Frequency of Challenging Fires

by

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Topics for Discussion

- "Frequency of Challenging Fires" task
  - Goals
  - Suggested improvements
  - Comparison with current approach
- Lessons learned from examination of challenging fire initial phase scenarios

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Goal of Frequency of Challenging Fires Task

- Develop a ***practical***, ***mechanistic***, improved methodology for defining, characterizing, and quantifying the frequency of nuclear plant fire scenarios

Why Do We Want a New Method?

- To provide a mechanistic link between fire initiation and subsequent fire modeling
  - Current methods imbed this link in the “severity factor” and pilot fire assumptions
- The mechanistic approach is intended to eliminate or control optimistic and pessimistic assumptions, improve realism, and enhance clarity
  - Model how ignition occurs and progresses to burning a large source of fuel
  - Treatment of uncertainties is inherent in the approach (avoid “fallacy of the best estimate”)

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Process for Modeling Fire Initiation

- Define fire initial phase scenarios (FIPS) applicable to a given location in a plant, with well-defined characteristics specified in terms (probability distributions) that will support subsequent fire modeling
- Define an approach for adapting current data to the new model using expert judgment. Define a path to improved data collection to better support the new models.

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Comparison with existing approach

- Overall FRA model
- What is changing:
  - ϕ_{IE} x (Severity Factor) versus ϕ_{FIPS}
    - ϕ_{IE} x SF focus is on stylized "best estimate" pool fire
    - ϕ_{FIPS} focus is on uncertainty in 3-D HRR for particular FIPS
- Uses of data
  - Identify FIPS
  - Quantify FIPS
  - Compare challenging fires versus all fires

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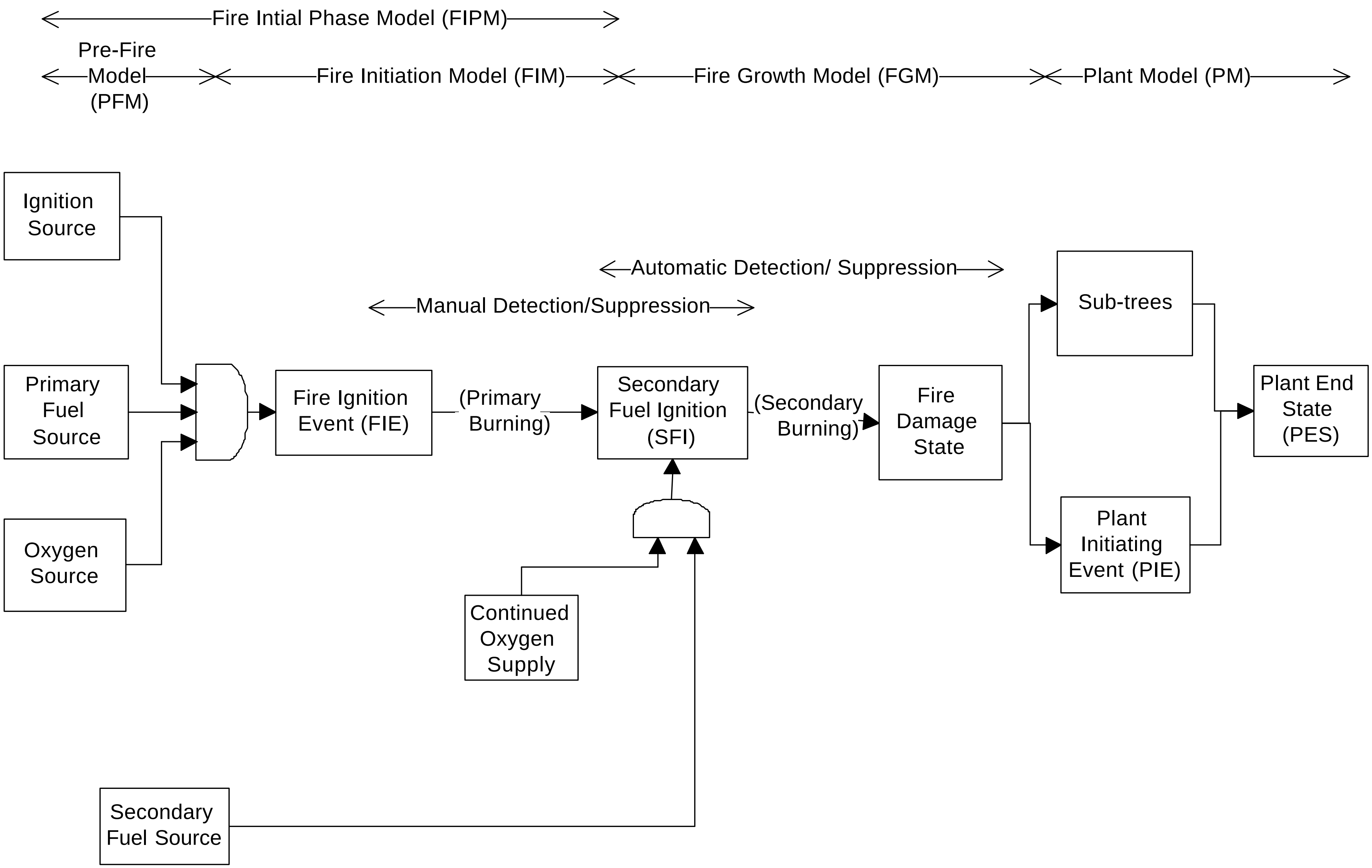

Fire Intial Phase Model (FIPM)
Pre-Fire Model (PFM)
Fire Initiation Model (FIM)
Fire Growth Model (FGM)
Plant Model (PM)
Automatic Detection/ Suppression
Manual Detection/Suppression
Ignition Source
Primary Fuel Source
Oxygen Source
Fire Ignition Event (FIE)
(Primary Burning)
Secondary Fuel Ignition (SFI)
(Secondary Burning)
Fire Damage State
Sub-trees
Plant Initiating Event (PIE)
Plant End State (PES)
Continued Oxygen Supply
Secondary Fuel Source

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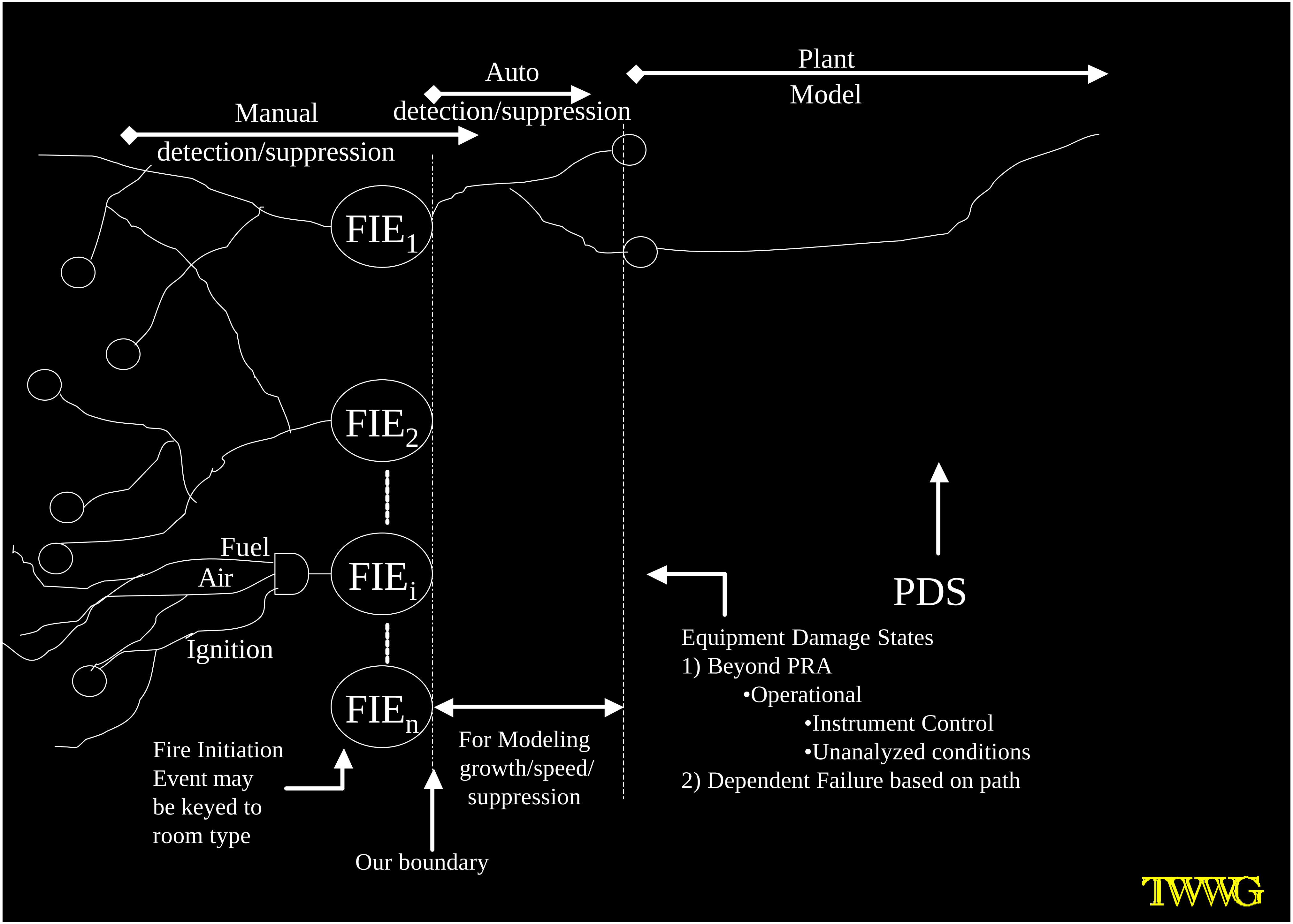
Plant
Model
Auto
detection/suppression
Manual
detection/suppression
FIE_1
FIE_2
FIE_i
FIE_n
Fuel
Air
Ignition
PDS
Equipment Damage States
1) Beyond PRA
•Operational
•Instrument Control
•Unanalyzed conditions
2) Dependent Failure based on path
For Modeling
growth/speed/
suppression
Fire Initiation
Event may
be keyed to
room type
Our boundary
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Classes of FIPS

<table>
<tr><td>Class 1</td><td>ignition source→primary fuel→ secondary fuel</td><td rowspan="3">large fire:

flames
heat
smoke
toxic gases</td></tr>
<tr><td>Class 2</td><td>high energy ignition source→
large fuel source</td></tr>
<tr><td>Class 3</td><td>dispersed air/fuel mixture→ ignition source→deflagration (→secondary fuel)</td></tr>
<tr><td>Class 4</td><td>dispersed air/fuel mixture→ ignition source→detonation (→secondary fuel)</td><td>shock wave +
above challenges</td></tr>
</table>

Development of FIPS

- Catalog of generic FIPS
- Method for developing new FIPS
- Plant-specific analyses
  - Adapt generic FIPS
  - Develop new FIPS

- Plan – collect results of new FRAs to expand catalog of generic FIPS

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Data Categories for Fires

- Data collected by “large component groups” within room types
- Implicit assumptions
  - All members of LCG within RT are equally likely to burn
    - within RTs across plants
    - with sub-room within RT
  - Equivalent to
    - all members of LCG in RT are equivalent
    - within RT, frequency is independent of location
- Implication: subdivide RTs and LCGs as far as necessary to make assumption true

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Quantification

- Evidence for frequency
  - Industry data for prior, ϕ_{Prior}
    - Can use as is for now
      - Routine cases – adjust data among categories judgmentally*
      - Big fires – perform expert elicitation to interpret available data*
    - Can develop as wanted in future data*
  - Plant-specific data for Bayesian updating

- Evidence for heat release rate (HRR)
  - EPRI/Sandia experiments/data
  - Elicitation*
  - Experiments

* NRC/EPRI may cooperate for these cases

Lessons Learned from Examination of Challenging Fire FIPS

- Electrically induced multiple (often simultaneous) fires are much more heavily represented in challenging fires than in the general fire database
- Self-ignited cable fires all involved power cables
  - Low cable rating
  - mechanical damage
  - excessive current due to other electrical faults
- Few transient fuel challenging fires, but staging for outages may be increasing exposure

Lessons Learned (continued)

- Room-to-room fire propagation observed
  - FSU plants – doors left open or cable penetrations not sealed
  - US plants – fire barriers failed in vertical cable trays

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- Most large NPP fires occur in turbine building
- Three fires where suppression system was defeated by shear magnitude of fire
  - Turbine building, large oil-filled transformers, areas where large quantities of flammable liquid stored
- A number of fires affected multiple safety trains

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Lessons Learned (continued)

- Effects of fire and smoke on plant operators not well documented or analyzed
  - Operators have ensured available cooling path, when significant degradation in performance occurred
  - Damage to non-safety related control systems may create cognitively challenging situations for operators
  - Smoke can seriously affect operators and fire fighters
  - Ex-control room actions and control room evacuation procedures can be challenging
  - Confusion in “proving” a fire exists and methods for suppression have delayed suppression and caused confusion
  - Response implementation can be complicated by fires

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Lessons Learned (continued)

- Shipboard fires
  - Rapid spread of fire through dust in ventilation ductwork
  - Invisible spread of fire along temporary cables run through ductwork
  - Direct heating of propulsion systems digital control system from fire in ventilation duct caused permanent control system failure; dead in water
  - Spray of oil onto hot equipment caused major fire (maintenance/temporary fix failed)

Lessons Learned (continued)

- Observations from the fire database
  - There are very few automatic suppression cases in the database; almost all were detected by humans
  - Fires detected by sensors are almost all manually suppressed
  - Three cable spreading room fires in database; two are among the few automatically suppressed
  - Switchgear fires all small except two medium
  - Eight control room fires in database; all extinguished by humans
  - A number of fires in the database are indicated as explosions
  - Many welding initiated fires, including a few at power; all extinguished by attending personnel

Conclusion

- Certain factors not generally modeled in FRA need to be considered
- Inclusion can be either explicit or implicit in the quantification of uncertainty
- Full-scale applications are needed

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