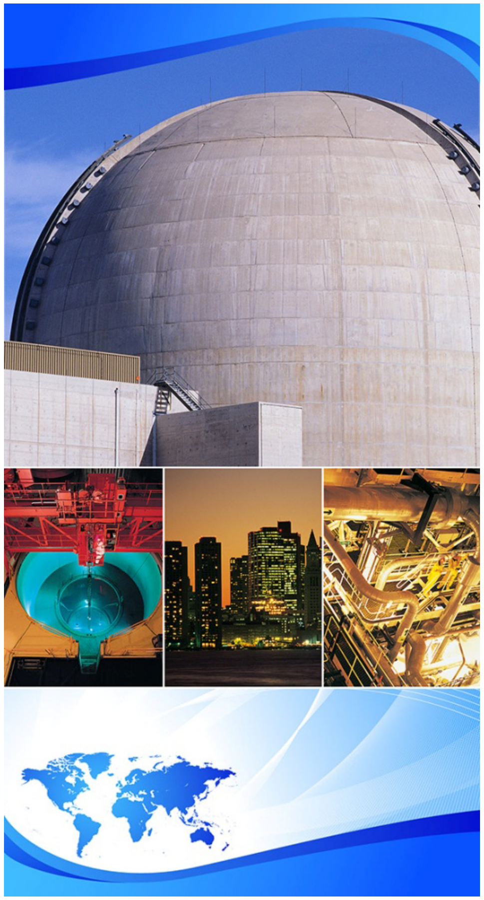


# EPRI/NRC-RES FIRE PRA METHODOLOGY

## Task 12 – Fire Human Reliability Analysis

**NEI Fire Protection Information Forum**

September 2009

**J.S. Hyslop, US NRC**

**Jeffrey Julius, Scientech/EPRI**

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

# Outline of the Presentation

**Overview of the EPRI/NRC Fire HRA Guidelines**

- **Objectives/Tasks**
- **Fire HRA Guideline Summary:**
  1. Identification & definition of post-fire human failure events
  2. Qualitative analysis (timing, instrumentation, actions)
  3. Quantification methods:
     a) Screening
     b) Scoping
     c) Detailed (EPRI approach & ATHEANA)
  4. Dependency & Uncertainty
- **Timeline**

# Background on the Issue of Fire HRA

- Almost 50% of USA plants transitioning to NFPA-805
  - Using NUREG/CR-6850 for the Fire PRA Guidance
- NUREG/CR-6850 addresses:
  - Identifying human failure events (HFEs)
  - Assigning conservative screening human error probabilities (HEPs)
  - Post-fire Performance Shaping Factor (PSF) information
- NUREG/CR-6850 does not:
  - Describe a methodology for developing best-estimate HEPs (given fire related effects)
  - Address the requirements of:
    - ASME/ANS RA-S-2009, "Standard for Level 1 / Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," Part 3 for fires
    - Consequently, there is a need for fire-specific guidance for best-estimate HRA quantification

# Overall Project Objectives

- Joint NRC and industry effort
- Address the need for HRA guidance
  - NUREG/CR-6850 limitations:
    - Identifies factors potentially affecting operator performance
    - Provides rough screening human error probabilities
  - Address best-estimate HEP quantification in fire PRAs
    - Developed methodology
    - Provided guidance for implementation
- Develop a joint EPRI/NRC report
  - Similar to NUREG/CR-6850

# Project Tasks

1) Data collection
   - Fire events (reviewed historical event data)
   - Some plant interviews (with more during the testing phase)
2) Method Development:
   - Started with a review of the EPRI Fire HRA Guideline
   - Updated NUREG/CR-6850 screening for long time windows.
   - Adding a Fire HRA Scoping method
   - Detailed Fire HRA based on EPRI approach or ATHEANA
3) Peer reviews (2 planned)
4) Testing at plant sites
5) Documentation – in a joint NUREG/CR & EPRI report, similar to NUREG/CR-6850

# Task 1 – Fire Data Review

- “Data” in a generic sense
- Used existing guidance & literature, such as:
  - PRA Standards (internal events & fire PRA)
  - NUREGs: NRC’s “Good Practices in HRA” (1792) & Fire Manual Actions (1852)
  - Draft EPRI Fire HRA Guidelines
- Started with NUREG/CR-6850 considerations of fire effects
- Verified these considerations (and identify any needs for updating):
  - Collected and reviewed recent NPP fire events
  - Collected and reviewed plant data
    - Considered a range of plant responses (fire response strategies).
    - Performed some plant interviews

# Task 2 – Fire HRA Development

- Examined **HRA process**, identified how the process and tasks would change in a fire environment or accident response scenarios in response to a fire
  - Successive screening/quantification
- 3 categories of fire-related actions:
  - Existing post-initiator HFEs
  - Post-initiator fire response HFEs (including Main Control Room abandonment)
  - Undesired response to spurious cues or actuation
- Decided on a progressive approach for fire HRA quantification (reflecting fire PRA development):
  - Rough screening per NUREG/CR-6850 ***(relaxed for late events)***
  - Scoping fire HRA approach ***(newly developed)***
  - Detailed fire HRA quantification using EPRI's Cause-Based Decision Tree & HCR/ORE and/or NRC's ATHEANA ***(modified for fire effects)***

# Task 3 – Fire HRA Review & Testing

**Peer Review:**

- NRC and industry team with 7 reviewers:
  - NRC: Gareth Parry, Erasmia Lois, J.S. Hyslop
  - Industry: Stuart Lewis, Kenneth Kiper, Young Jo, Zouhair Elawar
- In general, was the **right approach** taken and implemented?
  - Is the technical approach sound and reasonable?
  - Are the selected HRA models appropriate for the application?
  - Are the assumptions presented in this methodology reasonable?
  - Does the guidance meet its stated objectives?

**Testing**

- Plant 1: Conducted in August 2008, tested flowcharts
- Plant 2: Conducted in September 2008, tested flowcharts

# Fire HRA Guideline Summary: Objectives and Scope

- Identify/analyze **existing post-initiator** HFEs
- Identify/analyze **post-initiator fire response** HFEs
  - Includes Main Control Room abandonment
- Identify/analyze **post-initiator HFEs modeling response to spurious actuations and indications**
- Implement post-initiator fire HEPs in fire PRA model(s)
  - First quantification/screening and/or detailed fire PRA model
  - Including dependency analysis
- Out of Scope
  - Pre-initiators (per NUREG/CR-6850)
  - Fire brigade response (except for impacts on fire PSFs)

# Fire HRA Guideline Summary

- Standard HRA **process** used for Fire HRA modeling:
- Fire HRA **steps**:

1. **Identification & definition** of human failure events (HFEs):
   - Substantial guidance provided, including feasibility test
   - Feasibility Evaluation (Go / No-Go) example criteria
     - Sufficient time available to complete action
     - Sufficient manpower
     - Procedures & cues exist
2. **Qualitative HRA analysis** described:
   - Certain activities required for all analyses; others only for specific detailed HRA method
3. **Quantification**
   - **NUREG/CR-6850 screening:**
     - Refinement/relaxation for areas identified in NUREG/CR-6850 implementation

# Fire HRA Guideline Summary (cont'd)

Fire HRA **steps**: (continued)

3. **Quantification (cont'd)**
   - **Scoping Fire HRA** method added (new):
     - Developed to address the majority of HFEs, thereby conserving HRA resources
     - Guidance being developed to aid reproducibility & reviewability
     - Can be used for defined scenario contexts that are generalized & constrained with respect to PSFs
     - Current format: decision trees
   - **Detailed Fire HRA**, existing methods with performance shaping factors modified for the fire scenario:
     - EPRI Cause-Based Decision Tree & HCR/ORE; & THERP
     - ATHEANA
4. **Dependency (between actions) & Uncertainty**

# Fire HRA Project Timeline

- Project initiated: March 5, 2007
- First integrated draft: May 2008
- Peer review: June 2008
- Testing at 2 plants: Summer/Fall 2008
- Revised draft: April 2009
- Quick review by NRR & NRO: April 2009
- ACRS sub-committee information presentation: June 2009
- Piloting by PWR Owner's Group: Summer 2009
- Issued for public comment: September 2009
- Joint EPRI/NRC-RES as part of NUREG/CR-6850 Fire PRA Training Course: June/October 2009 (for information only)
- ACRS sub-committee presentation: December 2009
- Publication of final report: Spring 2010

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

EPRI

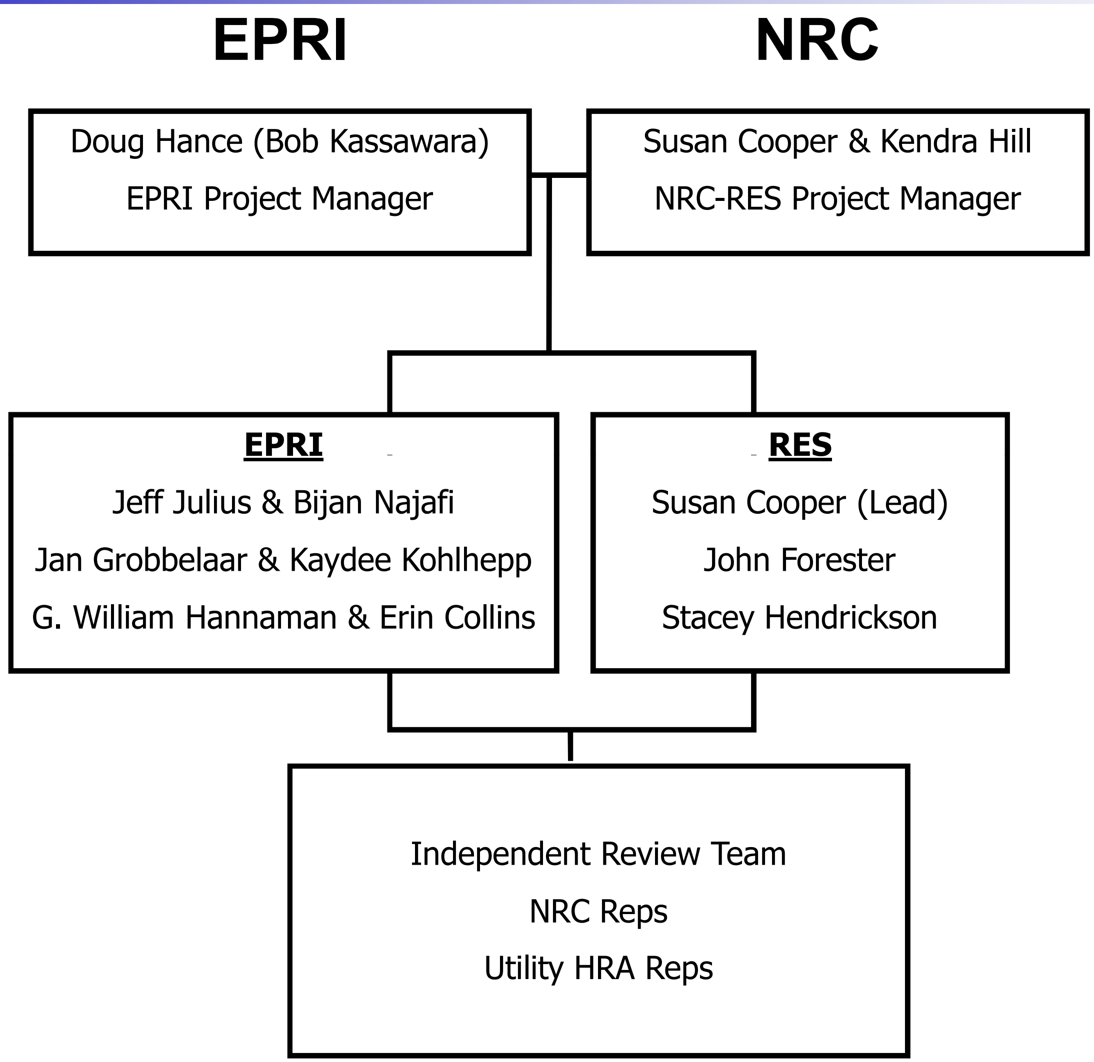
CURTISS WRIGHT
Flow Control Company
SCIENTECH

Sandia National Laboratories

SAIC®
From Science to Solutions™
Science Applications International Corporation

# BACK-UP SLIDES

# EPRI/NRC Fire HRA Guidelines: Development Team



# Categories of Fire Post-Initiator Operator Actions

- Existing internal events operator actions
  - From current Level1/LERF PRA model
- Fire response operator actions
  - New actions per fire procedures
  - New actions to address recovery of spurious actuation
  - MCR abandonment is a subset of fire response actions
- HFEs Corresponding to Undesired Operator Responses
  - New actions to address undesired operator actions in response to spurious indications per Part 3 on Internal Fires in ASME/ANS Combined PRA Standard

# Performance Shaping Factors

- Cues and Indications
- Timing
- Procedures and Training
- Complexity
- Workload, stress, pressure
- Human-Machine Interface
- Environment
- Special Equipment
- Crew Communication, Staffing and Dynamics

# Example of Fire Specific Context Definition

**Description:** Locally open valve (8804A) for high pressure recirculation following a spurious PORV LOCA

1. Initial Conditions: Steady state, full power
2. Initiating Event:

   Fire in Area 5A2

   The fire starts in transformer and impacts targets in the plume and vertical trays adjacent to the flames.

   PORV spuriously opens resulting in small LOCA
3. Accident sequence (preceding functional failures and successes):

   Reactor trip,  Turbine trip

   No containment spray required

   AFW successful

   SSPS not impacted

   SI actuates due to open PORV

   Cooldown and depressurization required.

   Switch over to recirculation required.

   Valve 8804A failed to open from CR due to fire damage.

# Example of Fire Specific Context Definition
## - Continued

4. Preceding operator error or success in sequence:
   - Operators fail to detect spurious PORV opening prior to auto SI actuation
   - Operators controlled ECCS flow to match make-up flow with leakage rate
   - RHR pumps tripped
   - Cooldown and depressurization either failed or failed to be completed before RSWT reaches 33%
5. Operator action success criterion:
   - Locally open 8804A and B located at 73' RHR Access or 100' GE - 8804A failed to open from CR due to fire damage
6. Timing
   - Time to RWST 33 % = 180 minutes
   - Time to RWST 0% = 268 minutes
   - Time required to perform local valve operations = 25 minutes

# Example of Fire Specific Context Definition
## - Continued

7. Consequence of failure: Core damage

8. Availability of Cues and Indications:

- RCS Pressure decreasing would be the primary cue operators would be focused on for diagnosing stuck open PORV. RCS pressure indicators are not failed by the fire
- RWST Level indications not impacted by fire
- Monitor light boxes: The indicators at the switch would not be available to alert the operators that the valve failed to close but the monitor light boxes would be giving conflicting information and the operators tend to look at both the position switch and the monitor light boxes

# Timing Example

**Description:** Locally open valve (ID 1234) for high pressure recirculation following a spurious PORV LOCA

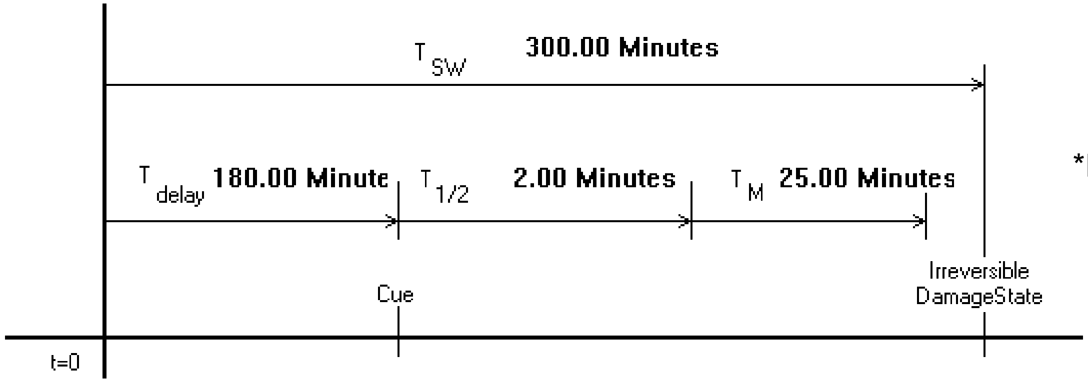



*Figure based on EPRI timing definition

- Tsw - 300 min. Time to RWST depleted
- Tdelay =120 switchover to recirc. RWST <33%
- Tw= 300-120 = 180 min
- T1/2 (Td) = 2 minutes. Estimated time attempt to close CR switch and relies that valve must be closed locally.
- Tm = 25 minutes from operator interviews

Time Margin Calculation

$$TM = \frac{t_w - (t_d + t_m)}{(t_d + t_m)} * 100\%$$

$$\frac{180 - (2+25)}{2+25} * 100 \sim 566\%$$

# Three General Approaches to Quantification

- Screening: Slightly modified from NUREG/CR-6850 to cover long-term events
- New Scoping fire HRA quantification approach
  - Less conservative than screening, but designed to be slightly more conservative than detailed approaches
  - Some actions may not be able to meet some of the criteria (result in an HEP of 1.0)
- Two Detailed HRA quantification approaches modified for application in fire scenarios
  - EPRI Cause-Based Decision Tree (CBDT) HRA Calculator
  - ATHEANA

CURTISS WRIGHT
Flow Control Company
SCIENTECH

Sandia National Laboratories

SAIC®
From Science to Solutions™
Science Applications International Corporation

# Together…Shaping the Future of Electricity