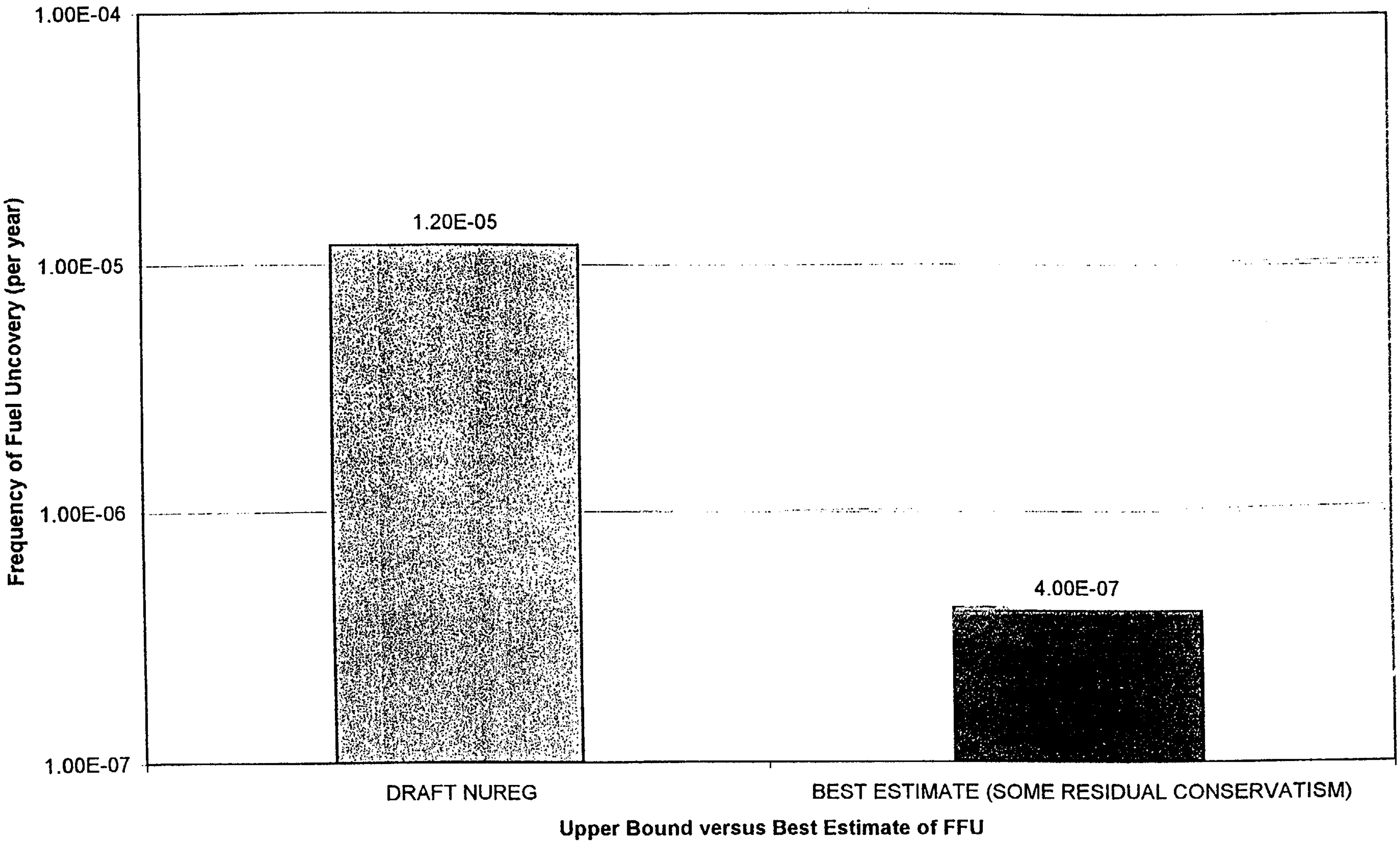


REQUANTIFICATION

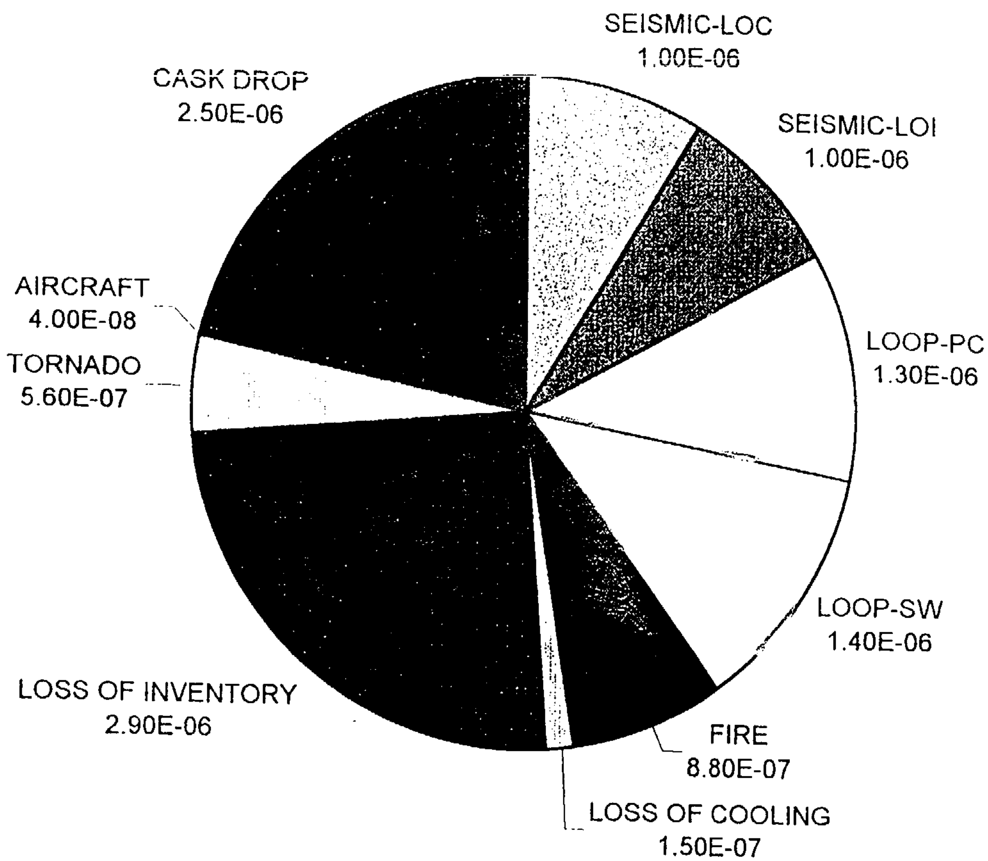
- Frame problem using realistic estimates and propagate uncertainty bounds on the sequences
- Reassess operator actions to credit
  - Alarm Response
  - Shift Changes
  - Diagnosis by Control Room Personnel
  - Self Checking Recovery based on Verification of symptom
- Ensure Best Estimate of:
  - Initiating Events
  - Equipment Response (e.g., DFP, Electric Fire Pump)

does not include seismic, so # ↑

COMPARISON OF POINT ESTIMATES



DISTRIBUTION OF CONTRIBUTORS TO FREQUENCY OF FUEL UNCOVERY (FFU) FROM DRAFT NUREG
(Case I Total FFU=1.2E-5/yr)



DISTRIBUTION OF CONTRIBUTORS TO FREQUENCY OF FUEL UNCOVERY (FFU) FROM BEST ESTIMATE CALCULATION
(Case I Total FFU=4E-7/yr)

No seismic

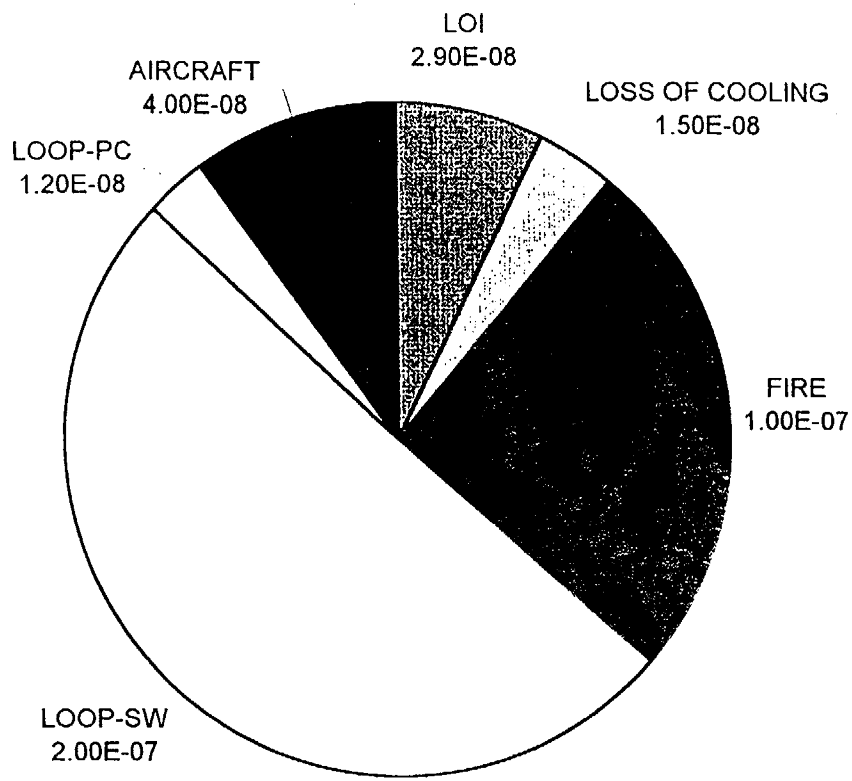


Table 5-2

RESULTS SUMMARY – FREQUENCY OF FUEL UNCOVERY (FFU)

Accident Initiator	Adverse Impact on Offsite Response	Plant Response Characterization	DRAFT NUREG Frequency (Per Year)	Revised Frequency Estimate Calculation (Per Year)
LOOP - Plant Centered	No	Frequencies are substantially lower and the time line extends beyond 7 days which according to AP-600 does not need to be considered as an accident.	1.3E-6	NA(3) (1.2E-8)
- Grid Related	No	Frequencies are substantially lower and the time line extends beyond 7 days which according to AP-600 does not need to be considered as an accident.		
- Severe Weather	Yes	Frequencies are substantially lower and the time line extends beyond 7 days which according to AP-600 does not need to be considered as an accident.	1.4E-6	NA(3) (2E-7)
Fire	No	Frequencies are substantially lower and the time line extends beyond 7 days which according to AP-600 does not need to be considered as an accident.	8.8E-7	NA(3) (1E-7)
Loss of Pool Cooling	No	Frequencies are substantially lower and the time line extends beyond 7 days which according to AP-600 does not need to be considered as an accident.	1.5E-7	NA(3) (1.5E-8)
Loss of Coolant Inventory	No	No mechanisms have been identified for the spontaneous failure of the SFP boundary causing loss of inventory. Data from NUREG-1275 is for cases with fuel movement and gates opened which are not applicable to the static conditions being considered here. Frequencies have been adjusted appropriately.	2.9E-6	2.9E-8

Table 5-2

RESULTS SUMMARY – FREQUENCY OF FUEL UNCOVERY (FFU)

Accident Initiator	Adverse Impact on Offsite Response	Plant Response Characterization	DRAFT NUREG Frequency (Per Year)	Revised Frequency Estimate Calculation (Per Year)
Seismic Event	Yes	Seismic Evaluation	2.0E-6	1E-7
CASK Drop	No	No heavy loads are being transported over the SFP during this time period. (Bundles need to decay for >5 years.)	2.5E-6	NA[3]
Aircraft Impact	Yes		4.0E-8[1]	4.0E-8
Tornado Missile	Yes	The tornado evaluation description in the DRAFT NUREG indicates that a tornado is not expected to damage the spent fuel pool itself. Therefore, the frequency cited in the DRAFT document is related to the failure of the cooling systems and makeup systems. Because cooling system failures lead to fuel heatup after 7 days, it is not considered an applicable accident scenario.	5.6E-7[2]	Not generally applicable NA[3] based on time to fuel uncovery
TOTAL			1.2E-5	5E-7

(1) Upper bound used from Appendix A.6.

(2) Main report says 2E-7/yr, Table 3.1-3 says 5.6E-7/yr., Appendix A.4 says 8E-7/yr for events that can cause missile damage to support systems for spent fuel cooling.

(3) Reflects the truncation of sequences that do not threaten fuel uncovery for significantly beyond 24 hours.

RISK INSIGHTS

- # Verify Reliability of Gate Seals
- # Spent Fuel Pool Cooling: Have siphon break valves
- # Temporary Pumps: Administratively control temporary pumps

  Suction

  Discharge

  Siphon Breaks
- # Provide connection for diesel fire pump to the spent fuel pool that can be aligned outside the refuel floor

SUMMARY

An approximate requantification demonstrates substantial conservatism in NRC risk estimates

Perform requantification of the risk analysis to reflect

Past NRC analysis

Current PRA HRA practice

Best estimate analysis -- not " worst case"

RESULT

- # FREQUENCIES OF ZR FIRE SEQUENCES APPEAR TO BE BELOW THE CREDIBLE RANGE OF 1E-6/YR

- # CONSIDER ACCIDENTS WITH FREQUENCIES CONSIDERED CREDIBLE

- # ACCIDENT THAT INVOLVE FUEL HANDLING MISHAPS MAY HAVE HIGHER FREQUENCIES

PROBABILISTIC RISK ASSESSMENT INPUT TO DECOMMISSIONING REQUIREMENTS

M Yankee - George ? Enrico

Big -

Oyster Creek - Jim

Conn Yankee - John

GE Pt. -

INDUSTRY'S EVENT MITIGATION ACTIVITIES

NEI

"Risk-Informed Basis for Decommissioning Exemption Guidance"

- Dominant Sequences for Long-Term Mitigation
  - Internal Fire
  - Loss of Power
  - Loss of Spent Fuel Cooling
- Dominant Sequences for Intermediate-Term Mitigation Events
  - Loss of Coolant Inventory

NEI

Event Initiators

- Self Revealing Event Initiators
  - Loss of Power
  - Seismic
  - Heavy Load Drop
- Internal Fire
- Loss of Cooling
- Loss of Inventory

NEI

Mitigation Activities

- Internal Fire
  - Prevention
    - Work Controls
    - Combustible Controls
  - Detection
    - Operator & Security Rounds
    - Fire Watches
    - Detection Devices
      - Routinely tested
      - Annunciated

NEI

Mitigation Activities (cont'd)

- Loss of Spent Fuel Pool Cooling
  - Detection
    - Operator Rounds - once or twice per shift (8/12 hour shifts)
    - Control Room Annunciation
      - Pool Temperature
      - Pool Level
      - Area Radiation Monitors
    - Operator Turnover Process
    - Security Rounds

NEI

Mitigation Activities

- Loss of Spent Fuel Pool Cooling (continued)
  - Mitigation
    - Detailed Procedures used following detection
    - Parallel Mitigation Strategies Pursued
      - Preplanned strategies commensurate with event speed, complexity, and probability of mitigation success
      - Personnel resources supplemented (e.g. E-Plan)
    - Multiple options available
      - Water sources
      - Water transport mechanisms
      - Power sources
    - Trained personnel

NEI

SUMMARY

- Event scenarios much simpler
- Detection assured
- For long and intermediate events:
  - Mitigating actions simpler
  - Parallel mitigation paths pursued
  - Mitigation effects easily observed

NEI

Conclusion

- Industry approach assures mitigation of long and intermediate events

- Industry will commit to actions discussed provided appropriate credit given in staff's probabilistic analysis

NEI