# Case Study Example using SFPE Guidelines for Substantiating a Fire Model for a Given Application

**Stephen M. Hill, P.E.**
**Craig E. Hofmeister, P.E., LEED AP ®**

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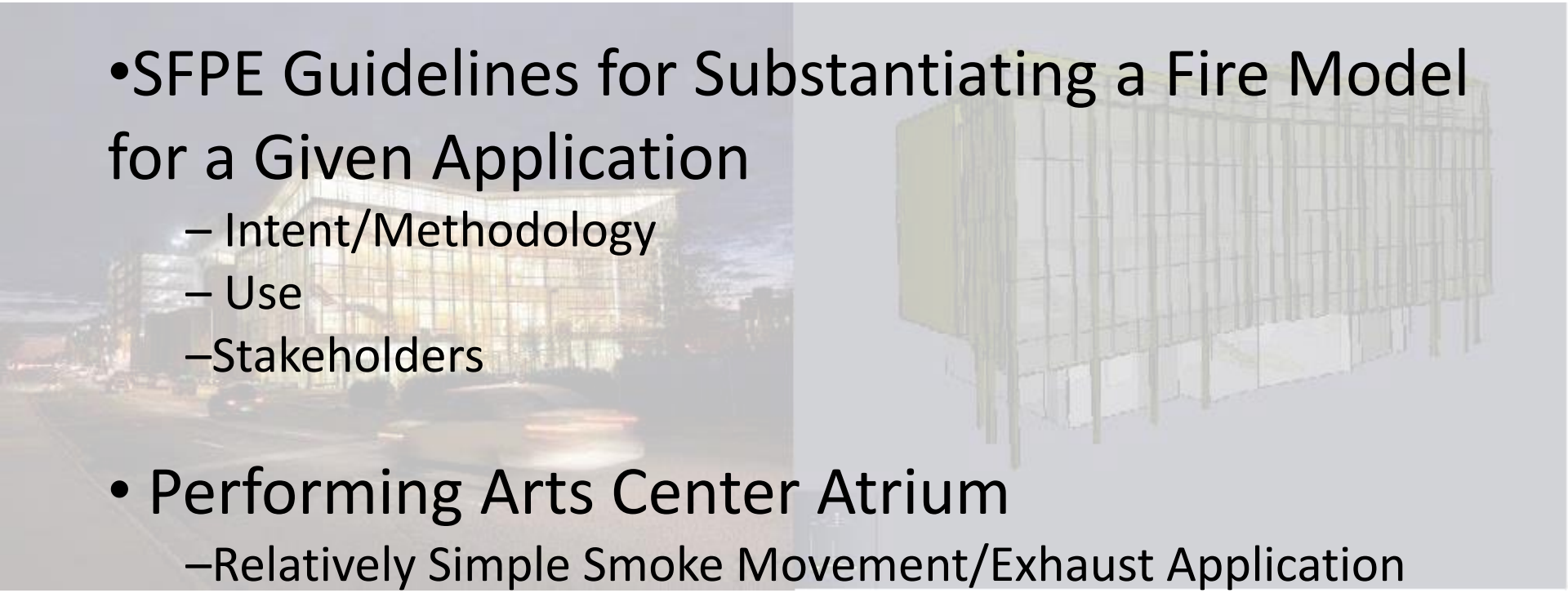
# INTRODUCTION



- SFPE Guidelines for Substantiating a Fire Model for a Given Application
  - Intent/Methodology
  - Use
  - Stakeholders
- Performing Arts Center Atrium
  - Relatively Simple Smoke Movement/Exhaust Application
  - Specific Atrium Geometry to “Wrap” Around Theater Space

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# BACKGROUND

- Class A Performing Arts Center
  - 3-Story Open Circulation Space forms Atrium

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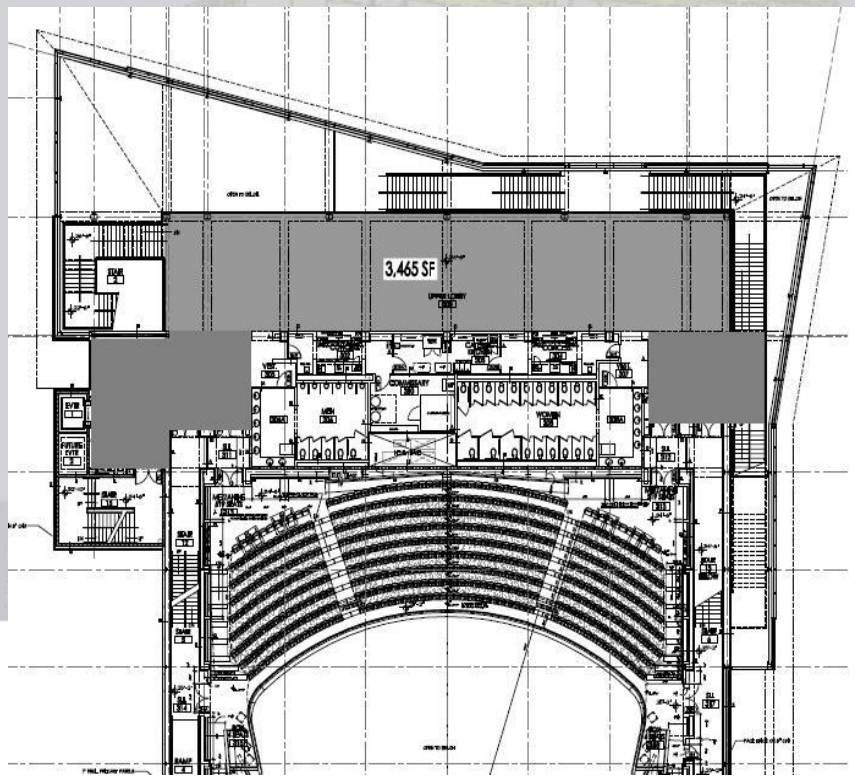
# BACKGROUND

- Class A Performing Arts Center
  - Open Stairs to Access Seating on Balcony Levels

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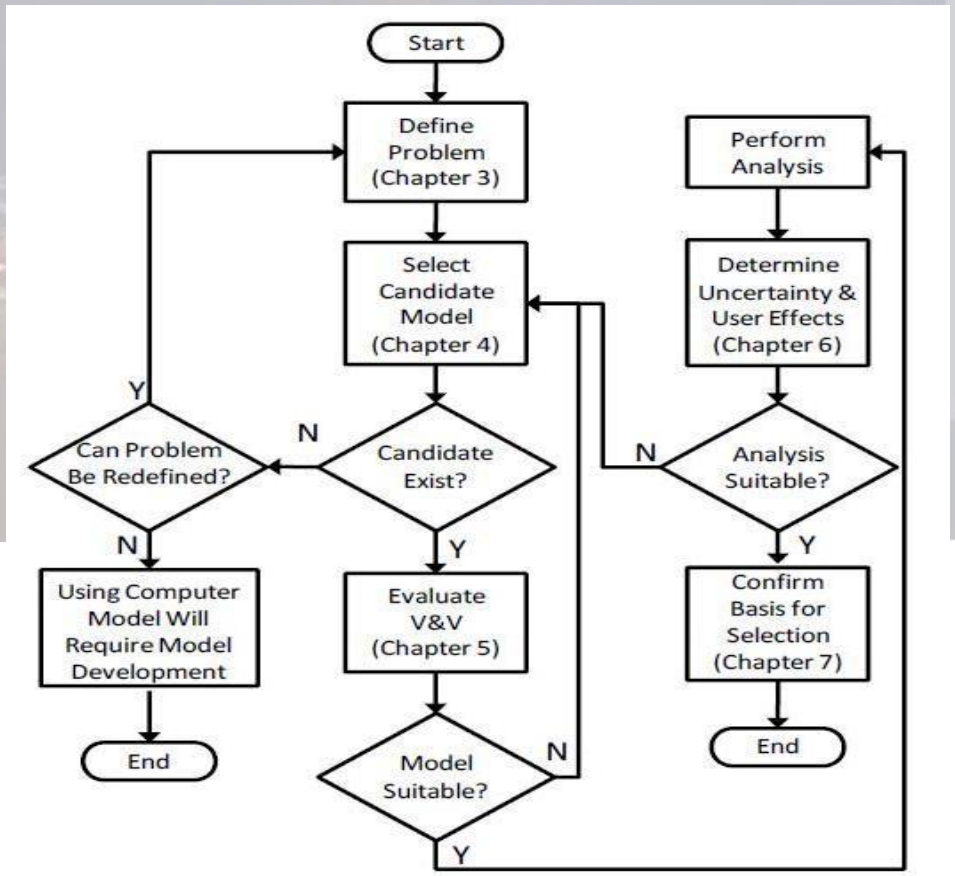
# ENGINEERING GUIDE METHODOLOGY

- SFPE Guidelines for Substantiating a Fire Model for a Given Application – published early 2011




1. Define the Problem of Interest
2. Select a Candidate Model
3. Verification and Validation
4. User Effects
5. Documentation

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# DEFINE THE PROBLEM OF INTEREST

- Scope of Problem
  - Atrium Smoke Control
    - Presumed Smoke Production, Smoke Movement, Mechanical Exhaust, and Mechanical/Passive Make-up Air
    - Review of Previous Work
- Key Physics
  - Smoke Movement, Smoke Temperature, Smoke Concentration, Smoke Layer, Compartment Pressure, Compartment Ventilation, Visibility
  - Heat Release Rate, Flame Height, Heat Flux, Ceiling Jet, Sprinkler/Detector Response

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# DEFINE THE PROBLEM OF INTEREST

- Other Parameters
  - Geometry: Relatively Well Defined
  - Timeline: Transient (could be steady-state)
  - Events: Fire Growth, Smoke/Fire Detection, Exhaust/Make-up Air Initiation
  - Materials: ??? (Actual or Assumed Conservative)
  - Initial and Boundary Conditions: Temperature, Fan/Vent Status, HVAC status, Wind

- Define Analysis Objectives
  - Smoke Layer Analysis
  - Tenability Analysis

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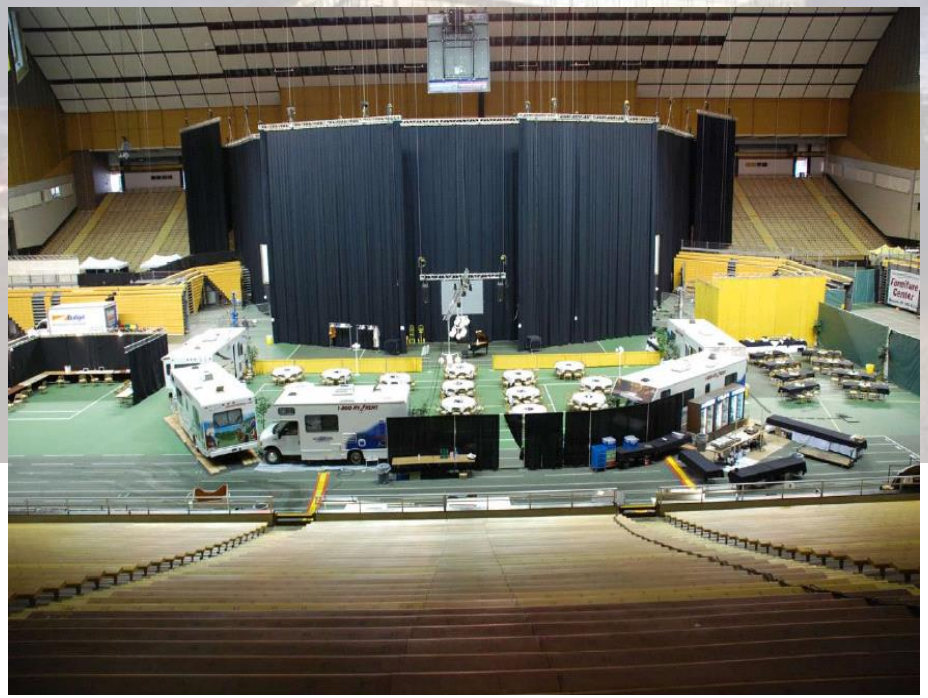
# DEFINE THE PROBLEM OF INTEREST

- Other Considerations
  - Example: Predicting the Use



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# SELECT A CANDIDATE MODEL

- Model Types
  - Algebraic
  - Zone/Lumped Parameter
  - Field/CFD
  - Combination
- Performing Arts Center Application
  - Input/Output Considerations
    - Available Input Data (Design Uncertainties)
    - Necessary Output Data/Resolution (Drives Model Selection?)
  - Smoke Layer Analysis vs. Tenability

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# SELECT A CANDIDATE MODEL

- Other Considerations
  - Available Resources (Conservative, Bounding, Sensitivity, etc)
  - Graphics/Presentation

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# Verification and Validation

- Purpose
  - –Assess the predictive capability of the model to be sure it is appropriate for its intended use
  - –Responsibility of model selection is that of the user
  - –Application of model is also responsibility of user

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# Verification

- Model Developer's should verify…
  - –The mathematics of the model is correct
  - –That physics are described by appropriate equations
  - –Appropriate methods are followed (ASTM E-1355)
- User's should verify for their application…
  - –Basic functionality of the model
  - –Consistency of input parameters
  - –That the input parameters are appropriately used
  - –The range of validity for input parameter values
  - –Consistency of results

# Validation

- Why?
  - –Determine that the predictions are appropriate for the intended use
- How?
  - –Comparison between predictions and experimental test data
  - –Calculated relative differences to experimental uncertainty
- Sources of Experimental Data
  - –Existing validation studies
  - –Commission fire testing for specific applications

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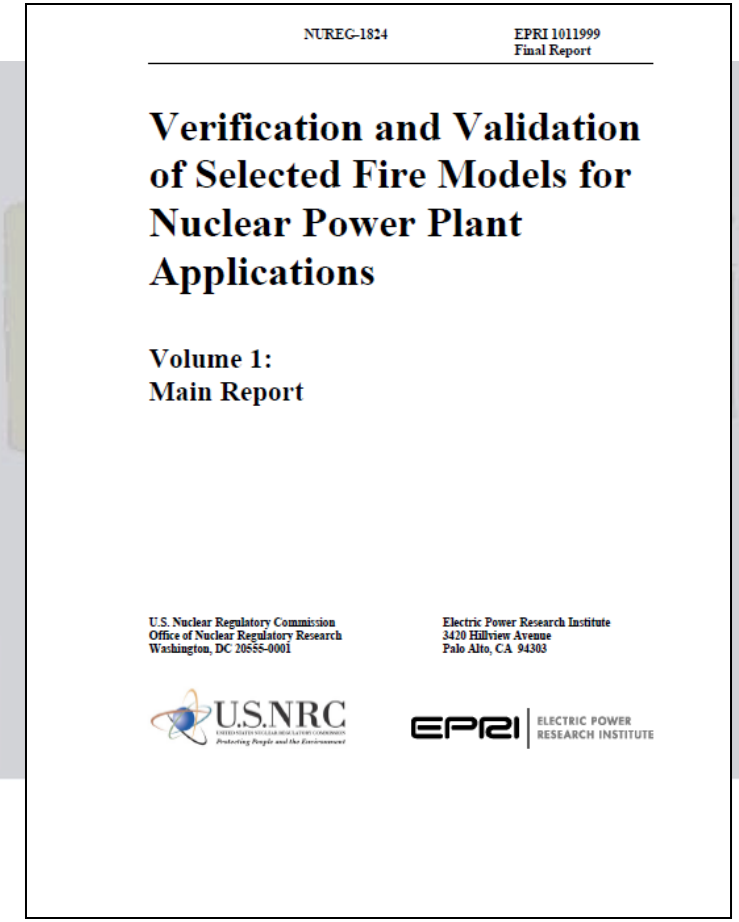
# Validation

- NRC/EPRI Report
  - –NUREG-1824
  - –EPRI 1011999 Final Report
- Calculations
  - –FDT$^S$
  - –FIVE-Rev1
- Two-Zone Fire Models
  - –CFAST
  - –MAGIC
- Field Fire Model
  - –FDS



NUREG-1824 EPRI 1011999
Final Report

**Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications**

**Volume 1:**
**Main Report**

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, DC 20555-0001

Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94303

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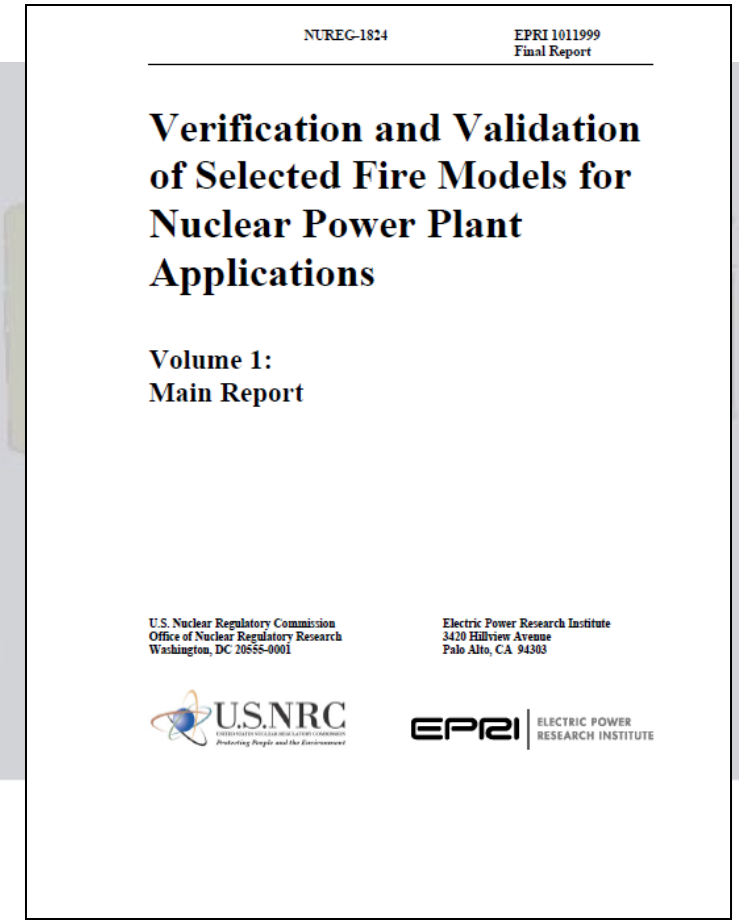
# Validation

- Fire Modeling Parameters
  - **HGL temperature** & height
  - Ceiling jet temperature
  - Plume temperature
  - Flame height
  - Radiant heat flux to target
  - Total heat flux to targets & walls
  - Wall surface temperature
  - Target surface temperature
  - **Smoke concentration**
  - **Oxygen concentration**
  - Room pressure



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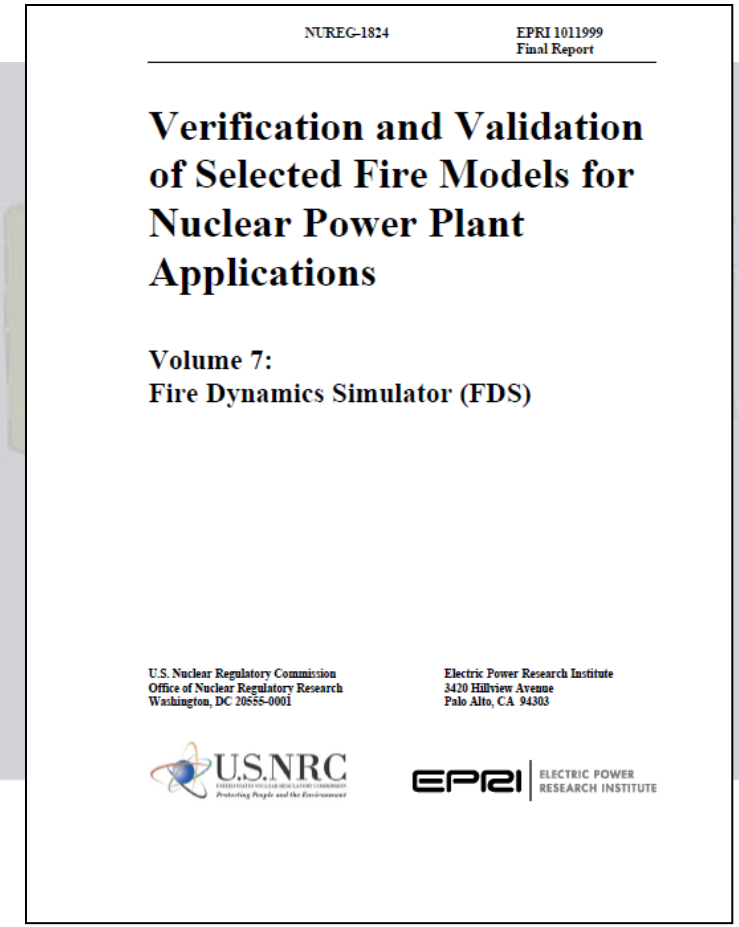
# Validation

- FDS Modeling Parameters
  - –V&V study compared model results to fire experiment measurements
- Ranking Criteria
  - –Are physics of the model appropriately described by the calculation?
  - –Do the model results differ significantly from the measured data?



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**Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications**

**Volume 7:**
**Fire Dynamics Simulator (FDS)**

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# Validation

- FDS Rankings
  - Green: Model satisfies both criteria
  - Yellow: Physics are properly satisfied but predictions may not match the experimental data
  - Red: Neither criteria satisfied
- Project parameters
  - HGL temperature
  - Smoke concentration
  - Specie concentration

# User Effects

- Additional Sources of Uncertainty
  - User-defined parameters
  - Spatial domain
  - Input assumptions
- User Responsibility
  - Sensitivity of parameters
  - Impact on model output

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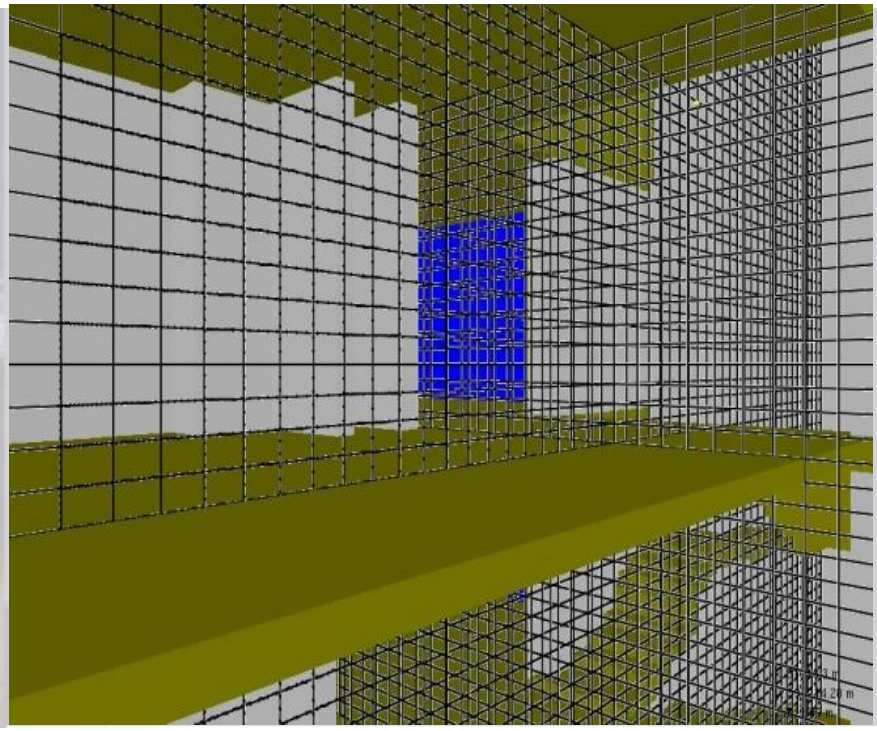
# User Effects – Spatial Domain

- Physical Space
  - –Depends on model type
  - –Resource limitations
- Grid Resolution
  - –Understand effect on analysis
  - –Results may vary
- Grid Selection
  - –General guidelines
  - –Grid resolution study



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# User Effects – Fire Definition

- Heat Release Rate
  - –Appropriate Size
  - –Growth
- Impacts
  - –Intentional (suppression)
  - –Unintentional (ventilation)

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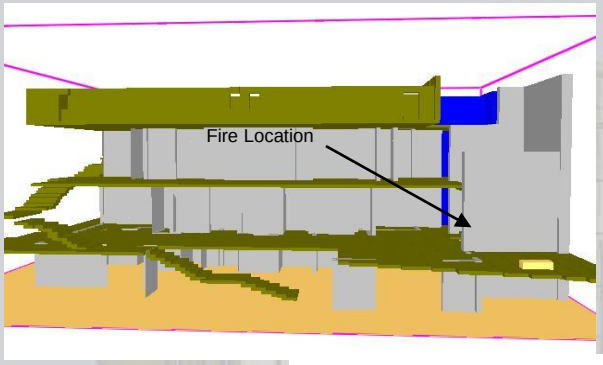
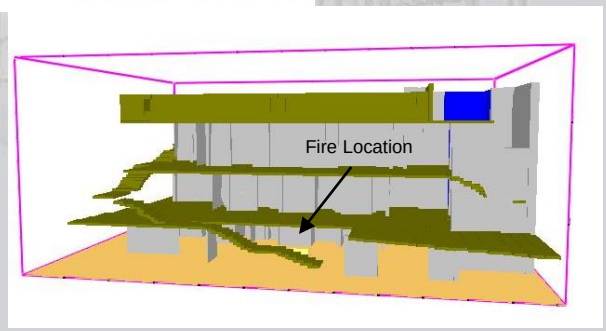
# User Effects – Fire Location

- Smoke Production
  - –Axisymmetric
  - –Balcony spill plume
- Spatial Concerns
  - –Boundaries
  - –Grid resolution impact
- Surface properties
  - –Thermal impacts
  - –Secondary item ignition
  - –Flame spread

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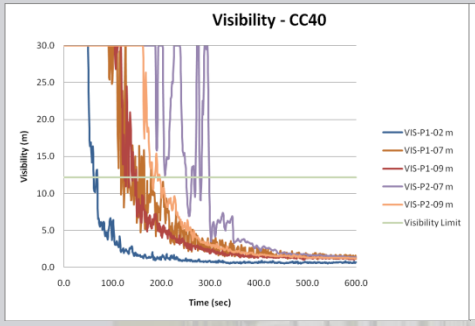
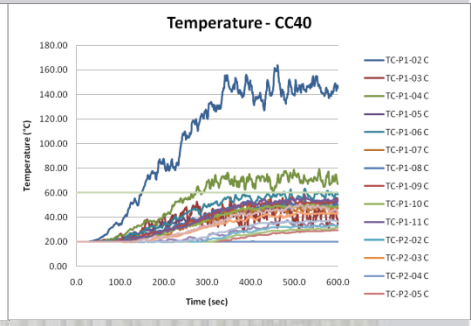
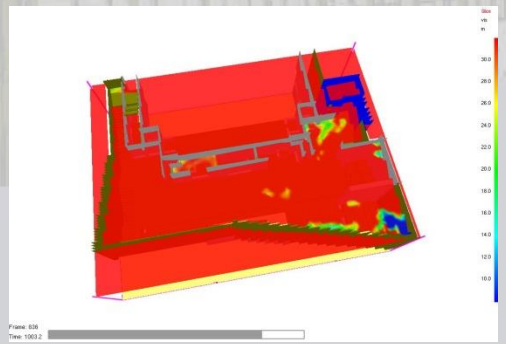
# User Effects – Measurements

- Location
  - –Point vs. average value
  - –Visualization vs. reported value
- Time-Dependence
  - –Frequency
  - –Threshold vs. averaged
- Safety Factors



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# Documentation

- Don’t Ignore this Last Step
- Engineering Guide Structured with a Purpose
  - Logical progression of steps
  - Self-documenting
- Qualification
  - Model’s use as appropriate for the application
  - Thoroughness of assessment
- Disqualification
  - Model’s use as inappropriate for the application

# Documentation

- Requirements
  - –AHJ
  - –Project Stakeholder
  - –Internal procedures
  - –Other authorities
- Undefined Format
  - –Checklist
  - –Project Report
  - –Appendix
  - –Internal record

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# Questions?

Steve Hill shill@rjagroup.com

Craig Hofmeister chofmeister@rjagroup.com

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