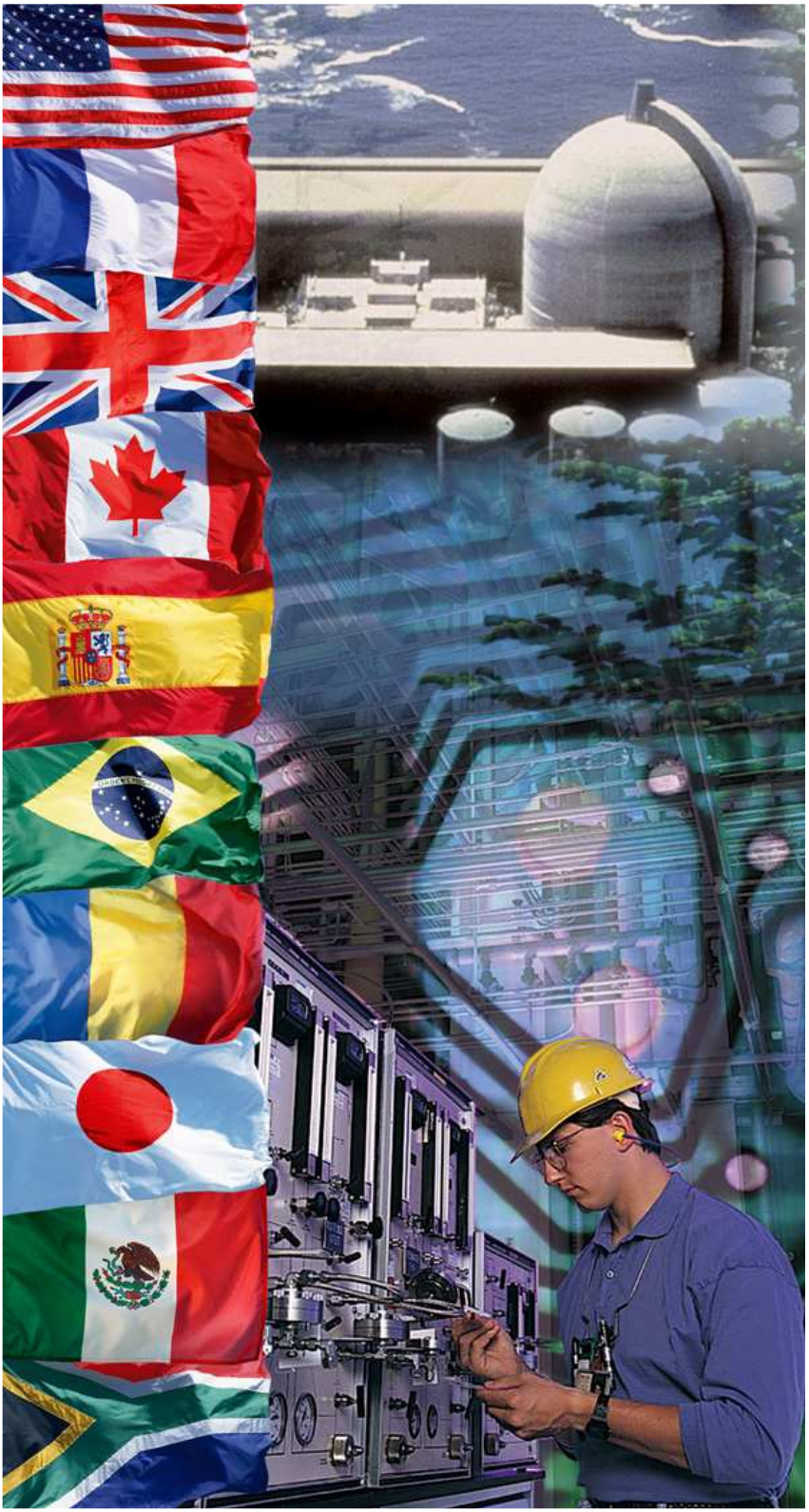

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Development of HRA Approach for Fire PRA

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Introduction

- **NFPA805 and Regulatory Guide 1.205**
- **NUREG/CR-6850 / EPRI 1011989**
  - Limited guidance for HRA
  - Coarse screening HEPs
- **Fire HRA guidance required by members of EPRI HRA Users Group**
  - Work performed in late 2006 / early 2007
- **EPRI / NRC joint effort started in March 2007**
  - To subsume EPRI guidelines

Scope

- **Limited to post-initiator operator actions**
  - If pre-initiators are modeled, existing guidance can be used
- **Fire detection and suppression actions generally excluded**
  - Non detection / suppression probabilities are based on empirical data in NUREG/CR-6850
  - If detection and suppression are modeled, existing pre-initiator guidance and/or new post-initiator guidance can be applied
- **Progressive fire HRA tasks**
  - Rough, quantitative screening per NUREG/CR-6850
  - Scoping fire HRA for scoping models
  - Detailed fire HRA using EPRI or NRC methods (joint project)

Approach

- **Same conceptual approach as used for internal events HRA per the ASME PRA Standard:**
  - Identification and Screening
  - Definition
  - Quantification
  - Documentation
- **Consistent with EPRI SHARP1 HRA framework**

Identification and Screening

- **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
    - As addressed in NUREG-1852
  - Undesired operator actions
    - New actions in response to spurious indications or actuations
    - Per Fire PRA Methodology Standard ANSI/ANS-58.23-2007

Identification and Screening: Internal Events Operator Actions

- **Identify fire-induced initiating events**
  - For example, general transients, loss of support systems, LOCAs
  - On a PWR, steam generator tube rupture not considered as SGTR not directly caused by fire
  - ATWS not considered in NUREG/CR-6850 based on low frequency arguments

- **Identify operator actions modeled in fault and event trees delineating the plant response to fire-induced initiating events**

Identification and Screening: Fire Response Operator Actions

- **Required in response to a fire, as directed by the fire procedure/s e.g.**
  - Mitigate or prevent fire damage to equipment
  - Recover existing internal events operator actions
  - Mitigate undesired operator actions in response to spurious indications or actuations
  - Abandon main control room and perform safe shutdown outside the main control room
- **Identification process can be**
  - Iterative as required in fire PRA
  - 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 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 and Screening: Undesired Operator Actions

- **Identify immediate operator actions that are required without verification in the annunciator response procedures (ARPs). Typically equipment protection actions e.g.**
  - Trip RCIC on false low lube oil pressure
- **Identify cues and indications used by operators in performing the emergency operating procedures (EOPs) that could lead to undesired actions if spurious and can not be validated by redundant or diverse indications, or by the context of the scenario e.g.**
  - Switchover to recirculation on false RWST low level

Definition:
Internal Events Operator Actions

- **HFE modified based on fire impacts:**
  - Cues and indications may be inaccurate
  - Time available may be reduced
  - Response time may increase
  - Workload may be high
  - Crew credited for recovery may not be available anymore
  - Higher stress
  - Accessibility may be impeded due to smoke, heat
  - Communication may be impacted

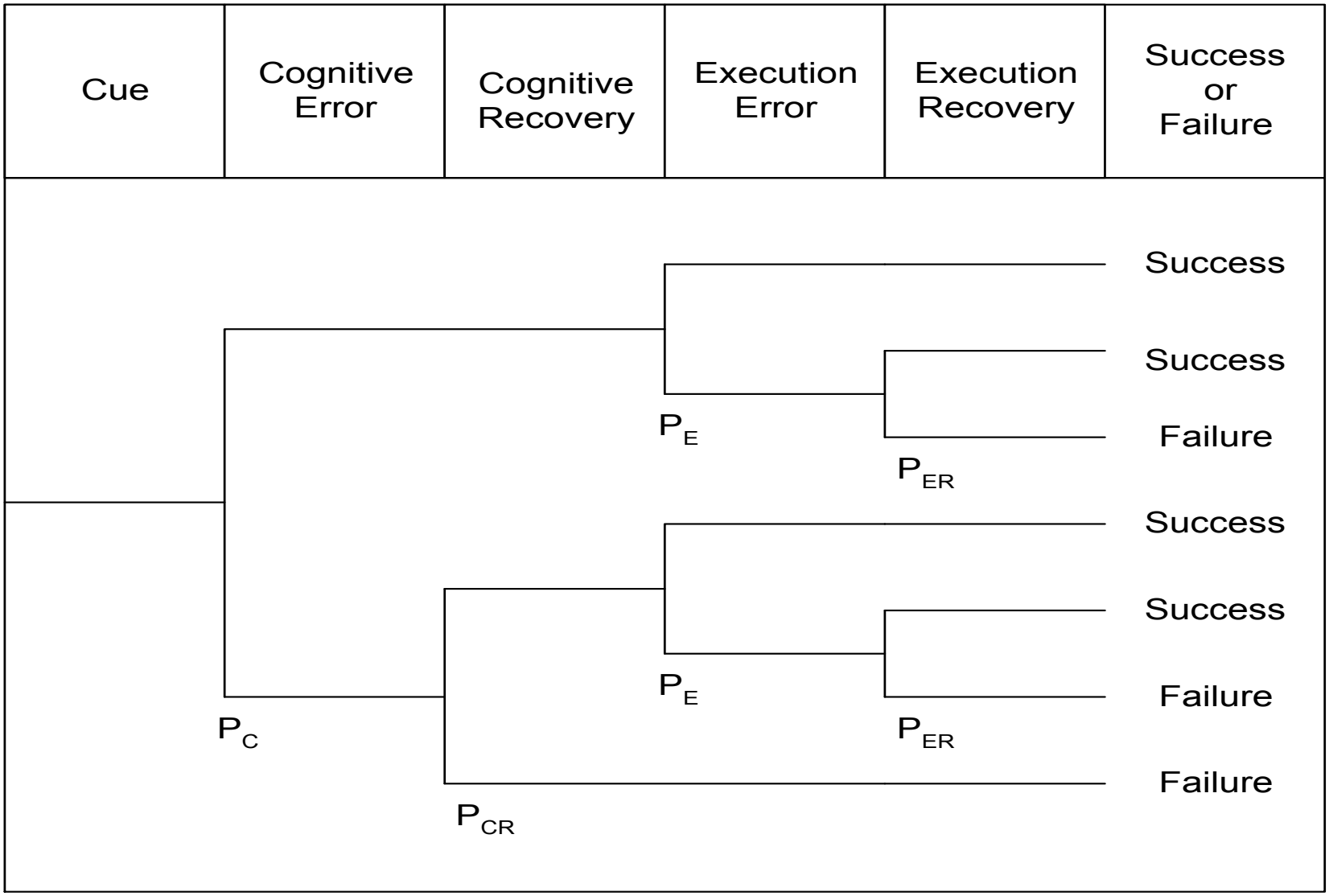
Definition: Fire Response Actions

- **Feasibility Evaluation**
  - Sufficient time available to complete action
  - Sufficient manpower
  - Fire procedures adequate
  - Accessibility, tools and equipment
- **Definition (qualitative) per HR-F in the ASME PRA standard**
  - Preceding failures and successes
  - Timing
  - Cues
  - Procedures
  - High level tasks

Definition:
Undesired Operator Actions

- **HFEs are 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 and are therefore to be modeled as HFEs.**

Conceptual Quantification Framework



EPRI Quantification Methods

- **HCR/ORE Correlation (Human Cognitive Reliability / Operator Reliability Experiment)**
  - Normalized time reliability correlation (function of $T_{available}$ / $T_{required}$)
- **CBDTM (Cause Based Decision Tree Method)**
  - 8 Decision trees based on insights from ORE
- **THERP (NUREG/CR-1278)**
- **EPRI *HRA Calculator*® software**

HCR/ORE Correlation

$$P_C = 1 - \Phi\left[\frac{\ln\left(\frac{T_W}{T_{1/2}}\right)}{\sigma}\right]$$

- P_C = Probability of cognitive non-response
- σ = Logarithmic standard deviation
- Φ = Standard normal cumulative distribution
- $T_W = T_{SW} - T_{delay} - T_M$ = time window for cognitive response
- $T_{1/2}$ = Crew median response time

Cause Based Decision Trees

Type	Designator	Description
Failures in the Operator–Information Interface	**p_c a**	**Data not available**
	p_c b	**Data not attended to**
	p_c c	**Data misread or miscommunicated**
	p_c d	**Information misleading**
Failures in the Operator-Procedure Interface	**p_c e**	**Relevant step in procedure missed**
	p_c f	**Misinterpret instruction**
	p_c g	**Error in interpreting logic**
	p_c h	**Deliberate violation**

Quantification: Internal Events HEPs

- **Timing**
  - Reduce time available, increase operator response time standard deviation
- **Cause Based Decision Trees**
  - Availability and accuracy of cues and instrumentation in the control room (all, partial, none)
  - Warnings in procedures regarding inaccuracies
  - Specific training
  - General training
  - High or low workload
  - Single or Multiple procedures performed concurrently

Quantification: Internal Events HEPs

- **Recovery Factors**
  - Levels of dependence applied to recovery factors (both cognitive or execution) were increased
- **Execution Stress**
  - Changed to “High”
  - For HFEs with initial high stress, apply an additional multiplication factor of 2
  - For operator actions required more than 65 minutes after fire, nominal stress retained

Internal Events HEPs with Fire Impact based on CBDTM

Fire	Instrumentation Impact	Action Description	P_{cog}	P_{exe}	P_T	EF
No		Locally manipulate AC breakers	1.6E-04	4.3E-04	5.9E-04	10
Yes	None		6.0E-03	2.1E-02	2.7E-02	5
Yes	Partial		1.6E-01	2.1E-02	1.7E-01	1
Yes	Complete		1.0	1.0	1.0	
No		Remotely cross-tie ASW (LOSP)	3.2E-04	1.9E-04	5.1E-04	10
Yes	None		3.3E-03	5.1E-04	3.8E-03	5
Yes	Partial		1.5E-01	5.1E-04	1.5E-01	1
Yes	Complete		1.0	1.0	1.0	

HEP Sensitivities Expressed as Ratios Using HCR/ORE + CBDTM

Case #	Tsw [min]	Fire	Instruments Impacted	Procedural Recovery	Td = 5 σ = 0.57	Td = 0 σ = 0.88	Td = 5 σ = 0.88
1	15	No			1.0	1.0	1.0
2	15	Yes	No		7.8	10.3	23.4
3	15	Yes	Yes	Yes	8.4	10.9	24.0
4	15	Yes	Yes	No	36.0	38.5	51.6
5	30	No			1.0	1.0	1.0
6	30	Yes	No		4.7	7.3	9.4
7	30	Yes	Yes	Yes	4.9	7.4	9.5
8	30	Yes	Yes	No	20.4	23.0	25.1

Fire Response HEPs

- **NUREG/CR-6850 recommends screening HEPs:**
  - HEP = 1.0 for t < 60 minutes
  - HEP = 0.1 for t ≥ 60 minutes

- **Above screening HEPs are deemed too conservative, so the following suggested for feasible fire response actions**

Screening HEPs for Fire Response Actions

	Tsw	Time Required	Time Available	Nominal ASEP HEP	UB ASEP HEP	Screening HEP
Local	15	15	0	1	1	1.00
	30	15	15	6E-02	2E-01	0.50
	45	15	30	3E-03	1E-02	0.30
	60	15	45	1E-03	5E-03	0.10
MCR	15	1	14	8E-02	3E-01	0.50
	30	1	29	3E-03	1E-02	0.30
	45	1	44	1E-03	5E-03	0.10
	60	1	59	8E-04	3E-03	0.05

Quantification: Undesired Operator Actions

- Initial HEP = 1.0
- May be recovered if appropriate fire response actions can be identified

Documentation Requirements

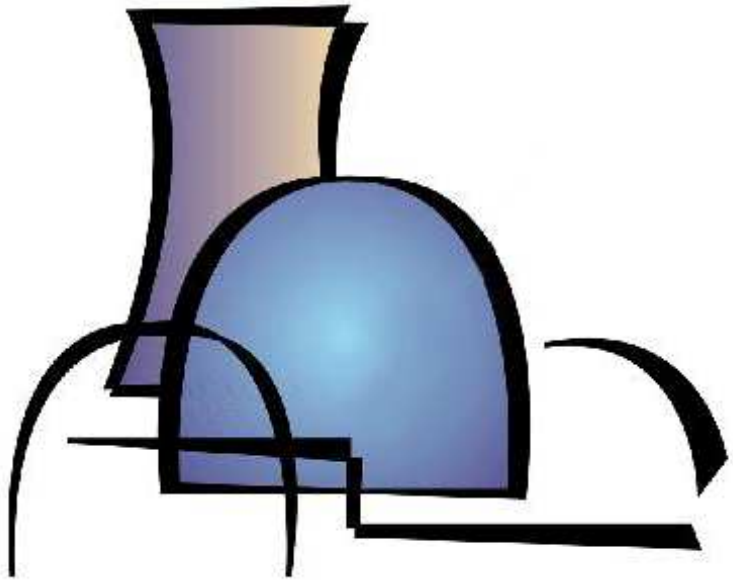
- HR-E in the ANS Fire PRA Standard
- HLR-HR-I of the ASME PRA Standard
- *EPRI HRA Calculator* has self-documenting features

Concluding Remarks

- HRA Guidance in NUREG/CR-6850 limited to coarse screening HEPs
- EPRI HRA UG sponsored development of fire HRA guidance for EPRI
- This guidance may be sufficient for the more detailed tasks as well, but further work may be required
- This guidance has been applied at 5 US utilities to develop scoping fire HEPs.
- EPRI and the NRC Office of Research embarked on a joint project to develop guidelines for performing HRA for fire PRA, which will subsume the EPRI guideline development described in this paper

Key Points of Contact

- **Public website:**
  - http://hra.epri.com
- **HRA Users Group member website:**
  - http://www.epri.com/hra
- **For software support & user group suggestions:**
  - Jan Grobbelaar (jgrobbelaar@curtisswright.com)
  - Jeff Julius (**jjulius@curtisswright.com**)
    - **+1 (206) 248.1818 (PST)**
- **For EPRI project management support contact:**
  - Frank Rahn (**FRAHN@epri.com)**
    - **+1 (650) 855.2037 (PST)**



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