United States
Nuclear Regulatory Commission

Fire PRA - Overview

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Presentation Objective

Establish a common framework for discussing

- potential technical issues in current fire PRA, and
- NRC's fire risk research activities and results

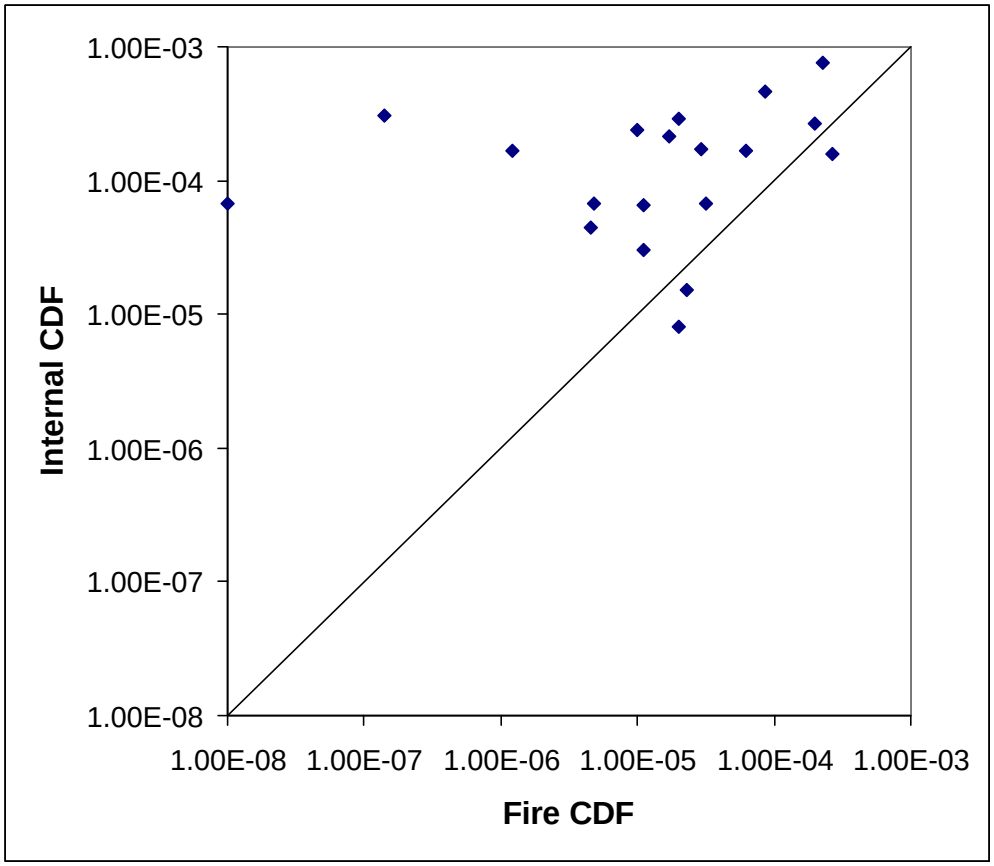
Presentation Outline

- Background
- Overall approach
- Fire PRA elements
- Concluding Remarks

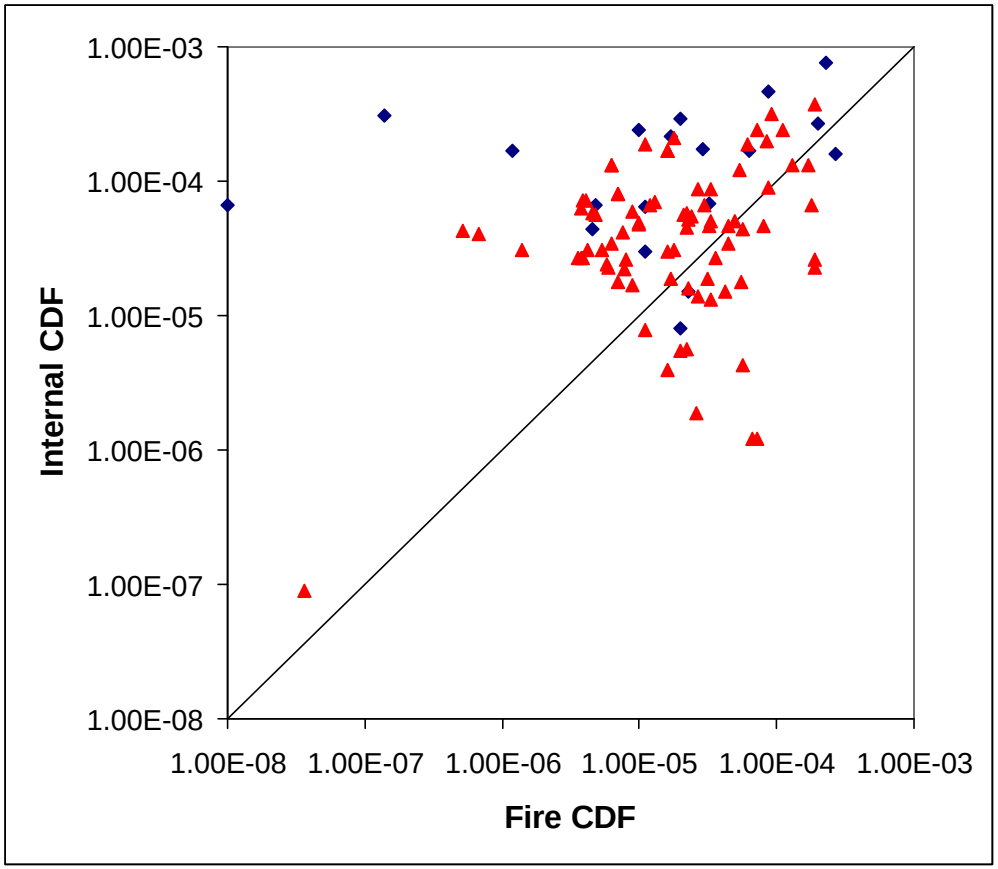
Some NPP Fire-Risk Related Questions

- What is the contribution of fire-initiated accidents to risk?
- What are the dominant contributors to fire risk?
- Are there any unique fire vulnerabilities?
- How can the fire risk be reduced?
- What is the risk impact of a proposed fire protection change?
- What is the risk significance of an inspection finding?
- What is the risk significance of a fire event?

Past NPP Fire PRA Studies: 1981-1994



Past Studies: Fire PRAs and IPEEEs



Commonly Identified Important Zones
(IPEEEs)

- Control room
- Cable spreading rooms
- Cable vault/chases/tunnels
- Switchgear rooms
- Turbine buildings
- Diesel generator rooms
- Battery/charger rooms
- Electrical equipment/relay rooms
- Electrical penetration areas

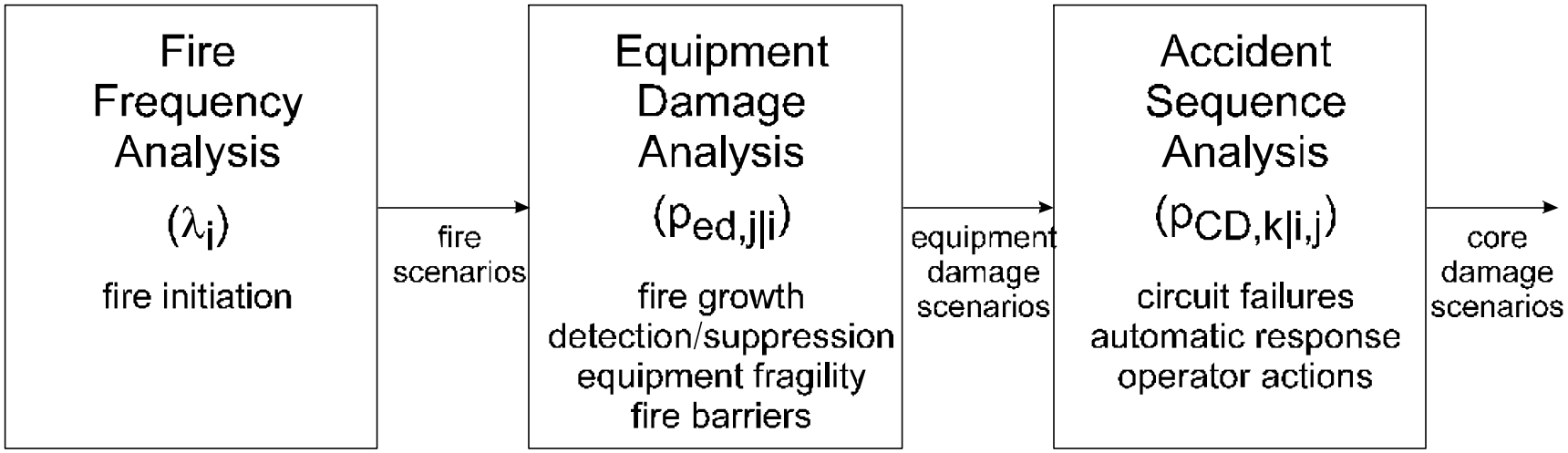
Fire PRA for Nuclear Power Plants

- Risk = {scenarios, probabilities, consequences}
  - What can go wrong?
  - How likely is this?
  - What are the consequences?
- Typical fire PRA for nuclear power plants
  - Scenarios: fire-initiated accidents leading to NPP transients
  - Probabilities: based on Poisson model; focus on estimating scenario frequencies and uncertainties
  - Consequences: core damage
- Purpose: support decision making

General Approach

- Approach parallels a fire protection definition of defense in depth
  - Prevent fire occurrence (fire frequency analysis)
  - Rapidly detect and extinguish fires (component damage analysis)
  - Mitigate the effects of fires (accident sequence analysis)
- Application requires:
  - Extensive data gathering (e.g., locations of equipment and cables, compartment characteristics, operating procedures)
  - Extensive screening and iteration

Fire PRA Methodology Overview



$$CDF = \sum_i l_i \sum_j p_{ed,j|i} \sum_k p_{CD,k|i,j}$$

Fire Frequency Analysis

- Objectives
  - Identify and characterize potentially significant fire scenarios
  - Estimate scenario frequencies
- Data: historical fire events
- Estimation
  - Generic
  - Plant-specific
- Some concerns
  - Frequency partitioning
  - Reporting consistency

Equipment Damage Analysis

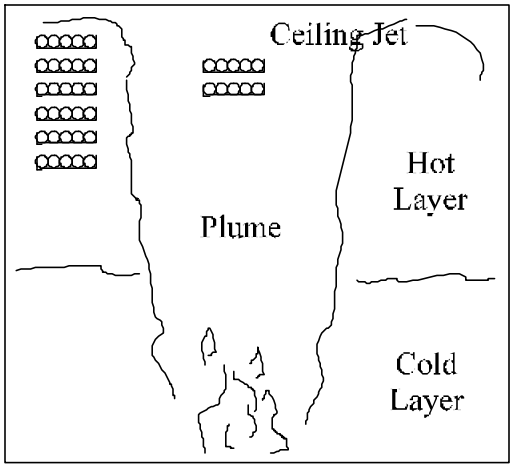
- Objectives
  - Identify potentially significant combinations of equipment that can be damaged by a fire scenario
  - Estimate conditional probabilities of equipment failure modes, given a fire scenario
- Underlying model: competition between damage and suppression processes

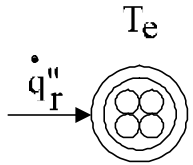
Damage occurs if $t_{damage} < t_{suppression}$

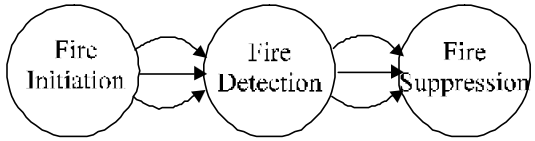
Equipment Damage Analysis Schematic

FIRE ENVIRONMENT | EQUIPMENT RESPONSE | FIRE SUPPRESSION

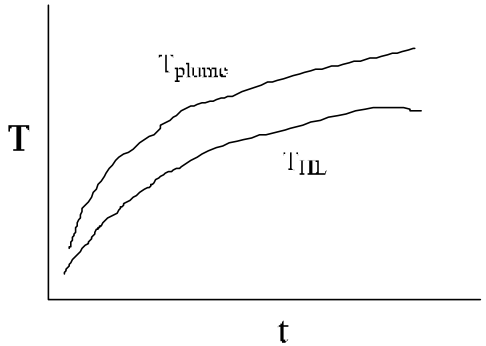
MODEL

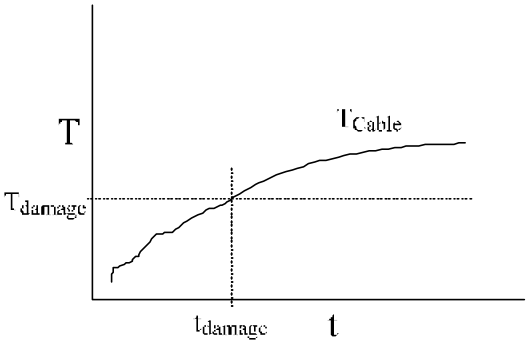


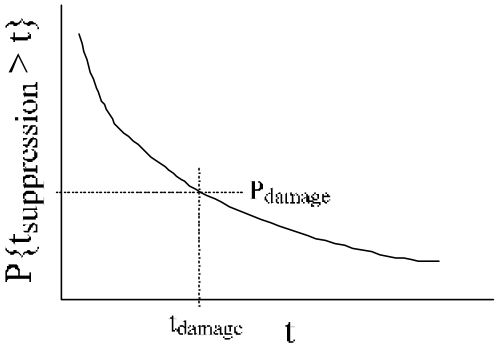




OUTPUT







Equipment Damage Analysis (cont.)

- Prediction of fire environment
  - Correlations
  - Zone models
- Equipment response/component fragility
  - Temperature and/or heat flux thresholds
  - Probabilistic models for failure modes
- Fire suppression
  - Historical data
  - Fire brigade drills
- Some concerns
  - Fire model limitations and uncertainties
  - Component fragilities (e.g., smoke effects, multiple spurious actuations)
  - Consistency with actual events

Accident Sequence Analysis

- Objectives
  - Identify potentially significant fire-induced accident scenarios
  - Estimate conditional probabilities of core damage, given fire-induced equipment loss
  - Estimate fire-induced CDF
- General approach: propagate fire-induced losses through a (modified) internal events plant model
- Some concerns
  - Effect of fire on operator performance
  - Fire-induced scenarios not in internal events model
  - Multiple hazards associated with fire initiator

Concluding Remarks

- Fire can be an important contributor to NPP risk
- Fire PRAs and fire PRA tools have been used to
  - Support plant risk studies evaluating potential changes
  - Identify potential fire protection vulnerabilities
  - Evaluate the significance of inspection findings
- Fire PRA use may increase to support risk-informed applications
- NRC/RES has a fire risk research program aimed at addressing fire PRA technical issues
  - Results presented at this workshop
  - Fire risk requantification study will provide an important test

Additional Slides

1995 PRA Policy Statement

"The use of PRA technology should be increased in all regulatory matters to the extent supported by the state-of-the-art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy."

- *Federal Register*, August 16, 1995 (Vol. 60, No. 158)

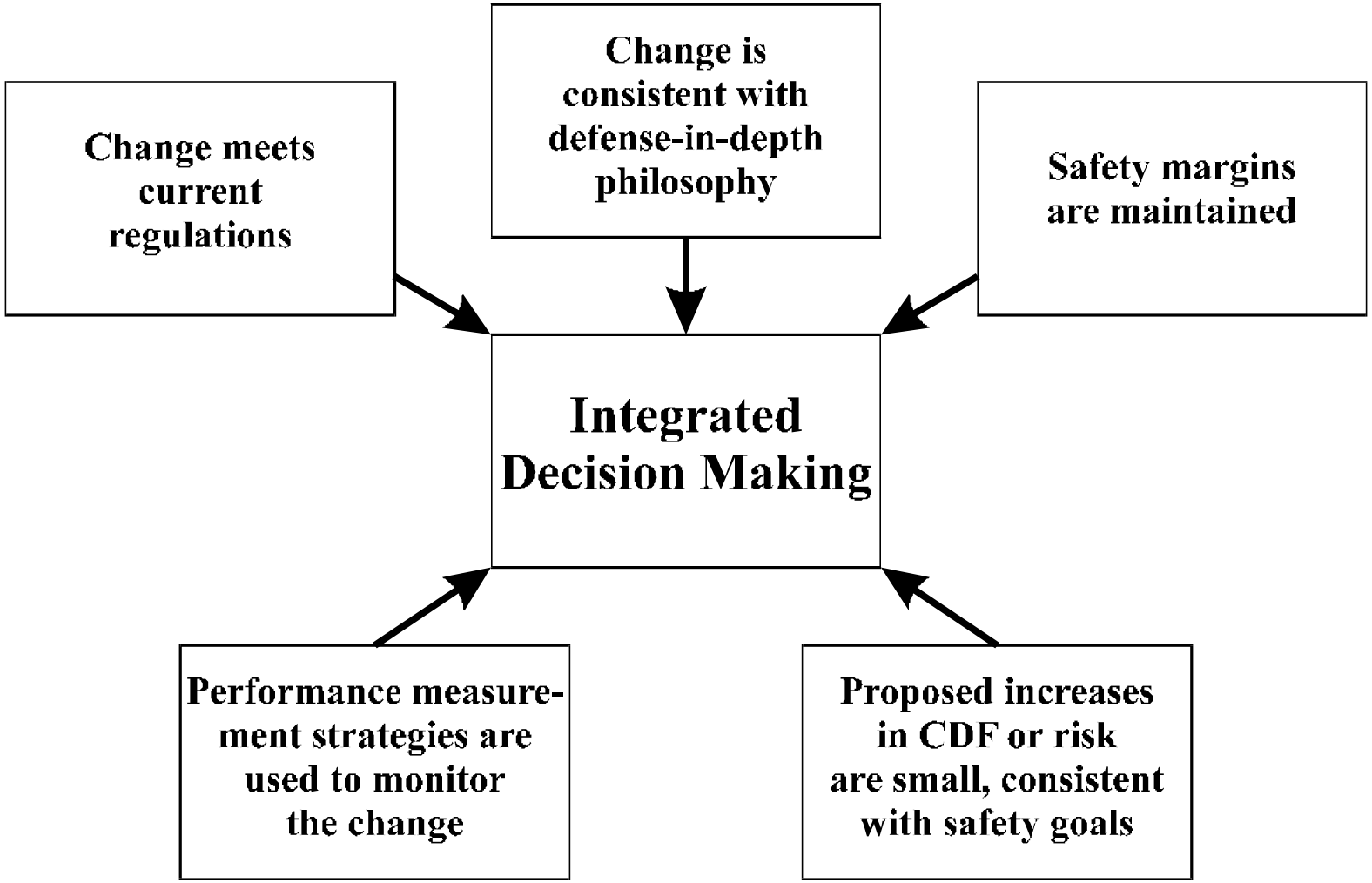
Note: additional statements cover the desire to reduce unnecessary conservatism in current regulatory requirements, the goal of realistic PRA evaluations, and the consideration of uncertainties when using the Commission's safety goals.

Risk-Informed Approach To Regulatory Decision Making

"A philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to health and safety."

- SECY-98-144 (June 22, 1998)

Integrated Decision Making (RG 1.174)



Fire Risk Research Program Tasks

(FY 2001-2002)

- Fire risk assessment tool development
- Fire risk requantification study
- Fire model benchmarking and validation
- Fire risk assessment guidance development
- Fire protection rulemaking support
- Fire protection for nuclear power plants
- Fire protection for gaseous diffusion plants
- Fire significance determination process support
- Fire risk assessment tools for precursor analysis