Public Meeting on Probabilistic Risk Assessment of Seismic-Induced Fire and Flood
December 11 to 12, 2013

Appendix B

Kevin Coyne's Presentation

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Protecting People and the Environment

NTTF Recommendation 3: Seismically Induced Fires and Floods

December 11, 2013

Kevin Coyne, RES/DRA

Background

- Seismic events have the potential to cause:
  - multiple failures of safety-related SSCs;
  - induce separate fires or flooding events in multiple locations at the site; and
  - degrade the capability of plant SSCs intended to mitigate the effects of fires and floods.

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Background

- The Fukushima Near Term Task Force (NTTF) recommended, as part of the longer term review, evaluation of potential enhancements to the capability to prevent or mitigate seismically induced fires and floods
  - Scope includes internal seismically induced fires (e.g., breakers, transformers) and floods (e.g., tanks, piping systems)
  - Also includes external seismically induced fires and floods
- Prioritized as Tier 3 in SECY 11-0137
  - Commission agreed with Tier 3 Prioritization, but
  - Directed the staff to initiate development of PRA method to evaluate potential enhancements as part of Tier 1 activities (i.e., begin without delay)

Background (con't)

- PRA Method Challenges:
  - hazard definition & characterization
  - seismic fragilities for SSCs, including fire protection components
  - modeling concurrent and subsequent initiating events
  - treatment of systems interactions
  - human reliability analysis methodologies suitable for seismically induced hazards
  - multiunit risk considerations

Key Considerations

- Limited number of NRC staff with required knowledge, skills, and abilities
- No current consensus state-of-practice methods exist for seismically induced fires and floods for NPPs
- ASME/ANS Joint Committee on Nuclear Risk Management has ongoing initiative on multiple concurrent events
- Other Tier 1 activities will provide substantial information relevant to this issue

Initial Planning

- NRC Staff developed an initial plan for PRA method development in SECY 12-0025.
- Initial PRA activities included:
    1. Preliminary information gathering
    2. Planning activities
    3. Feasibility study
    4. Coordination with other ongoing initiatives

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Near Term Activities

- Results from several Tier 1 recommendations may better inform the this issue:
  - 2.1 Seismic and flooding hazard evaluation
  - 2.3 Seismic and flooding vulnerability walkdowns
  - 4.2 Mitigation Strategies
  - 5.1 Containment venting
  - 7.1 Spent fuel pool
- More efficient to wait until sufficient information becomes available from these efforts.

Near Term Activities (con't)

- Ongoing:
  - Standards development organization engagement
  - Assess interim results from NTTF Recommendations and other activities
  - Continue PRA method development activities (including consideration of both quantitative and qualitative approaches)

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Appendix C

Bob Budnitz' Presentation

COMMENTS ON DEVELOPING A PROPER "FRAGILITY CURVE" FOR SEISMIC-INDUCED FIRE ANALYSIS (or SEISMIC-INDUCED FLOODING ANALYSIS)

December 11, 2013

"NRC Workshop on PRA for seismic-induced fire and flooding"
Rockville MD

Robert J. Budnitz

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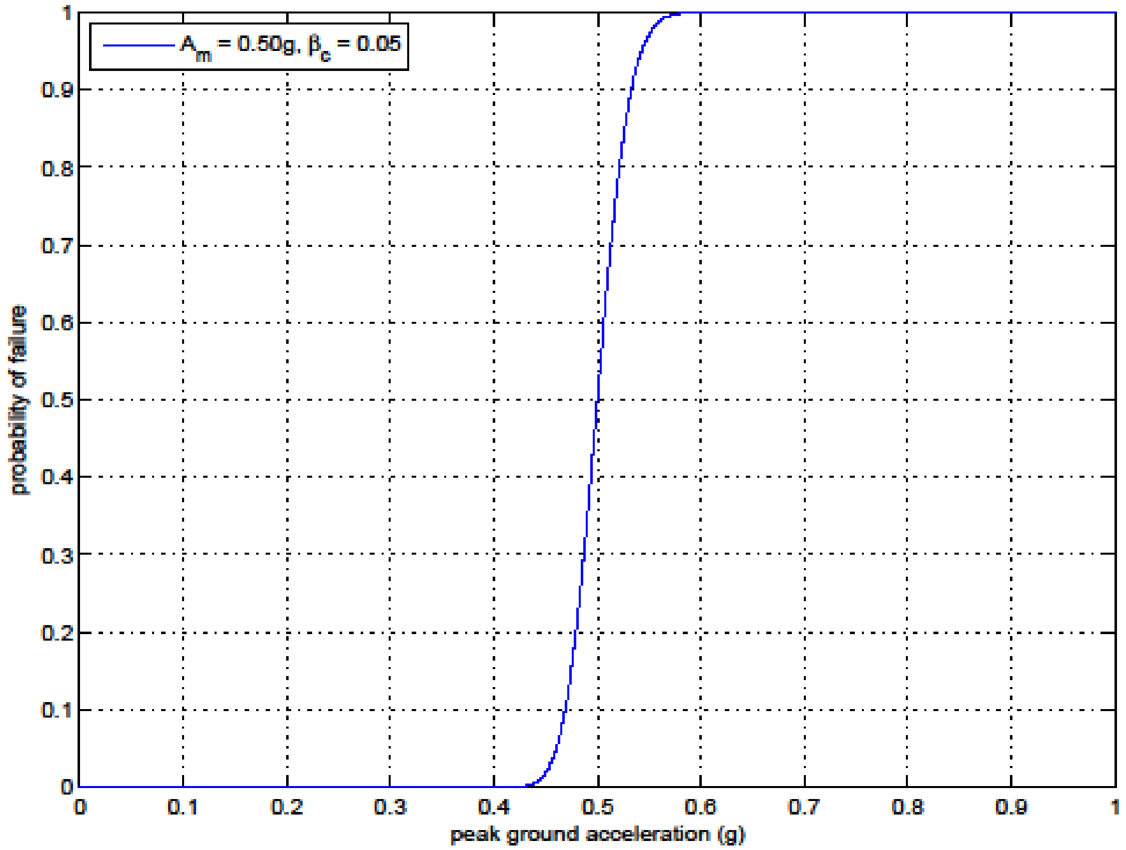
IPEEE guidance

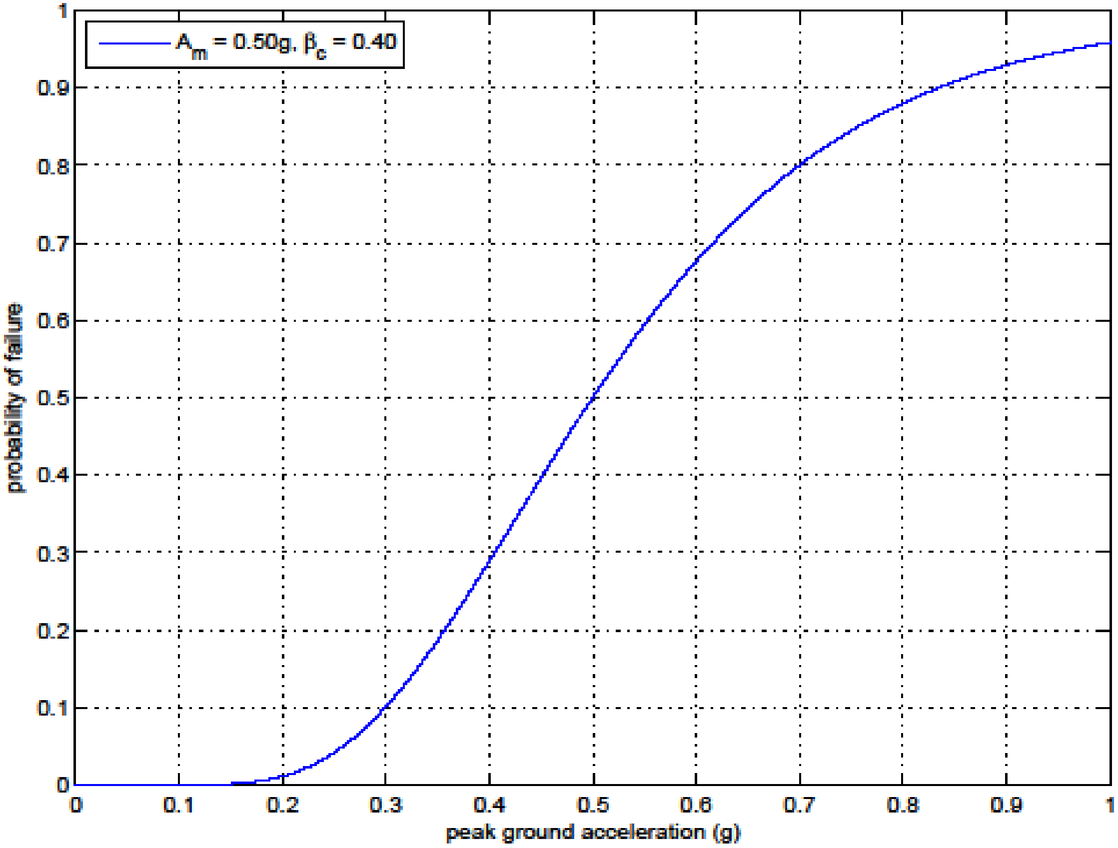
- Guidance for both seismic-induced fires and internal floods:
  - Walkdowns with these issues in mind
  - Find 'em
  - Fix 'em

[*There was no consideration whatsoever of possible PRA quantification*]

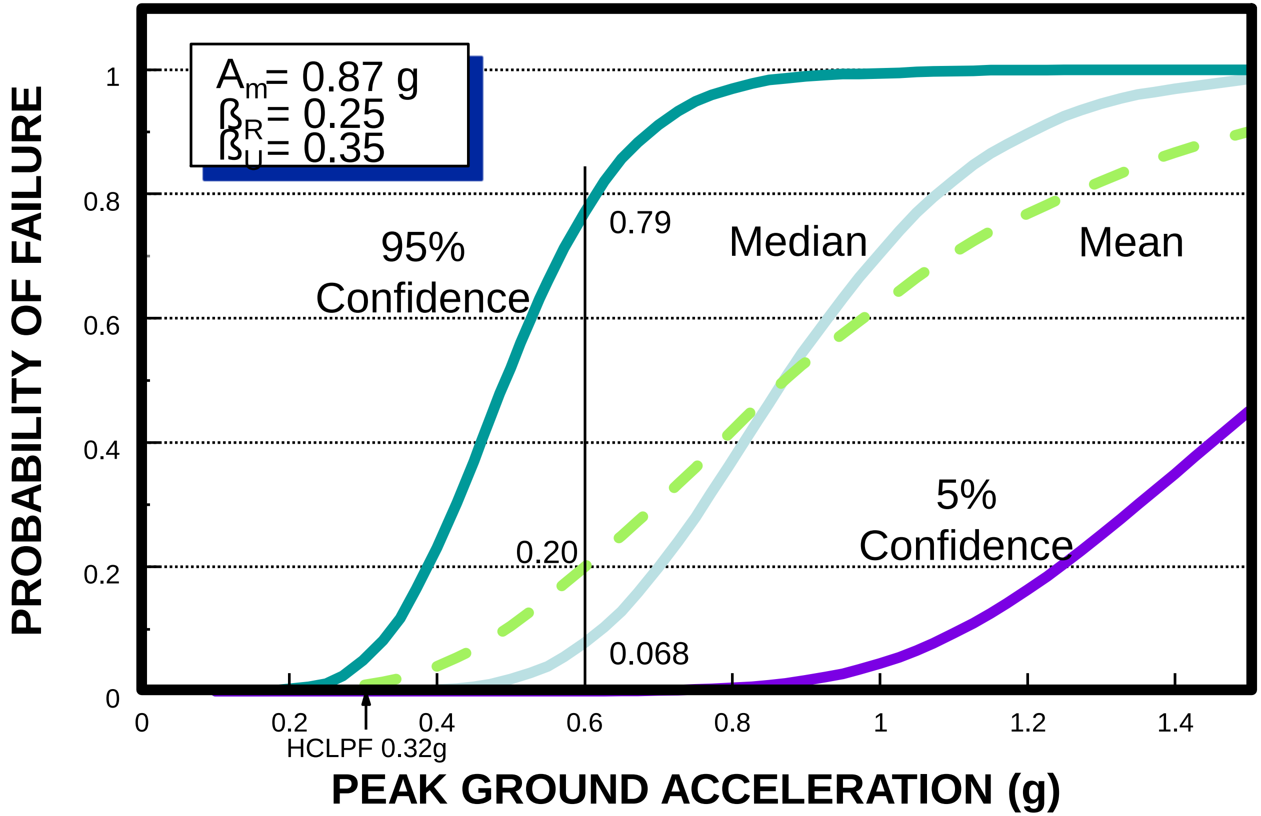
An unrealistically steep fragility curve



A more realistic fragility curve



An actual realistic “fragility curve” showing both variability and uncertainty



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Appendix D

Barry Sloane’s Presentation

PERSPECTIVES ON IDENTIFYING AND ADDRESSING SEISMICALLY-INDUCED INTERNAL FIRES AND INTERNAL FLOODS IN A SEISMIC PRA OR PRA-BASED SMA

Presentation to NRC Workshop on Seismically Induced Fire and Floods

Rockville, Md December 11-12, 2013

Barry Sloane, Vince Andersen,
ERIN Engineering and Research
Magdalena Moisin, Ontario Power Generation
Alexander Trifanov, Kinectrics

Based on a paper originally presented at
ANS PSA 2013 International Topical Meeting on Probabilistic Safety Assessment and Analysis, Columbia, SC, September 2013

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Overview and Perspective

- Consideration of “consequential” events is important to establishing a complete risk picture
- Existing guidance calls for addressing seismically-induced fire and flood
  - Consensus methodologies and data needed to do so quantitatively are not available
  - Significant gaps in knowledge needed for formal quantification
- A phased approach is most appropriate
  - Focus initially on potentially large source impacts and walkdown observations
  - Add refinement based on initial insights and qualitative risk impacts, to the degree supported by available knowledge
  - Drive development of additional R&D to address quantification issues

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Background

- After Fukushima, OPG was requested by Canadian Nuclear Safety Commission to provide information on risk from seismically-induced consequential events.
- Individual hazard PRAs (internal events, internal flooding, internal fire, seismic) and external hazard screening had already either been completed or were well along
  - Needed a methodology to back-fit impacts into SPRA or PRA-based SMA
  - We found numerous requirements, but no real methodology to apply
- Initiated project, with focus on seismically-induced internal fire/internal flood

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Requirements Exist, but not Detailed Methodology or Data; Examples

Summary of Existing Guidance / Requirements from Various Sources	
SOURCE	Example Guidance
IAEA SSG-3 [1]	"The potential for seismically induced fires and floods should also be included in the focus of the [seismic] walkdown;" and "… seismically induced fires and floods should be included in the Level 1 PSA model for seismic hazards, unless it is clearly justified that other seismic damage bounds additional effects from seismically induced fire and floods."
USNRC: **GL 88-20], NUREG-1407 [3],** **NUREG/CR-5088 [4],** **NUREG/CR-6850 [5],**	Provides expectations for addressing seismically-induced other hazards in some manner and suggest that the USNRC considers the evaluation of seismic /internal fire interactions worthy of evaluation. NUREG/CR-5088, Fire Risk Scoping Study [4], notes several specific potential impacts that can be postulat ed that could cause an interaction between earthquakes and internal fires.
EPRI reports: **EPRI TR1002989, SPRA Implementation Guide';** **EPRI NP-6041, Methodology for Assessment of NPP Seismic Margin [8],** **EPRI TR-1025287, SPID**	SPRA Implementation Guide recommends addressing seismically-induced internal fires and internal floods in the seismic plant walkdowns, and including issues that cannot be dismissed/remedied in the seismic PRA quantification. EPRI NP-6041: look, during required walkdowns, for potential for internal flooding from failures of Category II or Category I SSCs. SPID: seismically-induced internal fires and internal floods are not within the scope of that guidance, except that "… it is expected that the walkdowns would include consideration of seismically induced fire and flooding …" (although detailed analyses could be performed in a later assessment).
ASME / ANS PRA Standard	Seismic PRA requirements to consider seismically-induced internal floods and seismically-induced internal fires during fragilities and seismic PRA walkdowns ; refers to NUREG-1407 [3] and EPRI NP-6041 [8] guidance. Also includes fire PRA requirements to address seismically-induced internal fires qualitatively.

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Conclusion Regarding Existing Requirements vs. Methodology

- There is an expectation that a complete PRA will include consideration of seismically-induced fires/floods
- There is no consensus approach/methodology for how to do this
  - For Fire issues especially, there is a lack of data to support seismic fragilities of SSC failure modes that would actually lead to a fire
- There is no clear requirement that this be quantitative
- Walkdowns are important to identification of potential interactions

- So, what does actual experience show?

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Example Earthquake Experience Insights

Examples from Summary of Experience Review	
Event / Source	Reported Experience
Onagawa NPP (2005); Shika NPP (2007); Fukushima Daini NPP (2011); North Anna (2011)	***Fire and flood damage were not reported***, nor were safety related facility malfunction, damage or failures reported to have occurred. The ***external flooding that occurred from the tsunami at Fukushima Daini is outside the scope of this process.***
Kashiwazaki-Kariwa NPP (2007)	Fire and flooding event occurred in non-seismically qualified equipment, ***but malfunction, damage or failure to SSCs important to safety were not reported. Potential precursors included***: soil liquefaction leading to Unit 3 transformer pad shifting and fire, and leading to flood in the Unit 1 yard due to failure of fire protection piping; oil leakage from several transformers and the oil tank room of the turbine-driven AFW pump (but none of these sources ignited); Units 1 and 2 experienced non-significant leaks in fire protection piping; ***sub-stantial sloshing of water from elevated spent fuel pools at U1 and 2***.
Onagawa NPP (2011)	Fire reported in a non-seismically qualified power supply in the lower level of turbine building, but no reports of seismically-induced floods. The external flooding that occurred from the tsunami is outside scope of this process.
Fukushima Daiichi NPP (2011)	Several fire events reported; fire (possibly in the motor-generator sets) report-ed several days after the earthquake at Unit 4. External flooding that occurred from the tsunami is outside scope of this process. ***Fires associated with post-core damage H2 release from containment and subsequent ignition at Units 1, 3, and 4 are outside the scope of this process*** because these are related to Level 2 phenomena resulting from the tsunami-induced external flood.

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Conclusion Regarding Earthquake Experience

- Cannot be too conclusive since (fortunately) there isn't that much experience
- In the available experience, there is no particular indication of significant vulnerabilities relative to seismically-induced internal fires/floods
  - But there have been some events that the plants and operators were able to deal with
- Based on the available requirements and experience, proceeded to develop a methodology

Development of Methodology

- Adopted a "graded level of detail" philosophy
- Initially look for "large" fire or flooding sources and assess potential impact on existing Seismic PRA (SPRA) sequences
  - Justified by insights from plant earthquake experience
  - Consequential fires and floods have not resulted in significant impact on progression of post-seismic plant or operator response

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Selection of potentially significant sources

- Internal Fire:
  - Sources must be sufficient to result in
    - Adverse impact to seismic SEL SSCs credited in the SPRA, or
    - Adverse impact to operator seismic response
  - Started with NUREG/CR-6850 fire source bins
    - Retained bins involving significant quantities of stored fuel or oil supplies, H2 gas supplies, large oil-filled transformers
    - Other bins have limited potential to cause significant additional damage to equipment required for seismic response, beyond local fire (*but confirm via internal fire PRA*)
    - Retained sources were assumed to result in fire due to sparks/shorts (P=1)

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Summary of NUREG/CR-6850 Bins Selected As Potential Seis-Induced Fire Sources

6850 Bin	Bin Description	Comments
04	Main control board (in Main Control Room)	**Not representative of seismically-induced damage *assuming the SPRA/PBSMA has not identified low seismic capacity issues with the MCB***
08	Diesel generators	***Check susceptibility of fuel oil storage to seismically-induced damage and consequential fire***
12	Cable runs	***Check susceptibility of cabling between non-seismically-qualified buildings to seismically-induced cable fire***
15	Electrical cabinets	**Not significant source of seismically-induced fire *unless SPRA/PBSMA has identified specific cabinet vulnerabilities to seismically-induced shorts***
17	Hydrogen (H_2) tanks	**Evaluate for SPRA/PBSMA impact**
18	Junction boxes	**Not significant source of seismically-induced fire *unless SPRA/PBSMA has identified specific cabinet vulnerabilities to seismically-induced shorts***
19	Miscellaneous H_2 fires	Evaluate for SPRA/PBSMA impact
23	Transformers (oil filled)	Evaluate for SPRA/PBSMA impact
27	Transformers – catastrophic failures	Evaluate for SPRA/PBSMA impact
28	Transformers – non-catastrophic failures	Evaluate for SPRA/PBSMA impact
29	Yard transformers	Evaluate for SPRA/PBSMA impact
30	Boiler	Evaluate for SPRA/PBSMA impact
34	Turbine generator – hydrogen	Evaluate for SPRA/PBSMA impact
35	Turbine generators–oil	Evaluate for SPRA/PBSMA impact
--	Above ground fuel tanks [1]	Evaluate for SPRA/PBSMA impact
--	Fuel piping [1]	Evaluate for SPRA/PBSMA impact

Selection of potentially significant sources

- Internal Flood:
  - Source has to be sufficient to result in
    - Adverse impact to seismic SEL SSCs credited in the SPRA, or
    - Adverse impact to operator response
  - Focus on nonseismically-qualified sources (mainly tanks and piping)
    - Qualified piping/tanks have higher seismic capacity, more likely that related flooding events will occur when seismic conditional core damage probability (CCDP) is already high

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Walkdown and Preparation

- Review available internal flooding and internal fire PRAs for the plant (and associated walkdown summaries) to gain insights into important sequences involving fire/flood sources
- Apply screening criteria (later slide)
- Develop list of SSCs for additional walkdown
- Perform walkdown focused on gaining insights into potential fire/flood scenarios
  - Walkdown can be early or later in the process
  - Screen out sources where appropriate based on walkdown observations/insights

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Supplemental Walkdown Considerations

Considerations for Walkdowns of Potential Seismically-Induced Fire and Flood Sources
Check for potentially important sources of explosion (e.g., pressurized tanks of hydrogen or other gases) that might not have already been addressed in the seismic or internal fire PRAs.
Walk down routes operators are expected (or procedurally required) to take to perform post-seis mic event actions outside the main control room; identify internal fire or internal flood scenarios that could impact seismic response operator actions credited in the SPRA/PBSMA.
Examine outside transformers to see if they are mounted on a separate pad (potential soil liquefac tion issue). Assess the potential for transformer fires propagating into plant buildings.
Examine the ruggedness of fire protection piping (e.g., welded/bolted steel installations versus clamped connections/cast iron pipe) in areas with required safe shutdown equipment.
Examine fire brigade staging areas and equipment storage areas for potential for seismically-induced fire, or potential that fire brigade equipment may be damaged or inaccessible given the seismic event; in considering the seismically-induced fire, credit for suppression that is included in the fire PRA may need to be reduced or eliminated.
Check for CO2 in emergency generator areas (e.g., potential operator access issue due to seismic-ally-induced inadvertent release).
Check for Seismic II / I (i.e., non-seismically-qualified SSCs positioned over qualified SSCs) interacti on issues not already addressed within the plant-specific fragility analysis.
Examine proximity of emergency generator air intakes to fire / smoke sources.
Document results of walkdowns in a manner consistent with that of the SPRA/PBSMA.

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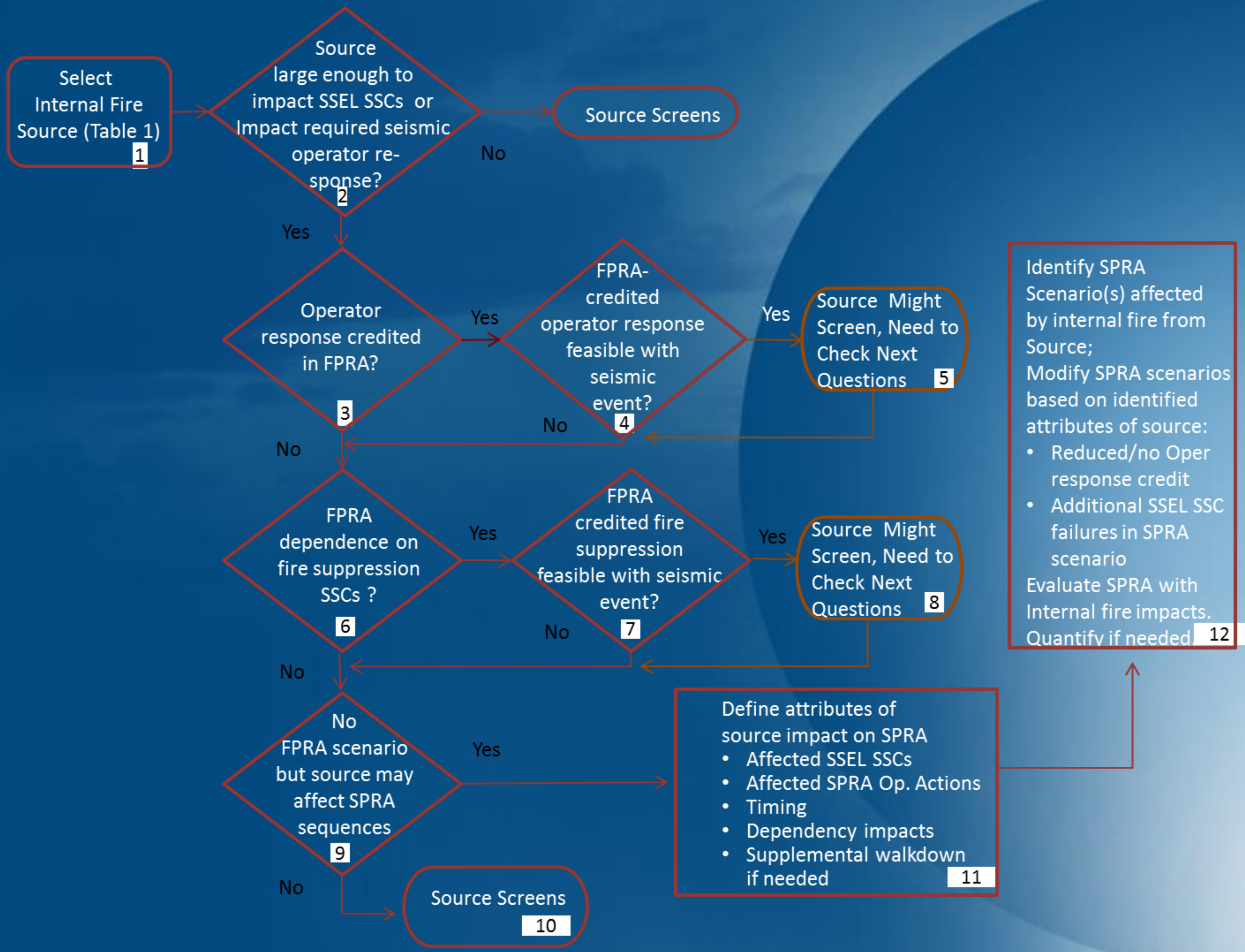
Process – Internal Fires (1)



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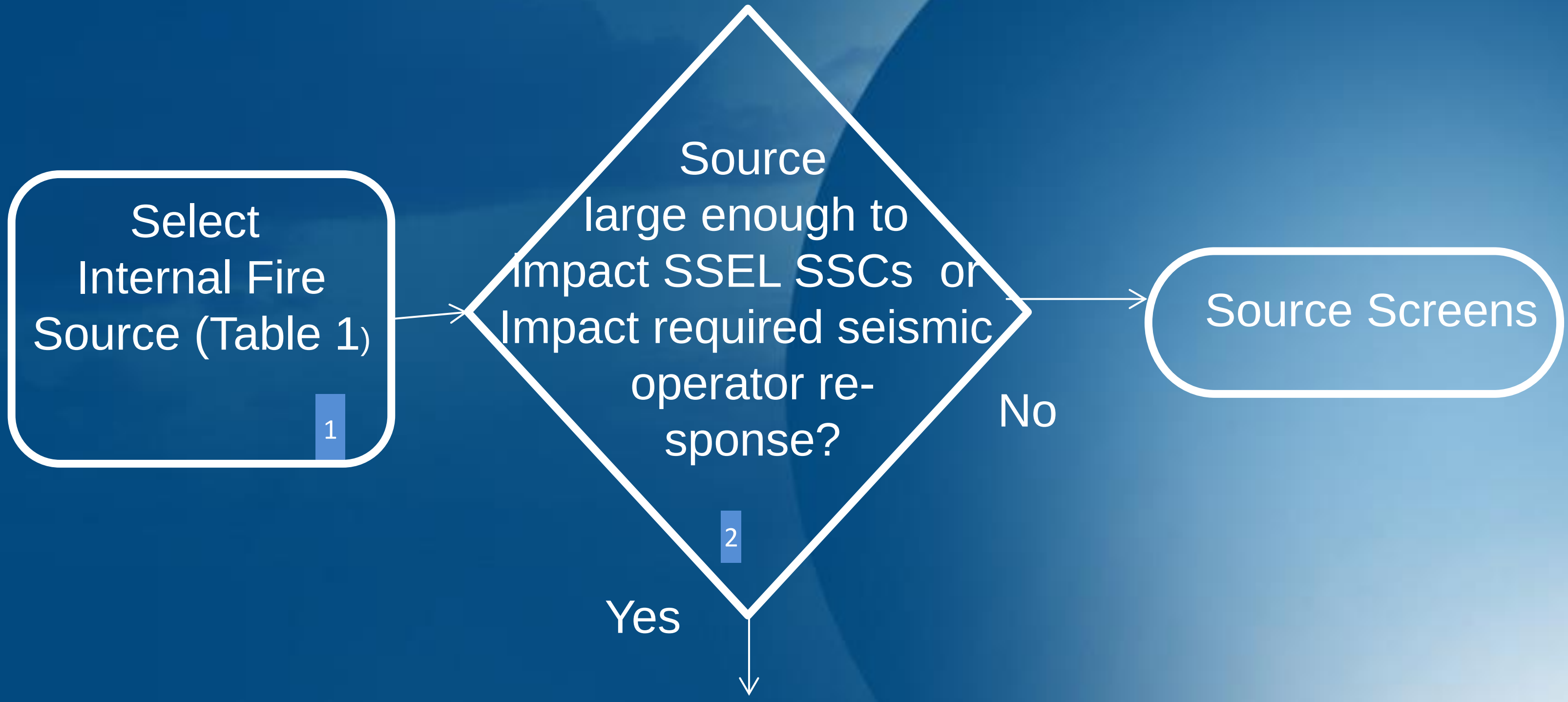
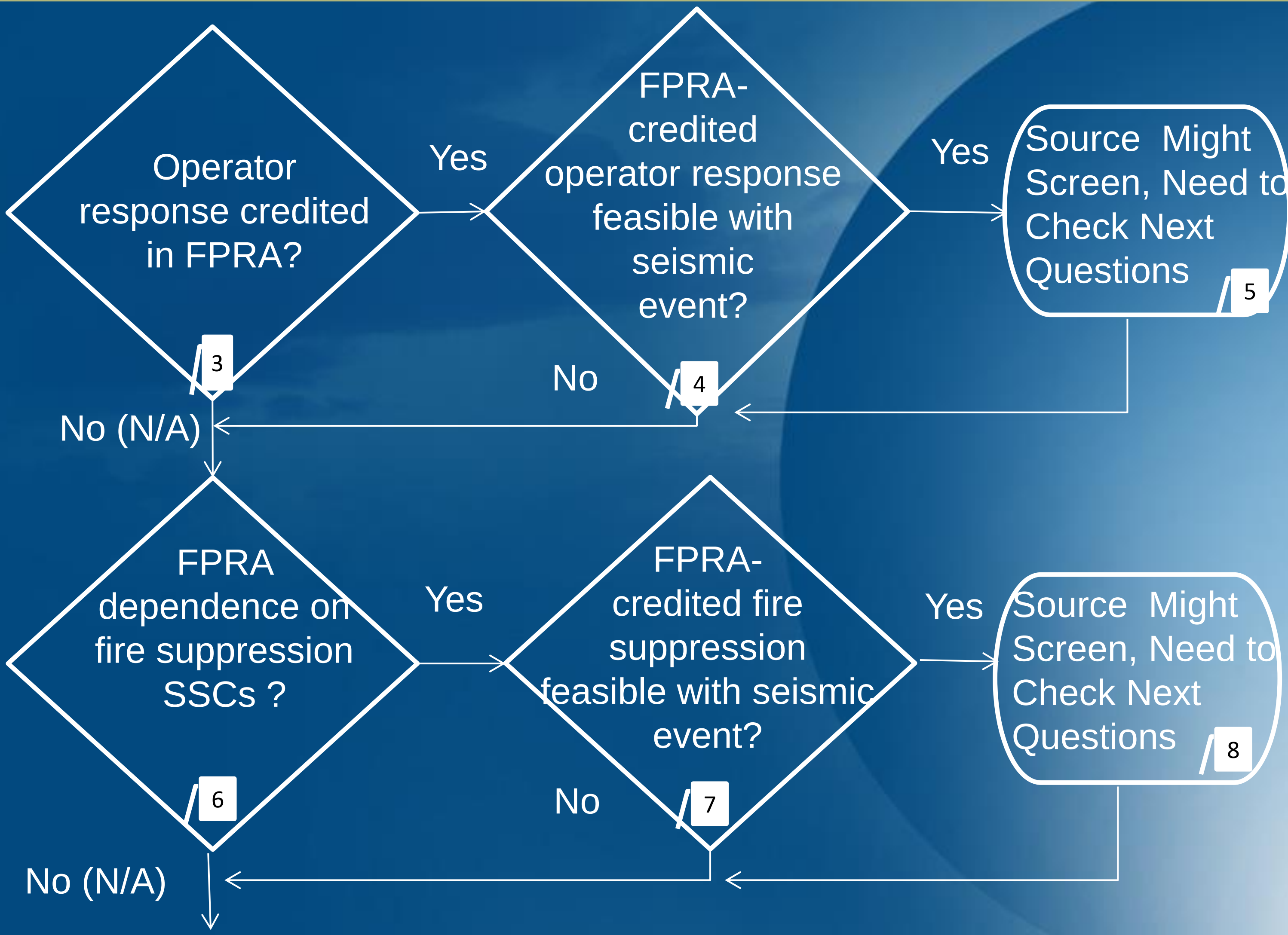
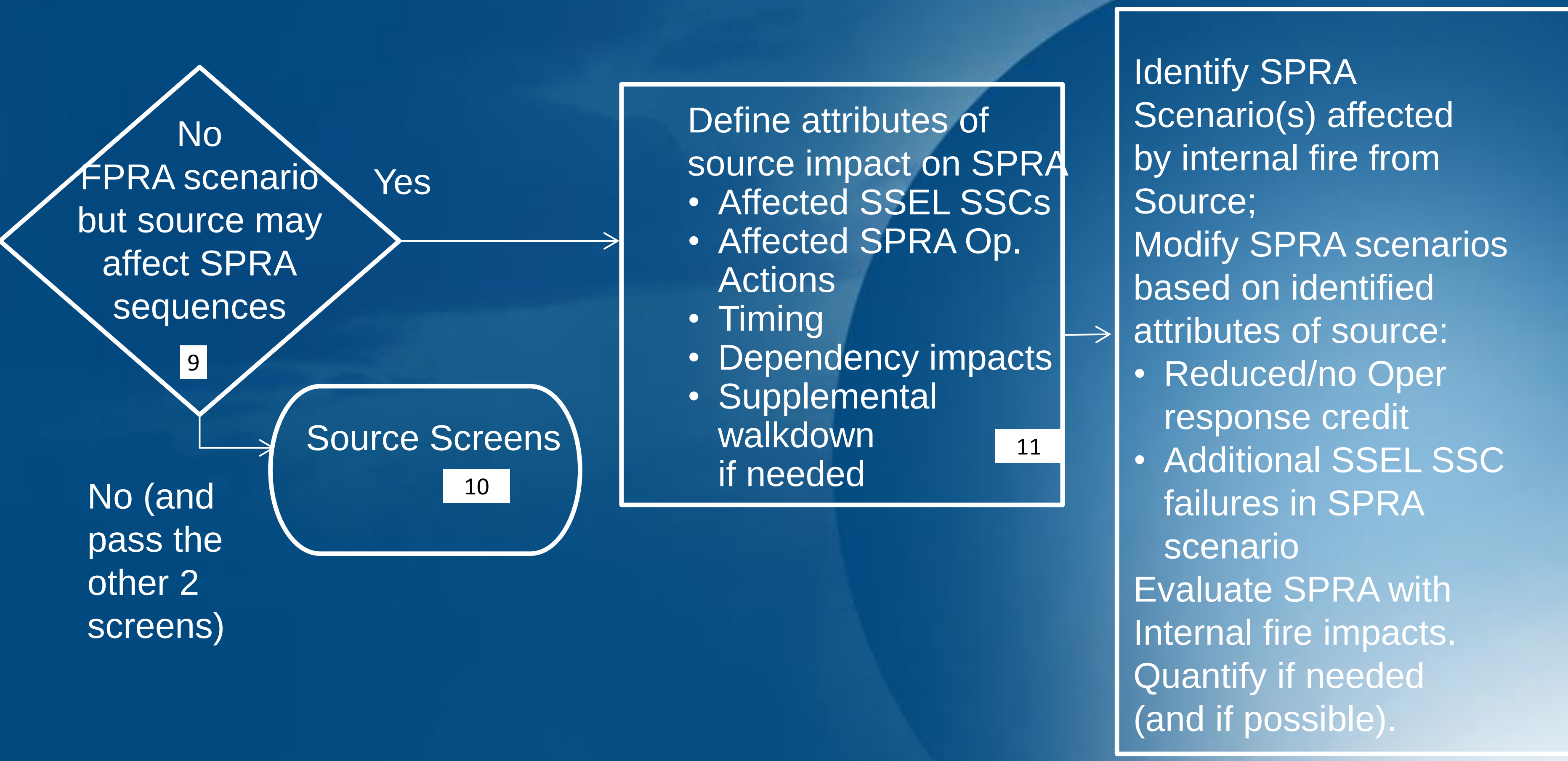
Process – Internal Fires (2)



Process – Internal Fires (3)



Process – Internal Fires (4)



Methodology – Internal Floods

- Similar process is used for internal flood
  - Begins with check to see if flood is terminated by the seismic event
  - Check if flood source is large enough to affect SPRA SEL SSCs or SPRA-modeled operator response
  - Subsequent screening steps check whether non-emergency power needed for flood response

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Initial Application Results Example

Examples of Initial Qualitative Screening Process Applied to Internal Fire Sources	
RETAINED	
Fuel oil and lube oil sources associated with emergency power generators, and the EPGs themselves.	Failure/ignition of the EPG fuel /lube oil supplies results in failure of the associated EPG, which is already accounted for in the SPR A, but seismic-induced spill/ fires from these sources should be reviewed for additional impacts and insights.
Non-emergency power standby generator (SG) fuel oil tanks.	SGs not credited for post-seismic response, and a fuel tank retain ing dike is designed to capture spillage, but there might be poten tial for smoke or heat from burning fuel oil to affect EPGs or oper ator seismic response. Identified as item for walkdown and additi onal review for impacts.
Waste oil tank farm in the yard.	Tanks are on the opposite side of plant from the designated oper ator Seismic Route, and contents are not readily combustible. However, it was judged that there might be potential that smoke or heat from burning lube oil could affect operator response to the seismic event, so it was deemed prudent to perform a walkd own for additional review for impacts and insights before screening.
Oil-filled transformers in the Yard areas.	Transformers are not credited in SPRA and are on the opposite side of the plant from the designated operator Seismic Route, but there might be the potential that smoke or heat from burning transformer oil could affect EPGs or operator response to the seismic event. Perform a walkdown for additional review for impacts and insights before screening.
Plant hydrogen sources	Retain for walkdown/additional review for impacts and insights.

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Initial Application Results Example

Examples of Initial Qualitative Screening Process Applied to Internal Flood Sources

RETAINED SOURCE	COMMENTS
Breaks in non-seismically-qualified lines that could impact SEL SSCs credited in SPRA.	
Sources from the internal flood PRA for whic h pumped source would be lost due to seismi cally-induced loss of power but for which gra vity drainage impacts are possible.	Check sequence timing and source drain-down volume for potential impacts.
Domestic water (DW) source floods for furth er evaluation of impact on the SPRA.	DW pumps assumed to lose power due to seismic event, but DW supply might have sufficient gravity back up, so possibility that supply would not be affected; assess likelihood of supply line integrity and timing of operator response per the internal flood PRA in subseq uent steps prior to screening.
Miscellaneous potential sources of flooding i n the Yard along Seismic Route, e.g., rupture d underground pipes.	Assess potential seismic response impact via walkdown .
Fuel oil tanks as potential flood hazard sourc es along the designated Seismic Route.	These have been counted as potential sources of seismi cally-induced fire, but could also represent significant flood and hazardous material hazard to the operators if the tanks/piping were to rupture and the dike fail.
Sloshing of water out of the irradiated fuel bays (spent fuel pools).	Determine potential internal flooding impacts

Initial Application Results Example

Examples of Initial Qualitative Screening Process Applied to Internal Flood Sources	
SCREENED SOURCE	COMMENTS
Sources for which it was clear from the internal flood PRA that loss of power would eliminate the impact on seismic response.	**Not a credible flood source**
Sources for which there would be no credible impact on SEL SSCs credited in the SPRA.	**For one such source, a relatively simple evaluation determi ned that the potential impact would require flooded rooms to hold a 44' head of water; given the configuration of the area, and non-water-tight doors near the bottom, this was determined to be highly unlikely and this source was screened out.**
Sources requiring breaks in seismically qualified lines or equipment.	**Screened per methodology groundrules**
Sources in the yard with limited potential to affect equipment or operator actions required for seismic event response	**For example, sources on the side of the plant opposite the required equipment and actions, with significant drain age pathways. (But to be confirmed during walkdown.)**

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Initial Application Results

- Review of retained potential sources showed 3 general types of potential SPRA impacts:
  - Barriers to operator traversal of designated seismic response route
  - Dense oil fire smoke with potential impacts on oper ation of the emergency generators
  - Opportunity for procedural error resulting in adverse impact on seismic response
- No specific SPRA scenarios impacts were identified in which seismic event would directly lead to equipment failures due to internal fire or internal flood and have an impact different than already captured in the SPRA.

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Initial Application Results

- Impact on Operator Response:
  - SPRA had already accounted for impact on operator ability to respond to seismic events as a function of increasing seismic magnitude
    - Effectively no credit had been taken in the SPRA for operator response at seismic magnitudes at which seismically-induced internal fires or internal floods might be considered more likely
  - The real mechanistic impact, if any, is not readily defined:
    - Pertinent "Fragilities" are unknown
    - Computation of a representative HEP would primarily involve guessing or bounding rather than adding realism into the model.
- Therefore, the possibility of obstacles affecting operator response was captured as an additional source of model uncertainty in the SPRA.

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Initial Application Results

- Dense Oil Fires Impact on Emergency Equipment
  - Most sources of oil fire were sufficiently remote that a direct fire impact on critical SSCs was not at issue.
    - Spillage of oil from fuel storage tanks or from large transformers in the yard, does not guarantee occurrence of a significant fire.
    - Even if a fire were to occur, there was nothing in the plant layout to suggest a channeling of smoke toward the emergency generator air intakes sufficient to interfere with their operation.
    - Even if this happened, the "fragility" of emergency generator failure due to smoke is unknown
  - Occurrence of this condition following a seismic event is believed to be unlikely, and it is not feasible to assign a meaningful probabilistic impact within the quantitative seismic model.
  - Further, emergency generators were already important contributors to the seismic results due to relatively low fragilities of support components, so adding a relatively low failure probability failure mode (smoke from seismically-induced internal fires into air intakes) would not significantly affect the seismic results.
- Possibility of dense smoke impact on emergency generator operation added to the SPRA sources of model uncertainty

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Conclusions

- Important insights can be gained from assessing seismically-induced internal fires and internal floods
  - A graded approach allows for level of detail appropriate to the plant-specific features
  - Allows for qualitative insights and also quantitative assessment if warranted
- Attempting to quantify all scenarios is currently impractical
  - Lack of fragilities for seismically-induced fires
  - Large uncertainties associated with impacts
- Adding significant quantitative uncertainties to evolving SPRAs will hinder their acceptance and use

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Appendix E

BNL Slides Summarizing the Preliminary Responses to the 15 Questions

1. What are the PRA-related issues for obtaining meaningful estimates of risk from SI-F&IEF scenarios?

1.1 Quantification of seismic induced internal fire initiating frequencies.

1.2 For external flooding, the issue of seismic initiating event frequency is probably the most challenging. Even for tsunami assessment, it is non-trivial to relate the occurrence of the tsunami-inducing seismic event and the flooding impact within a specific site. This is expected to extend to seismically-induced dam failures, and seismically-induced seiche.

1.3 Fragility information for seismic induced fires, internal flood sources, and external flood sources. Conservative estimates should be avoided so as not to compound the conservative modeling aspects of seismic PRA with the conservative modeling aspects of fire or flood PRA.

1.4 Understanding of the impact of concurrent events: If the seismic event is assumed as the initial hazard and the impacts of internal fires and internal floods are assessed separately, then the integration of both consequential internal fire and internal flood impacts may prove to be

complex, as each of the induced events (internal fire or internal flood) will have an impact on the other event. For example, an induced fire can result in an internal flood; an induced internal flood will have an impact on the mitigation of a fire source. Accounting for external floods would add additional complexities.

1.5 An important issue for SI-F&IEF scenarios is to identify those that are meaningful for inclusion in a PRA. In other words, those that provide added benefit beyond what can be gleaned from seismic, flooding, and fire PRAs. Some responders believe that any approach undertaken should first focus on potentially significant sources and scenarios rather than attempting to quantify all possible scenarios.

1.6 Assuming that we can do the Level 1 PRA portion, the existing methods should extend into the Level 2 portion (e.g., in-containment hydrogen burn). If a Level 3 is contemplated, the impact of earthquakes and possible external floods on evacuation needs to be considered.

1.7 HRA:

1) Need to extend the fire HRA work to cover earthquakes, floods and post-core-damage actions.

2) Quantification of operator actions: Performance shaping factors are not the same given the concurrent occurrence of a seismic event with an induced fire and/or flood in multiple locations (increased stress level, lack or false indication, impairment of access routes, etc.).

3) Operator access issues (modeling of blockage of operator access and the possibility of finding alternate paths). Also toxic environments.

1.8 PRA logic model development and quantification, including issues such as model simplification and truncation. Model solution should be manageable; the issue is understanding the detailed results (individual cut sets could be rather "involved").

1.9 See also responses to question 2.

2. *Are the key mechanisms of failure understood well enough so they can be modeled, or at least estimated with expert judgment?*

2.1 Failure mechanisms for some SSCs are well understood and can be modeled provided that all the physical interactions are clearly identified.

2.2 The failure mechanisms of other SSCs may not be sufficiently understood. Examples are: relays, Digital I&C, vibration-induced shorts potentially leading to internal fires.

2.3 There are also some mechanisms of failure that are not fully understood, such as:

1) Seismically induced failure mechanisms of a component that cause the component to catch fire. This, in turn, affects the assessment of the component's fire fragility (the probability that a fire is initiated as a function of ground motion).

2) Complex dependencies due to multiple concurrent events. Two examples are: A) there is potential for defeating train redundancy, resulting in increased risk estimates. A method to

define the level of correlation between failures due to seismic-induced fire or flood for equipment needs to be developed. B) For seismic-induced (internal) flooding scenarios, one concern is to realistically model potential differences in propagation path due to additional seismic failures, which may render the analysis more complex.

3) Additional dependency complexity for multi-unit stations.

2.4 Some issues such as the seismic induced arcing fault in a metal-clad switch gear cabinet observed at Onagawa after the March 2011 tsunami event should be studied in detail for insights. Possibly also other seismic induced shorts.

2.5 The fire operating experience from Japan associated with the March 2011 tsunami and the Kashiwazaki-Kariwa 2007 seismic event also should be looked at for failure mechanisms.

2.6 Seismic induced spurious actuations of Halon or Foam system or other that could fail key equipment (e.g., EDGs) should be considered as a fragility failure mode for that equipment.

3. *Do you believe that one or more of the current PRA methods can be used satisfactorily to assess SI-F&IEF scenarios? Or is it necessary to develop new or enhanced methods or approaches for this purpose?*

3.1 NUREG/CR-6850 (EPRI 1011989) has the following statement on seismically-induced fires: "…*This procedure does not provide a methodology for developing models and quantifying risk associated with fires caused by a severe seismic event...*"

3.2 There appear to be two main approaches:

1) More common: Using a seismic PRA, then augmenting it to include seismically induces fires (and floods) ("setting a seismic PRA on fire (and flooding it)")

2) Sometimes mentioned: Using a fire or flood PRA and quantifying each scenario in presence of the seismic event ("shaking a fire or flood PRA.")

3.3 Current PSA methods can be used to assess SI-F&IEF scenarios, provided that:

1) Walkdowns are performed as per NUREG 1407 with the focus on the SI-F&IEF

2) Assessment of SSCs fragilities for seismic induced fire and flood can be performed

3) The primary seismic event trees are developed in such a way that they can properly identify the fire and flood initiating events (sources), and the corresponding fire and the flood PSAs do include the seismic induced failure of SSCs, such as the degradations in fire suppression systems and capabilities as a result of an earthquake. The integral MCS file (including both the seismic induced fire PSA MCS file and the seismic induced flood PSA MCS file) need to be reviewed to check if some of the recoveries are still valid.

4. Could the current PRA standard activities for inclusion of concurrent events in the standard be used for addressing your identified issues?

4.1 The current standard is extremely loose on the inclusion of concurrent events. There are only a few SRs in Part 5 that discusses seismically-induced floods and fires and essentially rely on walkdowns to screen them out. If the potential for a seismic-induced fire or flood is identified, then the Standard simply points to NUREG-1407.

4.2 The PRA standard provides requirements for “what” to address in a PRA, but does not specify “how” such requirements would be met. It does not resolve issues involving lack of knowledge of phenomena or plant response.

5. Can the actions associated with other NTTF Recommendations 2.1, 2.3, and 4.2 be used or enhanced to support the PRA methods development activity? For example: can walkdowns document specific High Confidence of Low Probability of Failure (HCLPF) values of equipment that could cause or lead to fire or floods if failed? What feedback can be expected from this activity?

5.1 For Rec. 2.1: 1) it is expected that most plants will use industry's expedited approach, which only considers a small subset of the plant SSCs. 2) Rec. 2.1 calls, as in NUREG 1407, to FOCUS during the walkdowns on the potential for seismically induced fire and flooding. However, the assessment of seismically-induced fire and flooding is beyond the scope of the evaluations for which guidance is provided in this document.

5.2 The specific walkdowns already completed for NTTF 2.3, and being performed for NTTF 2.1, would likely not capture the insights needed here, unless such issues had been specifically included in the walkdown planning. Hence, additional walkdowns may be needed to conduct a seismic-fire-flood PRA.

5.3 Walkdowns themselves do not define an HCLPF value. The normal HCLPF methods (informed by insights gained during the walkdows) are largely based on NP-6041, which in turn is based on the SQUG experience database that looks for functional failure, not for the failure mode of the equipment catching fire.

5.4 In summary, it is doubtful that the other NTTF Recommendations can be used or enhanced to support the PRA methods development activity.

6. ***Could the current work on re-evaluation by the utilities in response to the NRC request factor into a PRA method? For example, could JLD-ISG-2013-01 Guidance For Assessment of Flooding Hazards Due to Dam Failure Interim Staff Guidance Revision 0, July 29, 2013, ML13151A153 and a utility response based on this reference be factored into a PRA Method?***

   6.1 The results of the external hazard characterization can be factored into the PRA allowing the quantification of the initiating events magnitude and frequencies but the modeling issues regarding the utility response to concurrent initiating events will still remain.

   6.2 One concern is that the site's ground motion is not necessarily the same as the ground motion experienced at an upstream dam. So, how to estimate the probability that an earthquake fails an upstream dam and also fails a flood barrier at the site?

   6.3 One responder mentioned that this can't be fully judged until licensees actually submit information that is reviewed and then assessed for its usability in this effort.

7. *Because of the general low frequencies that are expected for SI-F&IEF, how can one appropriately distinguish which low frequency events should be included and which should be screened out? Do you consider it possible to screen low frequency sequences while still adequately addressing rare events with high consequences?*

7.1 Based on the responders' input, it seems that the sequences (or MCSs) can be divided into 3 main groups:

1) Sequences that have significant frequency, so they should be kept.

2) Sequences whose frequencies are somewhat low (i.e., below a certain cutoff value), but not "too low," and that have "high" consequences. They also should be kept.

3) Sequences whose frequencies are so low (i.e., below another cutoff value), that they can always be screened out, regardless of their consequences.

7.2 The bigger issue is use of the same truncation/screening frequency throughout the entire PRA.

8. ***Assuming a plant has a seismic and an internal fire PRA, can it perform a seismically-induced Fire PRA today, using the available guidance? Is such a project expected to uncover new insights or change the assessment of current risk?***

8.1 While plant PRAs exist to individually address the hazards of internal fires due to random component failures, evaluation of these hazards coincident with or caused by seismic events may not have been systematically evaluated. Issues already identified in “The Fire Risk Scoping Study” and the following issues need to be fully addressed:

1) Credit of firefighting support equipment and fire brigade access routes.

2) Scope of the Walkdown for the seismic PSA and Internal Fire PSA when developed separately may not capture the seismic/internal fire interaction and the walkdown crew may not have the appropriate qualification.

3) Operator actions need to be re-quantified taking into account the possibility of having different concurrent fire sources as a result of the seismic event.

4) If the fire suppression system is conservatively not credited in the plant Fire PSA, this should be revisited knowing the fire suppression system may fail following a seismic event and result in an internal flood.

5) The analysis should cover and incorporate the failure probability of active and passive fire protection systems caused by an earthquake into the existing fire PSA.

6) An earthquake may initiate fires in multiple locations, so some methodology development is needed.

8.2 Identify the large flammable sources that are inside the plant with relatively low estimated fragilities (e.g., elevated turbine lube oil tank in Turbine Bldg) and that can cause a significant fire of interest. These are the focus of seismic fire.

8.3 Until very recently there have been requirements in various documents for performing seismically-induced internal fire PRAs, but essentially no guidance. Two papers published at the recent ANS PSA2013 conference have proposed similar approaches for performing such a study relying on existing (or in-development)

seismic and internal fire PRAs. Such an assessment could provide additional insights regarding plant/operator response to seismic events, but this will be highly plant-specific.

8.4 New insights are always gained by making a PRA, and it’s difficult to predict (guess) the increase in risk since there are no previous studies.

8.5 In summary, it does not appear that existing guidance is adequate to treat seismically induced fires.

9. *Assuming a plant has a seismic and an internal flooding PRA, can it perform a seismically-induced Internal Flooding PRA today, using the available guidance? Is such a project expected to uncover new insights or change the assessment of current risk?*

9.1 If a plant PRA is developed to individually address the hazards of internal floods due to random component failures, evaluation of these hazards coincident with or caused by seismic events may not have been systematically evaluated.

1) Scope of the walkdown for the seismic PSA and Internal Flood PSA when developed separately may not capture the seismic/internal flood interaction and the walkdown crew may not have the appropriate qualification.

2) Review what credits of access routes are still valid.

3) Operator actions need to be re-quantified taking into account the possibility of concurrent flood sources as a result of the seismic event. Even if these flood sources are deemed not large enough to impact the safe shutdown equipment list, nonetheless they

would require some operator action. Consideration should also be given to the impact of induced internal fires.

4) Identify the systems that can pump during LOOP/SBO scenarios (or gravity drain) from the UHS and create significant flooding in the plant.

5) If piping is generally robust in the plant such that building fragilities would dominate, then there is no need for modeling explicit accident sequences.

6) If piping selected is Fire Protection piping and the yard loop fragility or yard liquefaction is much more likely to occur than piping break inside the plant, then use yard loop fragility to explicit reduce frequency of flooding inside the plant for fire protection or use it as qualitative argument for not explicitly modeling such a flooding scenario.

9.2 Refer to points 8.2 and 8.3 as applicable to internal floods.

10. ***Assuming a plant has a seismic PRA and an assessment of external floods in response to the NRC request for reevaluation, can they perform a seismically-induced External Flooding PRA today, using the available guidance? Is such a project expected to uncover new insights or change the assessment of current risk?***

10.1 As is the case for the response to questions 8 and 9, there is no available guidance today for a combined assessment (i.e., guidance exists only for assessment of the individual hazards). Such an assessment could provide additional insights regarding plant/operator response to seismic events, but this will be highly plant specific.

10.2 The reevaluation will provide a realistic input regarding the frequency and magnitude of the hazards, however the modeling issues as identified in the responses above will remain.

10.3 It seems necessary to develop seismic fragilities for external flood sources that are not located at the site (e.g., upstream dams).

10.4 Existing external flooding risk information would be useful to scoping out scenarios to include in an SPRA.

10.5 If the seismic event is failing the dam (which may be located miles away from the site) and also impacting the plant, there is a correlation between the seismic input at the dam, the seismic input at the plant, and the seismic hazard curves used for the seismic PRA quantification.

10.6 For tsunami purposes, a hazard curve could be developed, translated to flooding maps at the site, and estimated (it is unclear whether a tsunami hazard curve is of wide interest for the US reactor fleet). For dams, this would represent a significant effort which may or not be informed by NTTF Recommendation 2.1 activities at certain sites.

10.7 New insights are always gained by making a PRA, and it’s difficult to predict (guess) the increase in risk since there are no previous studies.

11. A risk assessment typically involves a quantitative (e.g., frequency of occurrence) or at least a semi-quantitative assessment of the risk. Such quantification requires, in turn, probabilistic data such as frequency of earthquakes and probability of failure of a structure, system, or component (SSC) given a SI-F&IEF. What specific data sets are needed (for example, seismic fragilities of SSCs for seismically-induced floods)?

11.1 Seismic hazard curves. They will be available once licensees complete their seismic reevaluations (March 2014 for eastern plants; March 2015 for western plants).

11.2 Fragility curves for seismically-induced fires, that is, the probability that a fire is initiated as a function of ground motion. Assessing these curves is a difficult technical problem.

11.3 Fragility curves for seismically-induced internal flood sources. In particular, seismic fragilities of nonseismically-qualified piping, tanks, structures, etc. would be needed. Although estimating these curves is hard, it does not appear as difficult as assessing fragility curves for seismically-induced fires.

11.4 Fragility curves for seismically-induced external flood sources. Need to consider upstream dams as well as tsunamis (some research is available).

11.5 Human reliability data (or models) for concurrent events

11.6 Common cause failure models for the multiunit considerations.

12. *There is a recognized lack of data, such as seismic-induced fragilities of SSCs, that is, the likelihood that specified ground motions will result in the movement or failure of an SSC in a mode that creates a flood. What can be done with limited data available for these events? Are there sufficient data available for quantifying risk from SII&EF events? What sources of probabilistic data for this purpose are you aware of, if any?*

12.1 The experience database from SQUG would need to be expanded for additional failure modes.

12.2 Some fragility information for internal flood sources (e.g., fragilities of large tanks) is available. Theoretical analytical models, such as probabilistic fracture mechanics also can be used for the prediction of the seismic induced floods.

12.3 Piping fragilities are generally common calculations for SPRAs. Rigorists may wish to discuss whether further refinements could be made for piping fragility calculations (e.g., how big is the break in the piping?), but for the purpose of this meeting this aspect should be considered to be well understood.

12.4 However, other fragility information needs to be developed to complete a PRA. This is a major limitation. Responders disagree about the level of difficulty of developing fragility information.

12.5 One responder suggested that a debate is needed to discuss the merits of starting a PRA now, using it to help identify required information as opposed to doing a fragility study up-front.

12.6 One responder proposed that initially, investigation of seismically-induced fires and floods should focus on qualitative insights that can be gained without research, to help focus subsequent quantitative evaluations.

12.7 In general, expert judgment may have to be used.

13. What are the implications of cost versus value-added for satisfying the data needs referred to above? i.e., for obtaining such information generically or plant-specifically?

13.1 Very difficult to monetize the value-added of a seismic-fire-flood PRA. It can only be determined after a pilot study is done.

13.2 One responder considered that this question can only be answered after sufficient insights are obtained through qualitative or semi-quantitative assessments.

13.3 One key issue is to decide if we want to estimate the actual risk, or only show that it's relatively low when compared to other risk sources.

13.4 Another key issue is to understand how the results of the research could be implemented in regulatory space.

13.5 Since the seismic hazard varies from site to site, one or more plant-specific PRA studies would be required.

13.6 The resource estimates are plant specific. However, based on Ontario Power Generation (OPG) experience in applying the methodology developed by ERIN/Kinectrics to the Darlington and Pickering B stations, resources and effort are not onerous.

13.7 On the other hand, one responder believes the cost for a full-scope seismic-induced flood, fire or external flood would be extremely high and the return would be low.

13.8 Another responder believes that the cost for data efforts may easily exceed the value added if this project is not framed appropriately:

1) It could be more fruitful to look at, for example, generic fragilities for components and establish a subset of structurally non-robust items which could be coupled with fire or flooding vulnerabilities, and then explore whether their contribution is captured by individual hazard assessments or not, or

2) To study specific spatial dependencies where the seismic failure of a non-safety SSC could lead to the failure of a safety-related and/or risk-significant SSC. For fire, electrical components in switchgear rooms and switchyards may be candidates, for

flooding it may be specific piping fragility or the location of equipment with respect to flood paths.

13.9 Generic data for components, without consideration for where the component is located or how it is supported, would not bring too much benefit.

14. If a new set of data needs to be assembled for use in a SI-F&IEF PRA, who should spearhead this effort; NRC, EPRI, international organizations?

14.1 Possibly a joint effort between NRC and EPRI, which seems to have produced significant studies on the events in Japan and has also been involved in seismic database development.

14.2 One responder also recommended an update to EPRI NP-6989 regarding the low likelihood of seismic-induced fires in facilities. EPRI has considered this but said at this time it would not worth spending resources. It would also be good to have an EPRI report provide the same summaries related to seismic-induced flooding.

14.3 Good idea to touch bases with international organizations, but there is no agreement about how much original research they will contribute.

15. *What are the resource estimates for carrying out the PRAs assumed in Questions 8, 9, and 10 above?*

15.1 It is premature to ask before we have a better defined scope of work. A pilot study may be necessary.