Fire PRA Uncertainties, Including Consideration of Quality and Completeness

Dennis Henneke
GE-Hitachi Nuclear Energy

February 29, 2012
EPRI/NRC PRA Uncertainty Workshop

Purpose

Provide an overview of FPRA Parameter, Modeling and Completeness Uncertainty, including the issues found in recent FPRAs as a result of FPRA quality and completeness.

Discussion is based on the author's experience in review and use of NUREG/CR-6850, development of new FPRA supplemental methods, and performance of numerous FPRA Peer Reviews.

Opinions expressed do not represent GEH or BWROG technical opinions – but are the authors.

Quality and Completeness

- When we developed the FPRA Standard, we tried to develop CC II to have the same or similar uncertainty/accuracy as the internal events PRA standard.
- Analysts of Modern FPRAs struggle with completeness issues and when the FPRA is analyzed sufficiently. To date; we have not seen any fully complete FPRAs in the US.
- In most cases, the FPRA incompleteness results in conservatism in the results… but not always.
- For this presentation, items of completeness and quality are included in addition to items of model uncertainty. Text is identified in **Blue** for these items.

Plant Partitioning

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
PP-B	Credited partitioning elements and Fire barrier effectiveness	Partitioning elements that **lack a fire-resistance rating, credit spatial separation or active fire barriers, introduce some modeling uncertainties.** The majority of these uncertainties are modeling preference. Fire barriers are utilized to delineate the fire areas into physical analysis units. **Fire barriers failure rates** are included in the FPRA. Multi-Compartment Fires are typically low risk, but not always.	Low Medium

Equipment Selection (ES)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
ES-A/B	Equipment is selected that may cause an initiating event or fail FPRA equipment, including spurious operation.	Two sources of uncertainty; **a)** **Equipment selection is not complete** – this may result in an under prediction of risk, or if assumed failed, a conservative FPRA; and b) Selection of possible **fire-induced initiating events is incomplete,** resulting in missing accident sequences.	**High (both)**
ES-A/B/C	Equipment selection of Multiple Spurious Operation (MSO) scenarios is not complete.	NEI 00-01 includes a process for developing a plant specific MSO list, including review of the generic MSOs, and consideration for plant-specific MSOs. **Incompleteness in the MSO selection process** can result in failure to identify risk-significant MSO scenarios.	Medium – Likely the most risk-significant scenarios will be captured by other steps (e.g., modeling of the internal events PRA equipment).
ES-A/B/C	Equipment (including cables) identified are mapped to the appropriated FPRA Basic Event.	It is common that all **cables for each component are conservatively mapped to either multiple basic events (BEs) or the worst case BE.** Typically, refinement of the cable selection process can limit the cables affecting each BE (typically performed on a case-by-case basis). However, the probability of each spurious BE may still be conservatively estimated. For example, an MOV may be closed and spuriously close (driving the valve into the seat), thus preventing spurious opening.	Medium

ES - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
ES-B	Consider instrument air (IA) and the impact of a potential fire on the IAS.	**Fire damage to instrument air lines** can result in failure of the entire IAS given sufficient leakage. Soldered connects are looked at for a typical FPRA, which is assumed (if present) to fail the IAS. However, without soldered connects, the IAS is typically assumed un-affected by Fire when IAS lines are in the fire area. Impact may be conservative (if IAS is not credited) or non-conservative (If IAS is credited for most fires).	Low: Most areas of importance are electrical, with minimal IAS lines. Additionally, fire damage to IAS lines is possible, but less likely than cable and equipment damage.
ES-C	Equipment is selected that may impact the reliability of operator actions, including spurious operation.	Two Sources of Uncertainty: a) **Equipment Selection for instrumentation/alarms is incomplete,** and may result in an under prediction of the risk due to no degradation in the HEPs impacted by failed instrumentation. a) **Failure to identify potential undesired operator actions** may result in an under prediction of risk.	Medium (indirect impact on HEPs) Medium – undesired operator actions are typically not significant.

Cable Selection and Location (CS)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
CS-A	Cables and Circuits impacting selected equipment is identified and traced.	Three Sources of Uncertainty: **a)** **Circuits and cables are not completely identified** and may result in an under prediction of risk. Typical reason may include a limit on the number of cables considered that may cause a spurious operation. **b)** **Inaccurate cable tracing** may result in under or over prediction of risk, depending on the fire area. **c)** **Assumed Cable Routing** may be inaccurate and may result in under or over prediction of risk, depending on the fire area (see also FSS-A3).	a) Medium: typically, the circuit analysis is performed using detailed and conservative safe shutdown procedures. b) Medium: Same as above. **c)** **High:** Assumed cable routing is typically performed for credited non-safety components, such as Main Feedwater and Condensate.
CS-A	Permissives, interlocks and associated logic are modeled in the FPRA.	Modeling Quality can be impacted by either **conservative modeling (typical of SSA/NSCA) or incomplete modeling of I&C** (may be assumptions in the SSA/NSCA).	Medium: See above.
CS-B	Electrical Overcurrent Protect is performed for credited power supplies.	Failure to perform or correctly perform **overcurrent protection analysis** can either credit potentially failed power supplies, or if the FPRA is conservatively modeled (power supplies not coordinated are assumed failed), the FPRA can be conservative.	Medium: Typically the major power supplies are coordinated. New FPRA, non-safe shutdown equipment power supplies may not be analyzed.

Qualitative/Quantitative Screening

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
QLS-A	Qualitative Screening of Fire Areas not impacting the FPRA.	The above issues in ES may result in **fire areas** containing cables impacting the FPRA are **screened prior to quantification.**	Low: The addition of a few cables or components in a low-risk area will typically not result in the area becoming significant.
QNS-A/B/C	Perform Quantitative Screening, including the establishment of screening criteria and verifying the impact to the FPRA results is small.	**Quantitative screening** is performed prior to applying all factors to ensure realism, based on relatively high screening criteria. Generally, the screening criterion does not greatly impact the final total CDF or risk significant basic events.	Low

Plant Response Model (PRM)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
PRM-A	Develop the FPRA response model to determine CDF and LERF.	The Fire PRA shall include the Fire PRA plant response model capable of supporting the HLR requirements of FQ. 1. The **choice of FPRA PRM tools** may be a modeling preference, but it may result in some modeling and quantification limitations. 2. The FPRA models also **inherit the limitations from the internal event PRA models** (e.g., cannot quantify with TRUE runs, etc.)	Medium
PRM-B	The PRM models the fire-induced initiating events or accident sequences.	**Over-simplification or failure to model new initiating events or accident sequences** can result in an under-prediction of risk.	**High:** given numerous new scenarios added as a result of MSOs, failure to model these accurately can result in significant errors.
PRM-B	New Success Criteria should be developed and modeled.	**Use of existing success criteria** can result in either conservatism or non-conservatism, depending on the existing success criteria.	Medium: Typically, success criteria (typically timing) is not drastically changed.

PRM Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
PRM-B	Modify the PRM to include new equipment, including spurious operations.	**Incorrect modeling or failure to model new equipment** may result in an underestimate of risk.	**High:** Typically there are a large number of modeling changes to support the FPRA. It is common that the modeling is complicated involving logic for the location of the fire.
PRM-B	Perform data analysis for new basic events.	**Incorrect or incomplete data analysis** may result in conservatism or non-conservatism.	Low: Generally, the fire-damage impact of the new components is more important that the failure rate (e.g., events set to true when fire damage occurs).
PRM-B	Identify new accident sequences that go beyond CDF (e.g., impacting LERF).	**Failure to comprehensively review LERF sequences** may result in an underestimate of LERF.	Medium: ES requirements include consideration for MSOs impacting ISLOCA. Additional accident sequences are possible and may be missed.

Fire Scenario Selection (FSS)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-A	Develop one or more fire scenarios (combination of ignition sources and targets) for each unscreened area such that risk is characterized or bounded.	A typical Fire PRA includes both: a) Scenarios where the ignition source and target **grouping is conservatively performed,** resulting in conservative risk results. **b) Incomplete scenario development** where not all risk-relevant combinations of ignition sources and targets are developed.	**High:** FPRAs performed using NUREG/CR-6850 involves development and analysis of thousands of scenarios. Typically, most are conservatively modeled. For higher risk areas, it is possible to developed detailed scenarios where risk-relevant scenarios are not fully developed.
FSS-A	If exact cable routing is unknown, assume the cable is damaged.	It is not uncommon to know specifically in a room where every cable is located. As a result, the **FPRA assumes the cable is damaged for every fire** until the cable is traced in detail.	**High –** has shown up as a major conservatism in several FPRAs.
FSS-A	Select one or more scenarios for the Main Control Board involving damage to more than one function.	Incomplete scenario development where **not all risk-relevant combinations of ignition sources and targets are developed**.	**High:** MCB scenarios are often risk significant. Plant knowledge and engineering judgment are needed to develop the detailed scenarios, without analyzing all possible scenarios.

FSS Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-A	Select one or more scenarios for the Main Control Board involving damage to more than one function.	**Simplified modeling of control room abandonment** scenarios may result in either conservatism or non-conservatism. **Failure to consider detailed fire-damage** which can potentially fail safe shutdown outside of the control room can result in non-conservatism.	**High:** Typical FPRA modeling uses a bounding failure probability for control room abandonment, which may be conservative for most scenarios.
FSS-B	The Fire PRA shall include an analysis of potential fire scenarios leading to the MCR abandonment.	**Simplified modeling of control room abandonment scenarios due to smoke** may result in either conservatism or non-conservatism.	**High**. Typical FPRA modeling uses a bounding failure probability for control room abandonment, which may be conservative for most scenarios.

FSS - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-C	The Fire PRA shall characterize the factors that will influence the timing and extent of fire damage for each combination of an ignition source and damage target sets	**Realistic Estimates for Fire Damage is not performed:** Fire damage estimates typically start conservative, with more realism added to the top (risk-significant) scenarios. Details may include multiple heat release rate groups, inclusion of fire growth time, decay time, consideration for environmental conditions for realistic time to damage, and more detailed configuration considerations. Detailed fire modeling is time-consuming and is only performed for a limited set of significant scenarios..	**High:** Realistic Fire Modeling for each scenario requires a significant effort. Typically, a majority of the scenarios are conservatively modeled.
FSS-C	Analyze target damage times based on the thermal responses of the damage target (CC III of FSS-C6).	Fire Testing has shown that most cables can last for 30 minutes or more given a damaging fire. Without **consideration of thermal response,** a Fire PRA can be a factor of 2 or more conservative. Cable damage is also assumed in the FPRA when the cable tray is ignited, which may not be the case. However, there is no method presently developed to account for this last issue.	**High:** See above. However, Since this hasn't been fully implemented within a FPRA, may actually be medium. A 20 minute additional time for suppression changes the risk by more than a factor of 5
FSS-C	Fire Growth time is included in detailed fire scenarios	**Fire Growth time** is treated as a constant; 12 minutes for electrical fires, and 6 or 8 minutes for transient fires. However, growth time can vary, and may not be independent of HRR. Finally, some fires are assumed instantaneous (oil, hydrogen, etc.).	Medium: Many Fire PRAs are dominated by electrical cabinet fires. Growth time of 12 minutes is likely conservative for most fires. HEAF fires can result in instantaneous growth and are treated separately.

FSS - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-C	If severity factors are applied, factors should be independent of other factors.	**Severity factors** are applied either as a result of fire modeling (minimum fire heat release rate to damage cable), or **using existing empirical or statistical models.**	Medium: Fire modeling severity factors are generally based on conservative estimates (i.e., failure of the 1st target). Statistical and empirical models are based on generic models, and can be uncertain.
FSS-C	Established and apply damage criteria.	**Damage criteria** are developed for generic types of cable or equipment, and may vary depending on the specific cables or equipment installed. Other affects, such as cable loading, aging, installation of metal covers, and installation specific factors can impact the time to damage for a specific cable. Very **small percent of thermoplastic cables** may be excluded in the consideration of damage criteria.	Medium: variation within groups of cables is not large in comparison as variation between groups (e.g., thermal-set versus thermal-plastic). Low: depending on the functions of these thermoplastic cables, generally this uncertainty has negligible impact on the final FPRA results.
FSS-C	If fire wraps are credited; provide a technical basis for rating.	Testing has shown variation in the ability of **fire wrap** to protect cables. Installation problems can result is wrap not protecting cable for the designed duration.	Low: Typically, degraded fire wrap still provides sufficient protection to ensure the cables are low risk.

FSS - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-D	Apply Fire Modeling Tools to account for fire growth, damage criteria and scenario specific attributes within the known limits of applicability.	**Application of incorrect fire modeling tools** can result in either conservatism or non-conservatism.	Medium: NUREG-1824 provides guidance on the use of major fire modeling tools to various conditions and parameters. However, many of the entries are listed as "yellow" where "*there calculated relative differences outside the experimental and model input Uncertainty.*" For example, all of the listed codes are listed as "yellow" for smoke concentration, which is the basis for the control room evacuation analysis.
FSS-D	Use of generic fire modeling.	**Generic fire modeling** is often used to determine, for example, the minimal HRRs causing a damaging HGL, zone of influences for specific component types, etc. Application, other than possible ignition of intervening combustibles, is almost always conservative.	Low: Significant scenarios identified using generic fire modeling are further modeled using detailed fire modeling. Non-significant scenarios are typically not modeled further (e.g., are conservative).
FSS-D	Fire Growth resulting in propagation from one vertical cabinet to the next is included in the FPRA.	NUREG/CR-6850 includes deterministic rules on the **timing and spread of fires within cabinet groups** such as MCCs. The recent GEH report shows fire growth between cabinets is unlikely.	Medium: Cabinet-to-Cabinet fire growth is typically important due to the potential high HRR that results (not direct equipment damage). The resulting large fire can be significant. However, most fires do not have to spread in order to damage and ignite overhead cables.

FSS - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-D	Include an assessment of fire suppression effectiveness for each fire scenario being analyzed.	**Credit for Fire Suppression** is typically performed once the time to damage is determined from Fire Modeling. Generally speaking, with detailed fire modeling only performed on a small percentage of scenarios, the credit for suppression is conservative. Additionally, the existing NUREG/CR-6850 suppression curves are considered conservative (**no credit for control of fires** prior to suppression).	**High:** Estimates of conservatism for suppression is a factor of 2 for a typical Fire PRA.
FSS-D	Provide an assessment of smoke damage.	Evaluation is typically qualitative. Vulnerabilities are included in the quantitative model. Generally, the risk from **smoke damage** (other than for impact on HEPs) is considered low. However, it is possible that plant unique features could be vulnerable to smoke damage, and may not be captured by the qualitative review.	Low: Generally, the risk from smoke damage (other than for impact on HEPs) is considered low.
FSS-D	Perform walkdowns on detailed scenarios.	**Walkdowns** are performed to confirm all of the modeled aspects of the scenario analysis.	Low: Generally, the walkdowns are performed to confirm and document modeled scenarios. Errors are possible given the amount of information collected.

FSS - Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FSS-E	Estimate fire modeling parameters based on relevant generic industry and plant-specific information. Each parameter estimate shall be accompanied by a characterization of the uncertainty.	**Fire Modeling Parameter estimates** are typically either well known or applied as bounding estimates. This may include factors like room temperature, HVAC flow, wall material and thickness, etc.	Low: Generally low uncertainty in the parameters.
FSS-F	The Fire PRA shall analyze scenarios with the potential for causing fire-induced failure of exposed structural steel.	Scenarios are typically analyzed only when there is **exposed structural steel** and a high hazard source located nearby.	Low: Plant Risk for damage to exposed structural steel is generally low, except for selected plants.
FSS-G	The Fire PRA shall evaluate the risk contribution of multi-compartment fire scenarios.	Initially, **multi-compartment analysis (MCA)** was considered low risk. However, some FPRAs are showing MCA scenarios in the risk-significant scenario list. Two factors appear to impact these results: **a)** **Fire barrier penetration failures** in NUREG/CR-6850 are uncertainty, and do not clearly state if this is for a single penetration or all penetrations on an existing barrier. Additionally, treatment of barrier failure given the fire source impact is not clear. **b)** **Conservative Fire modeling** for a single area results in conservative MCA results.	Medium (Both).

Ignition Frequencies

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
IGN-A	Develop Fire Frequencies for each fire area and ignition source.	Three issues noted: a) Difficult to identify **plant-specific "outliers"** due to rare events for a given component type. b) NUREG/CR-6850 supplement 1 is considered conservative with relation to the assigned **Heat Release Rates.** c) Present NUREG/CR-6850 results in **different fire frequencies for the same equipment in different plants.** For example, older BWRs with less equipment than a new PWR may result in a factor of 2 higher fire frequencies for pumps or electrical equipment.	a) Low b) Medium c) Medium

Circuit Failure Likelihood (CF)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
CF-A	Apply circuit failure (CF) probabilities for undesired spurious operations.	Existing **CF probabilities** range from 0.3 to 0.6, with an EF of around 2 to 3. However, method 2 in NUREG/CR-6850 results in lower results. The DC circuits expert panel is re-looking at these failure probabilities and will likely show significant changes from some events, especially method 2 or components with CPTs. NUREG/CR-6850 and other Fire PRA methods do not include the probability or approach for **considering Spurious Operation Duration for DC circuits**. This would include duration of spurious PORV, MSIV, and SRV openings. The average duration for DC Spurious Operations appears to be around 2-3 minutes.	Medium: Could result in a factor of 2 difference in the FPRA. DC Circuit Testing has shown some factors affect the CF probabilities. **High:** For plants where MSOs contribute greatly to the overall risk, DC components typically are the most important. Short duration will mean the component will return to its failsafe position.

Human Reliability Analysis (HRA)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
HRA-A	Identify new FPRA actions relevant to the FPRA PRM.	**New Actions include actions from the Fire Emergency Response Procedures**, as well as actions associated with new accident sequences. Some plants have area specific actions. A comprehensive review can be time-consuming.	Medium: Generally, this is done completely, but a missed HEP can be significant.
HRA-A	Identify new **undesired** actions relevant to the FPRA PRM.	This action goes with the ES-C **identification of instrumentation potentially causing undesired operator actions.**	Medium – undesired operator actions are typically not significant.
HRA-B	Model any existing or new FPRA actions including accident sequence specific factors (timing, etc.)	**Inclusion of the HEPs into the model** may include modification to an accident sequence, system model, or recovery of an event. Failure to properly model the HEP impact can result in either conservatism or non-conservatism.	Medium: Generally, this is done completely, but a missed HEP can be significant.

HRA – Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
HRA-C	Perform Detailed HEP analysis for significant HEPs, including PSFs from Fire.	Results of **detailed HEPs**, especially when considering the fire-specific PSFs, is highly uncertain. Generally, most HEPs are lower risk. However, a few key HEPs are typically in the dominant sequences, such as control room evacuation.	**High:** Estimates for detailed Fire HEPs are highly uncertain.
HRA-C	Determine the time available and time to perform in support of detailed HRA	**Time-lines for HEPs** have uncertainty both on the time window for available time, based typically on T-H analysis and the time to perform, based on either simulator runs, walkdowns or talkthoughs. Fire HEPs add additional complexity, since the actions are typically in response to fire damage, which is typically conservatively estimated.	**High:** Timelines for Fire HEPs are often times based on conservative estimates for fire-damage, and best estimate but uncertainty time windows for available versus performance times.
HRA-D	Include operator recover actions that can restore function	The **addition of recovery actions** is typically performed at the end of the FPRA. In addition to having high uncertainty for any actions, Fire PRAs do not always credit recovery actions including procedural actions in the Fire emergency procedures. The total number of Fire PRA sequences makes the application of recovery actions difficult.	**High:** Estimates for detailed Fire HEPs are highly uncertain. Failure to include recovery values results in conservatism in the FPRA.

Fire Risk Quantification (FQ)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FQ-A/B/E	The Fire PRA shall quantify CDF	**Quantification of the FPRA** typically uses a separate solution process than the internal events PRA. Typically, input to this comes from an external database which interfaces with the circuit analysis and cable routing. This process is peer reviewed, so the solution process is ensured to be generally sounds. However, errors in specific accident sequences are possible.	Medium: For newer Fire PRAs, errors in some sequences are likely. Wholesale solution processes are typically not likely.
FQ-C	Model quantification shall determine that all identified dependencies are addressed appropriately.	**Dependencies in the HEPs** are common. Typically, the internal events methods are used, adjusting for the fire-specific HEP values.	Medium: Estimates for detailed Fire HEPs are highly uncertain. However, the dependencies are less important than individual HEPs.

FQ Continued

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
FQ-D/E	The Fire PRA shall quantify LERF	**Attributes affecting LERF** are often times independent of Fire effects. However, a limited amount of LERF contributors can be impacted by Fire, which may not be accounted for in the FPRA modeling. As a result, LERF may be under predicted.	Medium: It is not uncommon to fail to account for fire-impacts on LERF factors. Overall, the impact is moderate.
FQ-E	Significant contributors to risk are identified.	Use of the **FPRA quantification t**ools (such as FRANC) can make it difficult to quantify either **importance measures or uncertainty values.** Work-arounds and add-on tools are being used to solve this problem. However, the process is not as robust as the internal events process.	Medium: Work-arounds often times include a limited amount of fire PRA sequence results.

Seismic Fire Interactions (SF)

High Level Requirement Designator or Technical Element of PRA	What are the Sources of Model Uncertainty?	Discussion of Issue: How is the model uncertainty manifested in the PRA? How does the model uncertainty affect the PRA results?	Model Uncertainty Significance (High/Medium/Low)
SF-A	Qualitatively assess the potential for seismic/fire interaction issues in the Fire PRA.	The **SF assessment** looks at the impact of a seismic event on ignition sources, suppression and detection, plant response including brigade response, etc. The issue is treated **qualitatively** due to the estimation it is considered low risk in relation to seismic or fire risk analyzed independently.	Medium: For some plants, the qualitative evaluation may miss vulnerabilities that are potentially significant.

Summary

High (Quality/Completeness):

1. Equipment Selection Completeness
2. Assumed Cable Routing and assumed failures.
3. Simplification of Modeled Initiating Events
4. Modeling of new equipment and MSOs
5. Conservative Modeling of Fire Scenarios and Fire Damage
6. Simplified or incomplete Main CB scenarios.
7. Thermal Response for target cables included (CC III)
8. Detailed HRA performed.
9. Failure to include recovery HEPs.

High (Modeling/Parameter uncertainty):

1. 6850 Non-Suppression modeling is conservative
2. HEPs are highly uncertain for Fire PRA, including time-lines.
3. CF Duration is not included for DC hot shorts.