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Human Reliability Analysis for Implementation of Incipient Fire Detectors in Fire PRAs

U.S. Nuclear Regulatory Commission

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Overview

- Introduction
- Approach
  - Human reliability analysis (HRA) **plus** human factors (HF)
- HF tabletop
- HRA/PRA issue and scope
- Qualitative HRA
- Timing analysis
- Feasibility assessment and quantification
- Conclusions and possible future work

Introduction

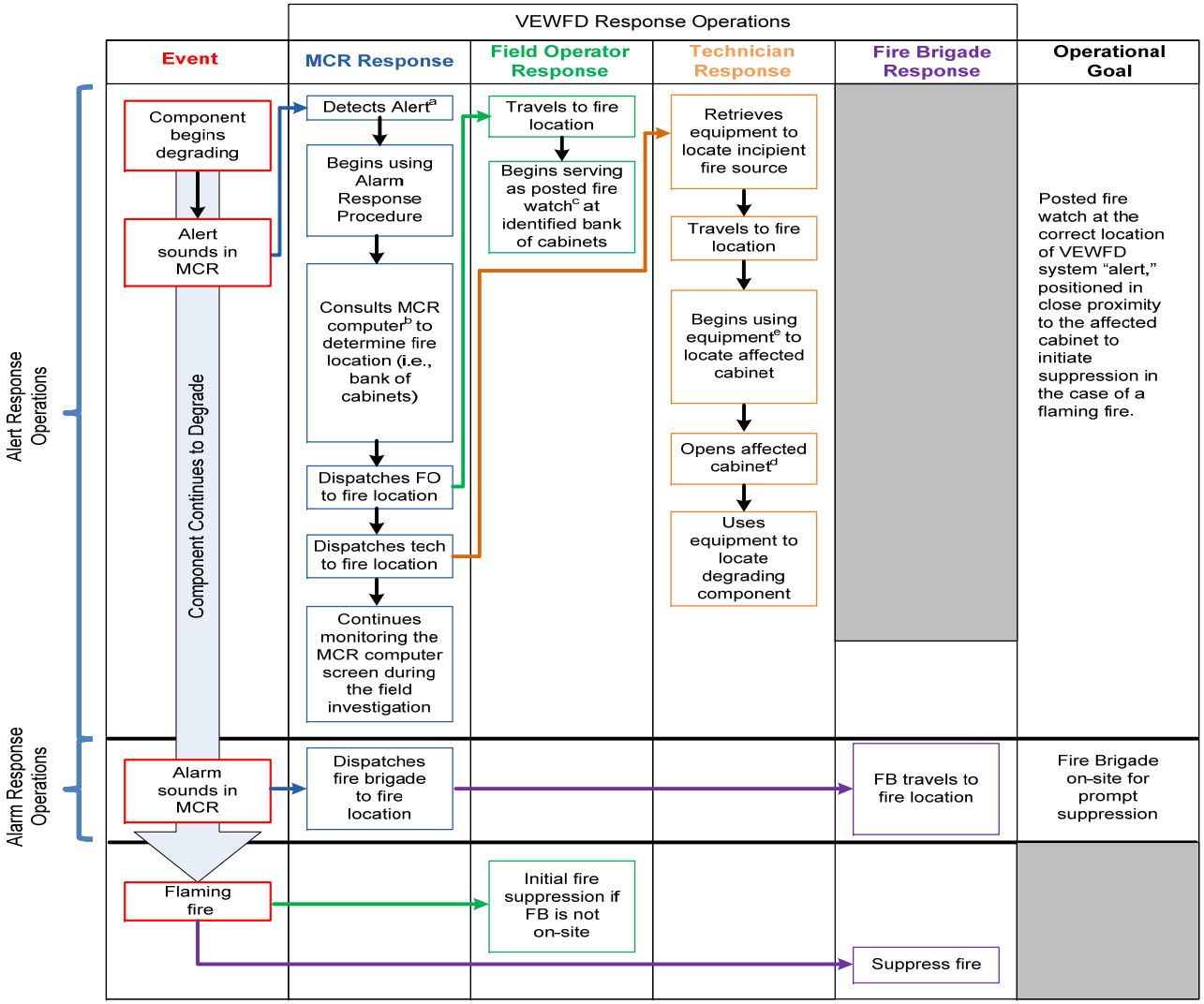
- NUREG-2180, *Determining the Effectiveness, Limitations, and Operator Response for Very Early Warning Fire Detection Systems in Nuclear Facilities (DELORES-VEWFIRE)*, was published in December 2016
- HRA performed:
  - represents how operator response can be modeled to take credit for earlier fire suppression than typically credited in fire PRA (i.e., PRA "credit")
  - is unique compared to typical HRA in support of PRA

HRA Approach

- Similar to that in NUREG-1921, Joint EPRI/NRC-RES Fire HRA Guidelines
  - some additional steps from ATHEANA
- Explicit support from human factors (HF)
- Examples of unique and/or key factors:
  - Actions take place before/without reactor trip
  - Joint response from main control room (MCR) operators, field operators & technician
  - Cues, procedures, training, equipment, etc. not addressed by current HF requirements (e.g., NUREG-0700) that typically support operators
  - Focus on in-cabinet installations with no damage beyond the cabinet of origin
    - Objective is “early” fire suppression
    - Important to differentiate “Alert” vs. “Alarm”
- Use of existing HRA methods depends on ability to “define” operator actions similar to those in typical HRA/PRAs
- As in typical fire PRAs, failure probability for fire suppression is represented with non-suppression probabilities

Human Factors Tabletop

In-cabinet VEWFD 'Alert' and 'Alarm' for a suppression Strategy



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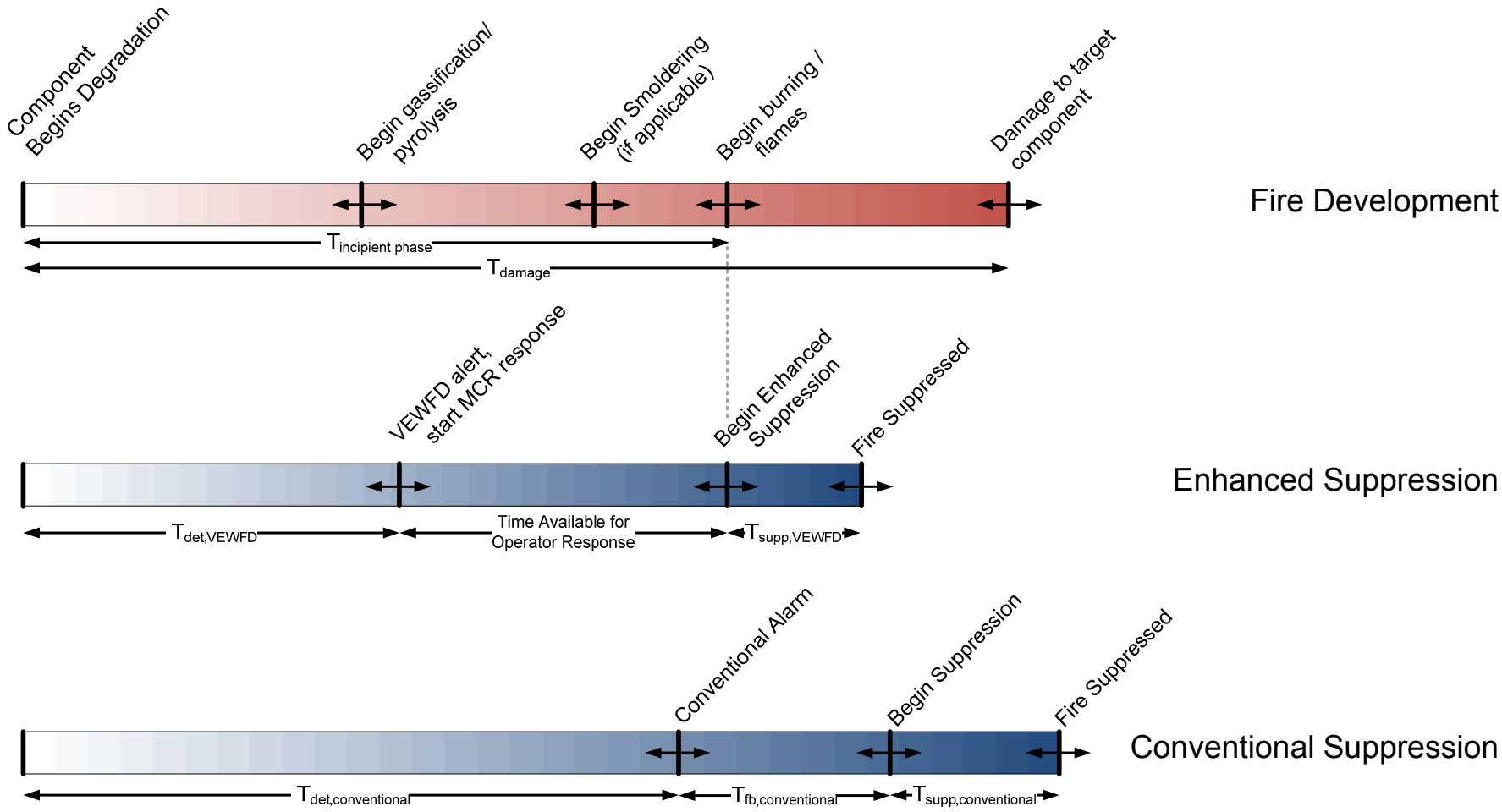
HRA qualitative analysis:

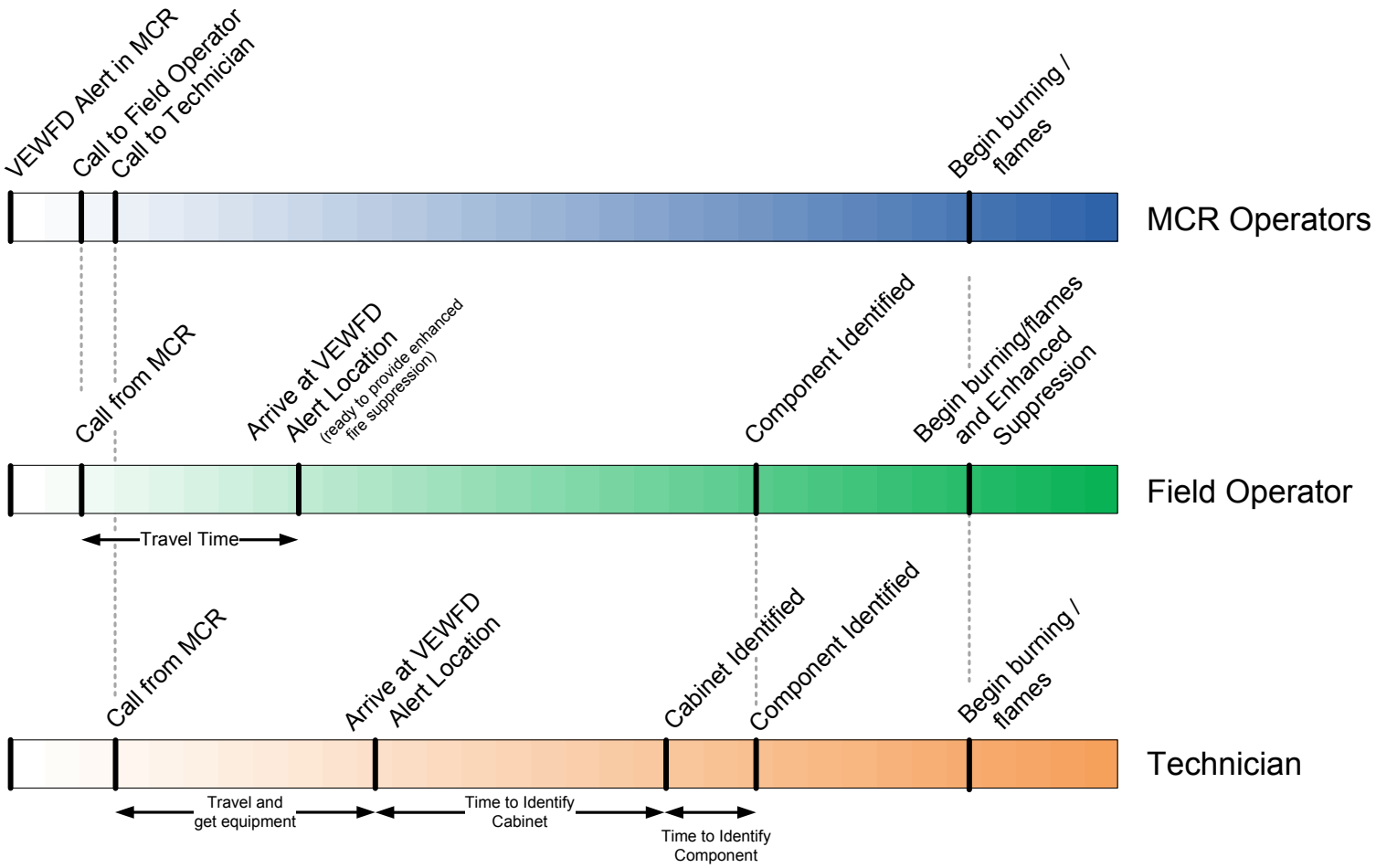
Examples of key results for MCR operator

- VEWFDS “alert” & “alarm” indications are located on front panels in the MCR
- MCR operators respond to VEWFD system ‘Alerts’ with urgency, as reinforced by procedures and training
- Alarm response procedures (ARPs) guide the MCR operator response to the VEWFD signals
- MCR operators dispatch the field operator (FO) closest to the detector in ‘Alert’ state
- Nuisance alerts/alarms are minimal
- VEWFD system ‘Alert’ / ‘Alarm’ signals are audible, according other MCR alarm standards

Time Available and Time Required



Timing – Operators/Technician

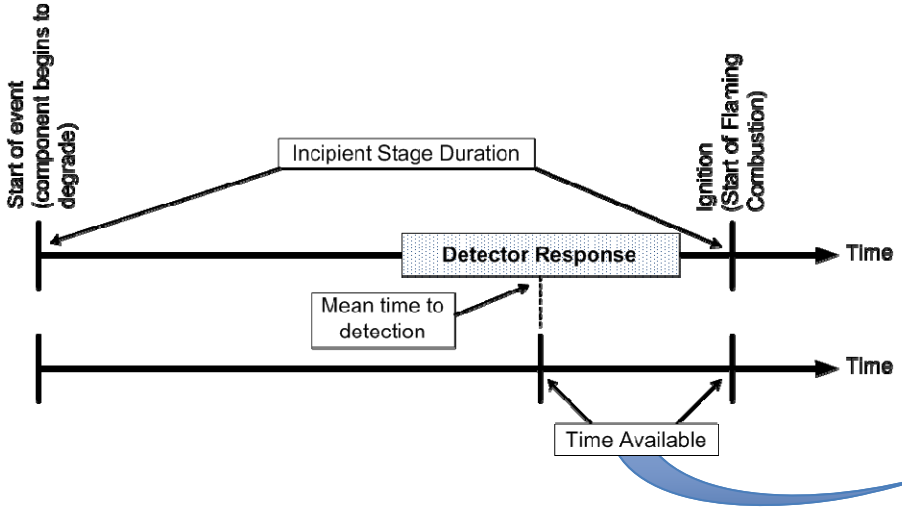


Key timing considerations

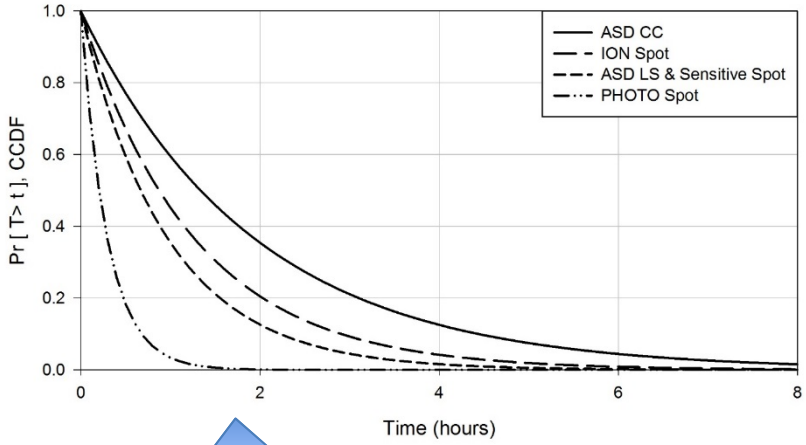
- System time window
  - Determined from operational experience in fire events database
  - Defined from start of component degradation to flaming conditions
  - Wide range of incipient durations is represented by a probability distribution
- Time available for operator response
  - Defined from time of VEWFDS alert to flaming conditions
  - Time when cue occurs is dependent on which detector technology is used & setpoints used in detector installation
- Time required for operator response
  - Determined from plant inputs on operator response (including travel time)

Time Available

- Incipient Stage
  vs.
  Time Available



- Distributions of Time Available by Detection Type



Time Required Inputs

Start of response	Who and Where?	Action(s) required for success	Time required (minutes)
Alert signal	MCR operator; MCR	Detect signal, use alarm response procedures, identify location of detector, and call to dispatch field operator	1-2
Alert signal	MCR operator; MCR	Dispatch technician to detector location	1
Call from MCR	Field operator in plant	Travel to location of VEWFD system in “alert”: standby as fire watch by cabinet(s)	2-8
Call from MCR	Technician	Obtain necessary equipment and travel to location of VEWFD system in “alert”	5-11
Arrival at location	Technician	Uses equipment to identify cabinet	1 cabinet: 0
			3 cabinets: 5
			6 cabinets: 10
			10 cabinets: 15
Cabinet identified	Technician	Uses equipment to identify degraded component in cabinet	3-4

Feasibility assessment

- NUREG-1921 provides several feasibility assessment criteria
  - Sufficient time
  - Sufficient manpower
  - Sufficient cues
  - Proceduralized & trained
  - Accessible location
  - Equipment & tools available
- "Sufficient time" is focus of HRA in NUREG-2180
  - time available must be larger than time required

Feasibility Assessment

Cloud Chamber VEWFD

Time required	Sample in probability distribution for time available	Time available from *alert*	Feasible?
3-10 minutes	1	0-12 minutes	Yes
	2	>12 minutes AND < 30 minutes	Yes
	3	> 30 minutes AND < ~1 hour	Yes
	4	> ~ 1 hour	Yes

HRA quantification

- Existing HRA methods were used (e.g., CBDT, SPAR-H)
- Human error probabilities (HEPs):
  - MCR operator response: 1E-4 (all cases)
  - Field operator (ready for fire suppression): Base HEP = 1E-3
    - Adjusted with respect to time available
- Note: Technician's role is not explicitly required for this strategy/analysis

HEP Calculations

Cloud Chamber VEWFD

Sample	Time available from *alert*	Split Fraction from Table 10-1	Base HEP	Base HEP x Split Fraction
1	0-12 minutes	0.1	1E-3	1E-4
2	>12 minutes AND < 30 minutes	0.13	1E-3	1.3E-4
3	> 30 minutes AND < ~1 hour	0.17	1E-3	1.7E-4
4	> ~ 1 hour	0.60	1E-4	6E-5
TOTAL HEP (ξ)				4.6E-4

Conclusions

- NUREG-2180
  - Published Final December 2016
  - Over 350 Small-scale and Large-scale Tests
    - System performance quantified
  - Through Review of Operating Experience
    - Domestic and International: available time quantified
  - Unique HF Analysis
  - Unique HRA Analysis
  - Spreadsheet tool to quickly evaluate non-suppression
  - Over 6 Years of Effort
  - Best tools, methods, and data available today to evaluate VEWFD system performance in Fire PRA

Possible Future Work

- NUREG-2180 identified data collection is needed (Appendix G)
- EPRI is planning on a new data collection effort
- EPRI & NRC's Office of Nuclear Regulator Research (RES) are exploring a possible new joint project under a Memorandum of Understanding (MOU)