Risk-Informing Design Basis Hazard Levels

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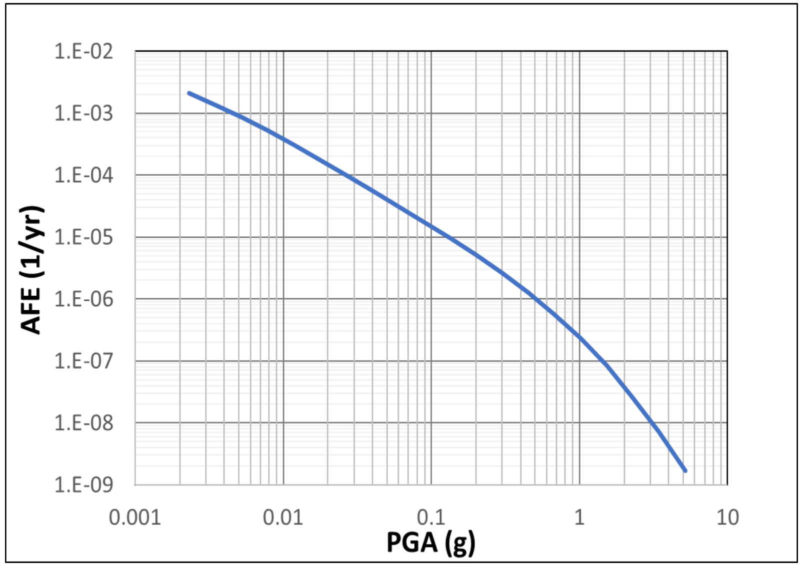
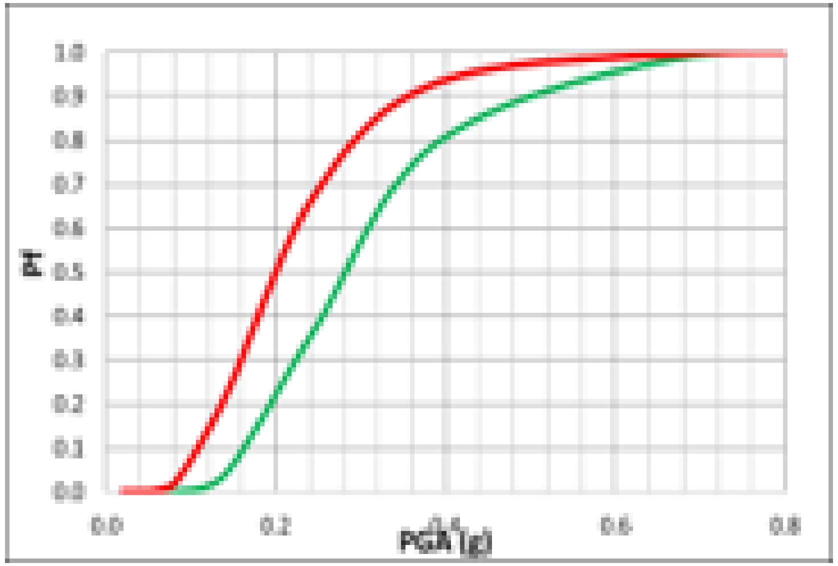
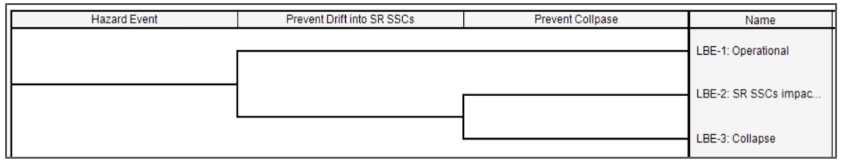
Background – External Hazard PRA Process

1. Hazard analysis (frequency vs. severity)



2. SSS Fragility (conditional probability of failure vs. hazard level)





3. Plant Response (LBEs with hazard-induced failures)

Problem Statement

- NEI 18-04 allows us to derive hazard-related requirements probabilistically.
- Probabilistic requirements apply to the whole event sequence, not just the initiator
  - Hazard is convolved with SSC fragility
- Need to address the effect of uncertainty
  - Hazard variability
  - Uncertainty and conservatisms in plant response
- Using 95th percentiles on *both* the hazard and fragility aspects of an event sequence causes compounded, possibly excessive conservatism in plant design requirements.

Constraints

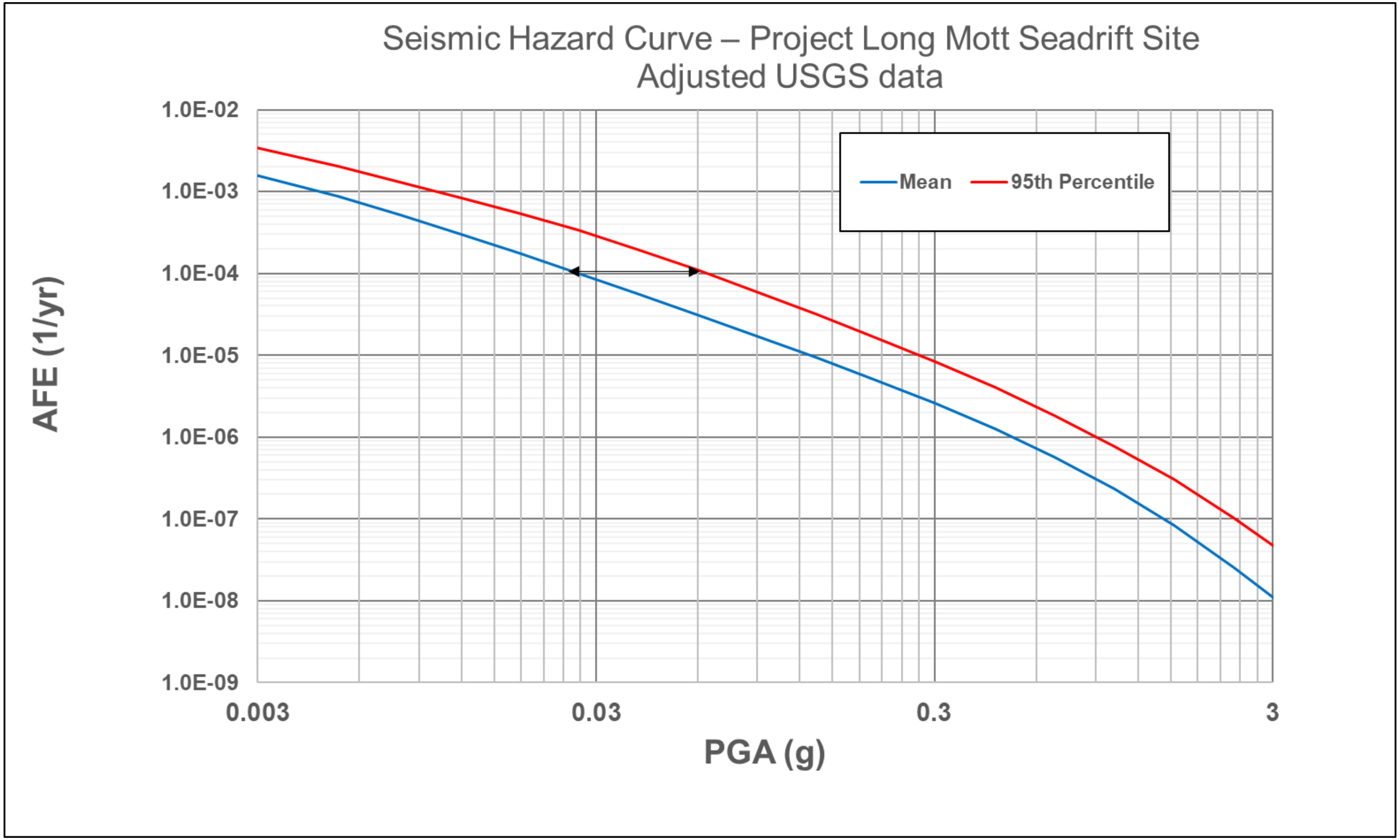
- Design Basis Accidents (DBAs) drive design requirements, which are deterministic in nature, and contain both implicit and explicit conservatisms.
- DBAs are derived from DBEs with only safety-related SSCs working
- An LBE with a mean frequency less than 10^{-4}/plant-year with a 95th percentile above 10-4/plant-year is **evaluated** as a BDBE and a DBE - *NEI 18-04*
  - Differing interpretations of this statement

- Need to account for cliff-edge effects
  - *Cliff edge effect*: an instance of a sudden large variation in plant conditions in response to a small variation in an input (e.g., change in flood height) - *ASME Non-LWR PRA Standard*
  - Non-linear cliff-edge effects may result in large variability in results around 1E-4/y

Proposed Approach to DBHL Evaluation

- Use 1E-4/y **mean** hazard level (e.g., flood height, wind speed, ground motion) as the design input for safety-related SSCs.
- Account for conservatisms in safety-related SSC fragility
  - Design margin
  - Inelastic energy absorption
  - Limit states short of total failure / collapse
- Show that 95% confidence frequency of any **LBE** with SR SSC failures is below 1E-4/plant-year.

Seismic Example



Mean 1E-4/y PGA = 0.027g
95% 1E-4/y PGA = 0.06g

Note: 10CFR50 Appx. S minimum PGA = 0.1g, so no direct impact on Project Long Mott

Seismic Example (contd.)

Fragility inputs

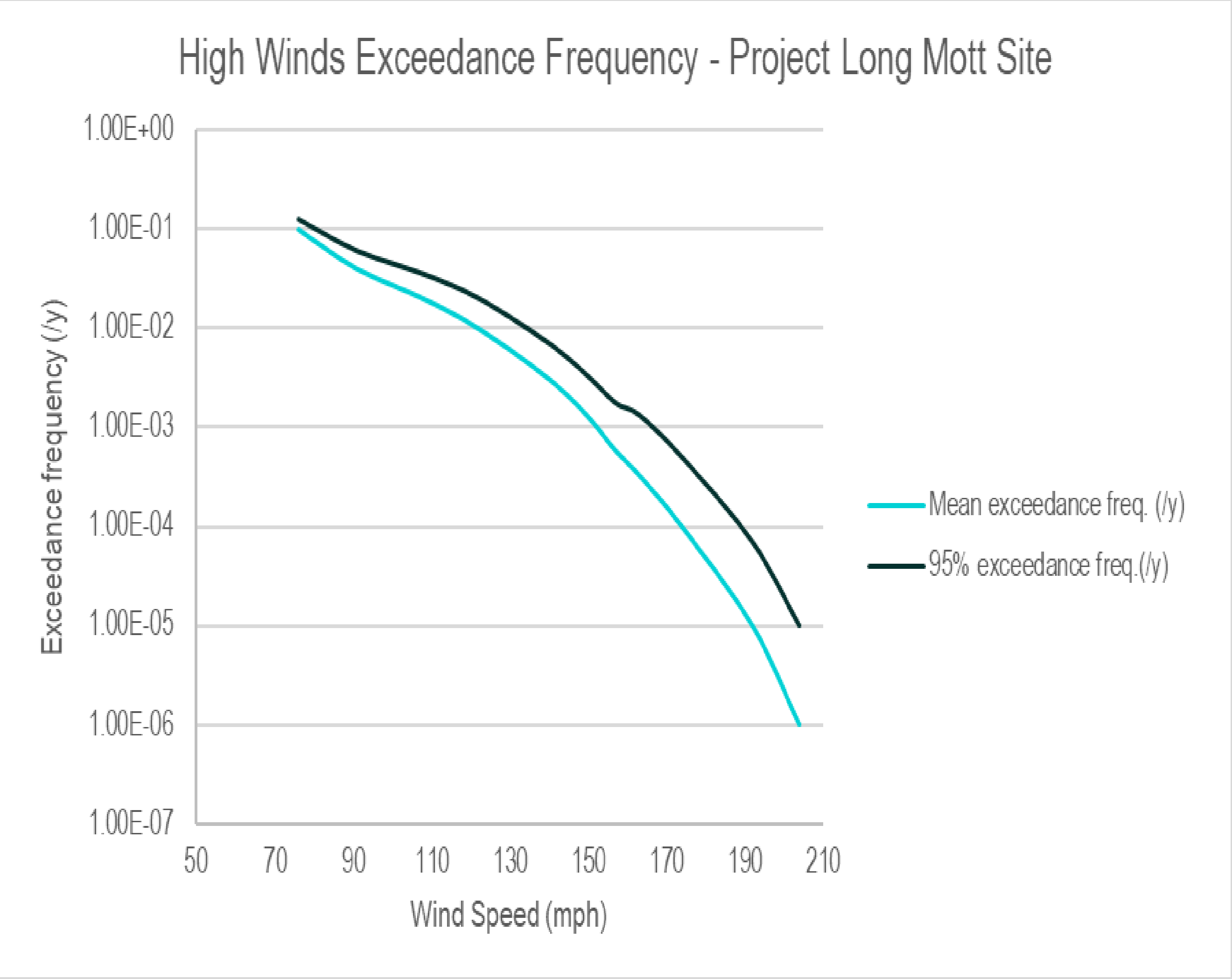
- Demand-to-capacity maximum ratio = 0.85 for SR structural failures
- Composite uncertainty βc = 0.4 (typical fragility value)
- No ductility credit (Fμ = 1.0) per ASCE 43 SDC5 limit state D

PGA (g)	Mean hazard freq. (/y)	95% Hazard freq. (/y)	Failure Event sequence freq. @95% hazard (/y)
0.0023	2.07E-03	4.45E-03	4.8E-08
0.0035	1.33E-03	2.99E-03	5.1E-06
0.0052	8.68E-04	2.04E-03	1.3E-05
0.0079	5.15E-04	1.31E-03	2.0E-05
0.0118	3.08E-04	8.57E-04	3.1E-05
0.0177	1.77E-04	5.47E-04	8.2E-06
0.0265	1.01E-04	3.39E-04	5.2E-06
0.0398	5.62E-05	1.99E-04	2.3E-06
0.0597	3.13E-05	1.11E-04	2.0E-07
0.0896	1.74E-05	6.01E-05	2.7E-07
0.134	9.56E-06	3.21E-05	1.6E-07
0.202	5.01E-06	1.64E-05	1.0E-07
0.302	2.62E-06	8.43E-06	9.9E-08
0.454	1.25E-06	4.01E-06	5.5E-08
0.68	5.63E-07	1.81E-06	3.4E-08
1.02	2.31E-07	7.69E-07	2.2E-08
1.53	8.36E-08	3.02E-07	1.5E-08
2.3	2.53E-08	1.01E-07	1.0E-08
3.44	7.15E-09	3.20E-08	7.8E-09
5.17	1.67E-09	8.52E-09	2.5E-08
			8.6E-05

Results

- **All LBEs with structural failures have frequencies below 1E-4/y with 95% confidence**
  - Design margin and conservatisms in design calculations more than compensate for using the mean hazard
- Satisfied for cumulative LBE frequency, so not dependent on seismic interval selection
- Satisfies NEI 18-04 interpretation of uncertainty / cliff-edge effects
  - All failure frequencies are BDBEs with 95% confidence

High Winds Example



Inputs	Units	Value
Design wind speed (mph)	mph	174
Design margin factor (C/D)	-	1.18
Margin to failure beyond design limits	-	1.10
Median wind capacity (mph)	mph	225
Log standard deviation (β_c)	-	0.15

Wind Speed (mph)	95% occurrence frequency	Failure prob.	95% confidence Failure freq. (/y)
76	8.48E-02	2.23E-13	1.89E-14
91	4.02E-02	7.70E-10	3.09E-11
108	1.98E-02	4.83E-07	9.57E-09
122	1.52E-02	2.20E-05	3.34E-07
139	4.80E-03	6.50E-04	3.12E-06
149	2.70E-03	2.95E-03	7.97E-06
157	8.71E-04	8.10E-03	7.06E-06
163	8.93E-04	1.56E-02	1.39E-05
174	4.40E-04	4.28E-02	1.88E-05
192	6.00E-05	1.44E-01	8.64E-06
204	1.00E-05	2.55E-01	2.55E-06
		Total	6.25E-05

Conclusion

Using the *mean* hazard as the design input level likely ensures there are no Design Basis Events with safety-related SSC failures at *95% confidence*.

- Needs to be confirmed by hazard PRA with uncertainty evaluations

<u>Factors affecting statement accuracy</u>

- Slope of the hazard curve around 1E-4/y
- Minimum design margin
- Margin to SSC median failure beyond code limits
- Cliff-edge effects, e.g. flood barrier overtopping

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