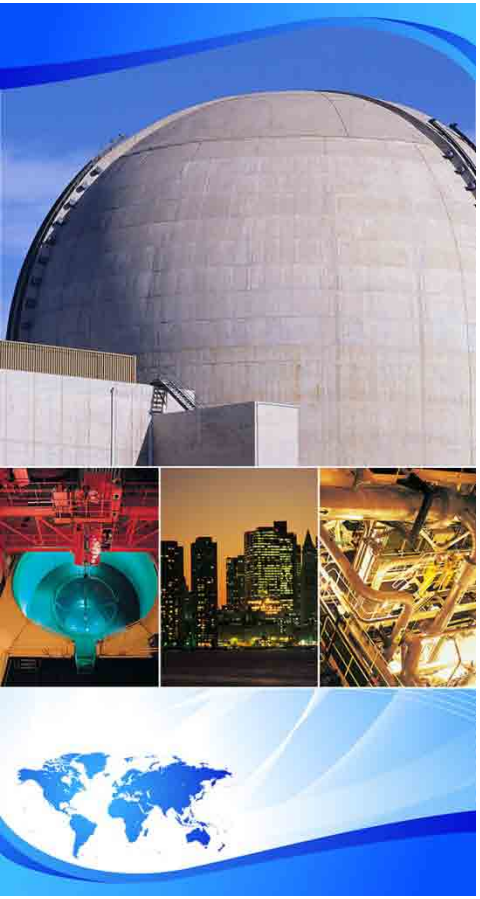


EPRI/NRC-RES FIRE PRA METHODOLOGY
Task 12 – Fire HRA

Identification and Definition of Fire Human Failure Events

Joint RES/EPRI Fire PRA Workshop 2012
Bethesda, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Course Overview

1. Overview of the EPRI/NRC Fire HRA Guidelines
2. **Identification and definition of fire human failure events**
3. Qualitative analysis
4. Quantitative analysis
   a) Screening
   b) Scoping
   c) EPRI approach (detailed)
   d) ATHEANA (detailed)
5. Recovery analysis
6. Dependency analysis
7. Uncertainty analysis

Fire HRA Module Training Objectives

1: Be able to name the **steps in the process** for conducting a fire HRA.

2: Be able to list the **different categories** of fire HRA human failure events.

3: Demonstrate knowledge of ASME/ANS PRA Standard **high level requirements (HLRs).**

- **For the HLRs associated with Identification and Definition**

4: Be able to identify **context and performance shaping factors** used in the qualitative analysis of fire human failure events.

5: Be able to list the **quantification methods** available for HEPs.

6: Understand the concept and importance of addressing **dependencies** between fire HRA events.

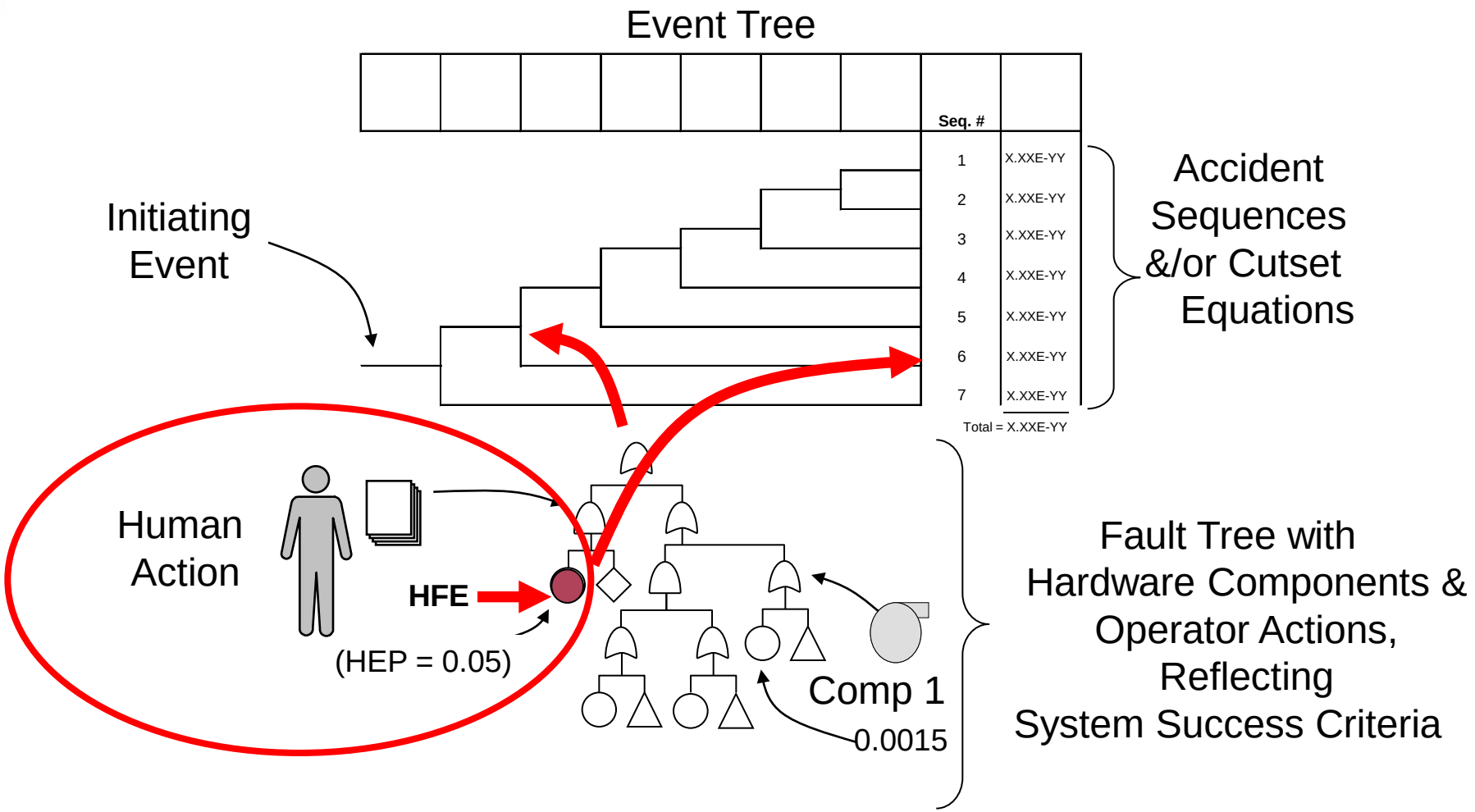
Outline of the Identification/Definition Module

- Introduction/Relation to NUREG/CR-6850 (EPRI 1011989) Tasks
- Applicable PRA Standard High Level Requirements
- Identification
- Categories of fire human failure events
- Definition and fire context
- Feasibility – initial assessment
- Summary

Introduction – What is ***Identification***?

- Human reliability analysis starts with developing understanding of role(s) of operators in responding to an event
- Actions relevant to post-initiator (after a fire) response are identified via:
  - Review of plant emergency and other operating procedures such as fire response procedures
  - Review of PRA event trees, fault trees, and results (sequences and/or cutsets)
  - Operator interviews
- Once relevant actions are understood, corresponding ***human failure events*** are ***identified*** for inclusion in the PRA models

Introduction – Depiction of Identification



PRA Standard Requirements for *Identification*

Relevant HLRs from Internal-Events Section (Chap. 2 of Standard)

HLR-**HR**-E

A **systematic review** of the **relevant procedures** shall be used to identify the set of operator responses required for each of the accident sequences

Relevant HLRs from Fire Section (Ch. 4 of Standard)

HLR-**HRA**-A (from the HRA element)

The Fire PRA shall identify human actions relevant to the sequences in the Fire PRA plant response model

HLR-**ES**-C (from the Equipment Selection element)

The Fire PRA shall identify instrumentation whose failure including spurious operation would impact the reliability of operator actions associated with that portion of the plant design to be credited in the Fire PRA.

Introduction – What is ***Definition***?

- After HFE Identification, ***Definition*** gives the initial basis for justifying inclusion of the action in the PRA model.
- Consists of objective, qualitative data:
  - PRA initiating event and accident sequence
  - Procedures applicable to the sequence
  - Cues (the prompts to initiate actions)
    - Alarms, indications, and/or procedure steps
  - Timing (time available and time required)
  - High level tasks (Capability Category requirements vary)
- Provides input to the subsequent Qualitative Analysis on the factors affecting human reliability
- Requires initial feasibility evaluation

PRA Standard Requirements for Definition

Relevant HLRs from Internal-Events Section (Ch. 2 of Standard)

HLR-**HR**-F

Human failure events shall be defined that represent the impact of not properly performing the required responses, consistent with the structure and level of detail of the accident sequences.

Relevant HLRs from Fire Section (Ch. 4 of Standard)

HLR-**HRA**-B

The Fire PRA shall include events where appropriate in the Fire PRA that represent the impacts of incorrect human response associated with the identified human actions.

Fire HRA Process Steps

NUREG/CR-6850 Task	Fire HRA Process Step
Task 2 – Component Selection	**Identification of <u>previously existing HFEs</u> & potential <u>response to spurious actuations/signals</u>**
Task 5 – Fire-Induced Risk Model	**Identification & Definition of Fire Response Actions**
Task 12 – Fire HRA	**Qualitative Analysis:** starts with **context definition**
Task 7 – First/Screening Quant.	**Quantification –** typically screening
Task 8 – Scoping Quantification	**Quantification –** typically scoping
Tasks 11/14 – Detailed Scenario Quantification	**Quantification & Dependency** could be screening, scoping or detailed HRA
Task 15 – Uncertainty	**Uncertainty**

Categories of Fire Operator Actions

1. Existing operator actions from the internal events PRA
   - From the Level1/LERF PRA model used to develop the fire PRA
   - To be modified for fire effects
2. Fire response actions
   - New actions contained in the fire procedures
   - New actions to address recovery of spurious actuation
   - MCR abandonment is a subset of fire response actions
3. HFEs corresponding to undesired operator responses
   - New actions to address undesired operator actions in response to spurious indications per Chapter 4 in the ASME/ANS Combined PRA Standard for fire PRA
   - EOCs are specifically addressed in fire PRA

Identification of Fire PRA HFEs (General)

Review plant response and PRA model:

- Review event tree sequences with applicable procedure/s:
  - Understand operator requirements to control plant response
    - Functions or systems manually initiated, controlled, or isolated
  - Typically a function of the initiating event
- Review system fault trees with applicable procedure/s:
  - Understand what is required of operators in controlling system or component response
    - Functions manually initiated or controlled
    - Potential recovery (e.g., align standby or alternate)
  - Typically independent of initiating event
- Review PRA results - sequences and cutsets
- Discussions with operators to confirm operator response

Identification of Fire PRA HFEs (General cont'd)

Review ET sequences, system FT, and PRA results to:

1. Understand what the operators are doing
2. Identify **cue(s)**, **procedure steps**, **and time window**
3. Identify procedural path leading to the step with cue
4. Document the PRA **context** from event or fault tree
   - Initiating event
   - Preceding operator actions in the sequence
   - Hardware/system successes and failures

<u>Good Practice (collect if the data is available)</u>

- Identify secondary cues or alternate success paths
  - Examples: critical safety function status trees, alarms or indications

Review of Plant Operations and PRA Data

- Best Practice for HRA analysts is to confirm with plant **operations personnel** at the start of the HRA:
  - Staffing during fire (number of operators and roles)
  - Procedural usage for fire (EOPs, AOPs, and fire response)
  - Main control room (MCR) staff interaction with fire brigade
  - Expected MCR staff response after detection of fire
  - Review of plant-specific fire history for insights
- Review of **PRA Information**:
  - Additional information beyond event and fault trees
  - Success criteria (in order to, for example, determine time window (time available))
  - Internal events HRA in order to understand initial model basis

Identification:
Operator Actions in Internal Events PRA

- Identify fire-induced initiating events included in the fire PRA
  - Done in NUREG/CR-6850 (EPRI 1011989) Tasks 2 & 5
  - Examples of actions carried into the fire PRA
    - General transients which may include spurious SI actuation
    - Loss of support system(s), e.g., loss of instrument air or loss of electrical bus
    - LOCA (e.g., due to spuriously opened relief valve)
    - Station blackout
- Identify operator actions modeled as delineating the plant response to the fire-induced initiators.
  - In event trees, fault trees, and in cutset recovery
- Includes manual start of safe shutdown components
  - Sometimes these are not “pre-existing” in the current PRA

Fire HFEs from Internal Events PRA - Examples

INCLUDE:

- Open a steam dump or steam relief valve and conduct a post-LOCA cooldown
- Manual start of an emergency diesel generator
- Manual start of auxiliary feedwater following automatic actuation failure
- Manually align a back-up power supply

EXCLUDE:

- Actions associated with internal events initiated not included in FPRA, for example:
  - Operators fails to diagnosis SGTR or RPV rupture

Identification:
Fire Response Operator Actions

- Required in response to a fire, as directed by the fire procedure(s), such as
  - Mitigate or prevent damage to equipment (e.g., pump dead-heading from fire-induced spurious valve closure)
  - Mitigate the effects of spurious indications or actuations (e.g., shut off above pump)
  - Abandon main control room and perform safe shutdown outside the main control room
- Identification process can be
  - Iterative as required in fire PRA strategy
    - Often not credited during initial quantification
  - Comprehensive based on fire procedure/s
- Examples on next slide

Fire Response Action Examples

- Identify protected instrumentation channels (to mitigate spurious indications)
- Defeat solid state protection system (to prevent spurious safety injection)
- Control auxiliary feedwater locally by throttling valves manually and starting / stopping pumps
- Place remote shutdown location back-up indication panels in service
- Obtain steam generator level locally
- De-energize all ADS valves
- Close HPCI steam supply valve locally
- Align 4 kV bus by locally operating breakers

Identification:
MCR Abandonment Actions

- MCR abandonment actions are a sub-set of fire response
- Operators will abandon if control room becomes uninhabitable, or due to loss of required control
- Identification process can be
  - Iterative as required in fire PRA (e.g., if additional spurious actuations are identified requiring mitigation)
  - Comprehensive based on review of the MCR abandonment procedure
- Some fire PRAs credit scenarios where the operators remain in the control room for monitoring and announcing; but perform local actions
  - In this case the fire specific scenario is to be identified and defined by the fire PRA analyst
  - HRA analysts identify the procedure guidance operators will follow

Identification: HFEs Corresponding to Undesired Operator Response to Spurious Signals

- An undesired operator action is *a well intentioned operator action, taken in response to a spurious indication, that unintentionally exacerbates the scenario*
  - Operators are generally trained to (1) believe their instrumentation and (2) follow their procedures
- Identified within the context of the accident progression
  - Review annunciator response procedures (primarily)
  - Review emergency operating procedures (best practice)
- Defined in terms of their impact on the function, system, train or component.
  - Although these actions are well-intended and not operator errors as such, the undesired consequences have the same impact as an error & are therefore modeled as HFEs

Identification and Definition of Factors for Undesired Operator Response to Spurious Signals

- Cue parameter/s
  - Single or multiple (redundant or diverse)
- Cue (procedural) hierarchy
  - Continuously monitored or procedurally checked only
- Cue verification
  - Required for immediate actions
- Degree of redundancy/diversity for a given parameter
  - Redundant/diverse channels mitigate consequences of single spurious indication

Examples of Potential HFEs from a Review of Annunciator Procedures to Identify Undesired Operator Responses

Spurious Annunciator	Undesired Action	Consequence
ESW PUMP MOTOR INSTANT TRIP	Place the affected pump's control switch in LOCKOUT.	One train of service water stopped, thereby reducing ESW probability of success in CCDP calculation. Can be restarted.
CCW PUMP MOTOR INSTANT TRIP	Place the affected pump's control switch in LOCKOUT.	Stopping one CCW pump increases operating temperature on many components in CCDP calculation. Can be restarted.
EAST RHR PUMP SUCTION VALVES NOT FULL OPEN	Immediately open 1-IMO-310, East RHR Pump Suction, or 1-ICM-305.	Depending on scenario (size of LOCA or not) could lead to cavitation of the pump. Loss of pump in recirculation mode.
RHR PUMPS MOTOR INSTANT TRIP	Place pump control switch in LOCK-OUT.	Delay start of RHR if not on or halts RHR if on. Impacts CCDP. Can be manually started.

Human Failure Event Definition (General)

- Define a set of HFEs as unavailabilities of functions, systems or components as appropriate to the level of detail in the accident sequence and system models
- Include all of the following in the definition:
  - Accident sequence specific timing of cues, and time window for successful completion
  - Accident sequence specific procedural guidance (e.g., AOPs, and EOPs)
  - The availability of cues and other indications for detection and evaluation errors
  - The specific detailed tasks (e.g., component level) required to achieve the goal of the response. (Cat III)
- Cognitive and execution elements

Definition during Fire PRA Tasks

- HFE definition starts during **Identification & Definition** with:
  - Cues/alarm or other indications, procedure, staffing, time available
- HFE definition includes:

  1) Feasibility evaluation is initially done during **Definition & Identification**, then expanded as HFE is developed through **Qualitative Analysis** &

  2) Identifies the **context** for the HRA evaluation
- Fire PRA context typically varies with NUREG/CR-6850 task
  - Task 7a – Screening HEPs often use qualitative info from Definition
  - Task 12 – Scoping HRA often uses qualitative information (context and PSF) associated with the scoping HRA trees
  - Task 14 – For risk significant HFEs perform detailed HRA using qualitative context & PSFs associated with the detailed quantification method

Definition during a Fire PRA

- Definition of existing internal events HFEs should be reviewed and revised for fire-specific impacts
- New fire response HFEs require definition
- Definitions should include:
  - Fire impact on instrumentation and indications used for detection, diagnosis and decision-making
  - Fire impact on timing of (1) cues, (2) response, (3) execution, and on (4) time available
  - Fire impact on success criteria
  - Fire impact on manpower resources, which affect recovery
  - Fire impact on local actions, e.g., accessibility, atmosphere, lighting
- Some data may not be initially available, but will be filled in during **Qualitative Analysis**

Initial Assessment of Feasibility

- Purpose: To decide whether an operator action can be accomplished or not, given the plant-specific and scenario-specific fire impacts.
- Feasibility evaluation – Set HEP to 1.0 for any of the following (as the action would not be feasible)
  - Failed **instrumentation** (so no cues for operator action)
  - Insufficient **time available** to complete action
  - Insufficient **manpower**
  - **Procedural guidance** does not exist
  - Other factors that may preclude credit
    - Fire is in same location as required actions
    - Inaccessible tools or equipment
- Feasibility is like a "continuous action step" that is re-visited as the NUREG-6850/EPRI 1011989 tasks progress.

Identification and Definition Summary

- HFE ***Identification*** finds where operator actions occur
  - In the plant response to initiating events included in the PRA model
- Identification consists of:
  - Review plant operating procedures and understand operator response
  - Review PRA event trees, fault trees, results and success criteria
- HFE ***Definition*** gives the initial justification for inclusion of the action in the FPRA and provides input to **Qualitative Analysis**
- Definition consists of documenting objective, qualitative data:
  - PRA initiating event and accident sequence
  - Procedures applicable to the sequence
  - Cues (alarms, indications, and/or procedure steps)
  - Timing (time available and time required)
  - High level tasks (Capability Category requirements vary)
- Initial feasibility evaluation is the Go/No-Go check

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1. Overview of the EPRI/NRC Fire HRA Guidelines
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3. Qualitative analysis **– NEXT!**
4. Quantitative analysis
   a) Screening
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