Modeling Smoke Transport in Aircraft Cargo Compartments

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(for systems website posting)

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed-Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Sandia National Laboratories Team Members

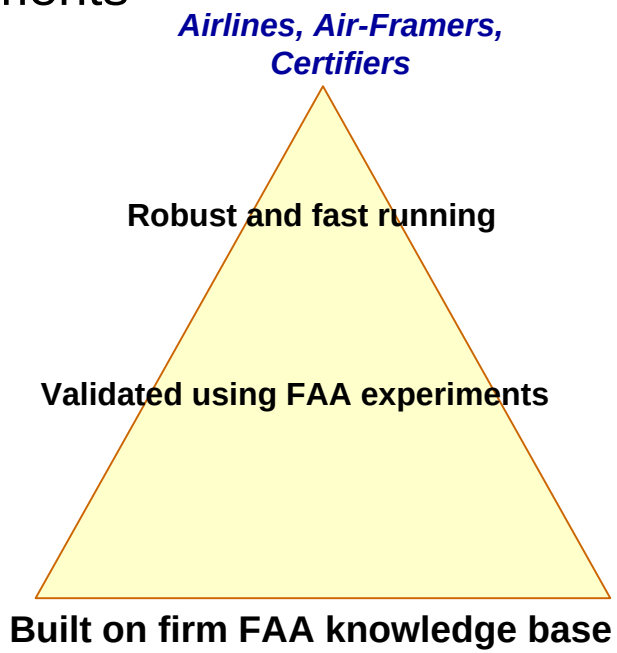
- **Experimental**
  - **David Blake, Walt Gill, and Jill Suo-Anttila**
- **Model Development**
  - **Jim Nelsen and Stefan Domino**
- **Graphical User Interface and Code Development**
  - **Carlos Gallegos**
- **Technical Support**
  - **Louis Gritzo, manager of the Fire Science and Technology Department**

Modeling Smoke Transport in Aircraft Cargo Compartments

Goal: Develop a CFD-based simulation tool to predict smoke transport in cargo compartments

- Improve the certification process
  - Identify optimum smoke detector locations
  - Specify sensor alarm levels
  - Identify most challenging fire locations
  - Reduce the number of flight tests

- Fast running
- Suitable for non-expert users
- Experimental data for source term characterization from FAA experiments
- Validated using FAA full-scale experiments



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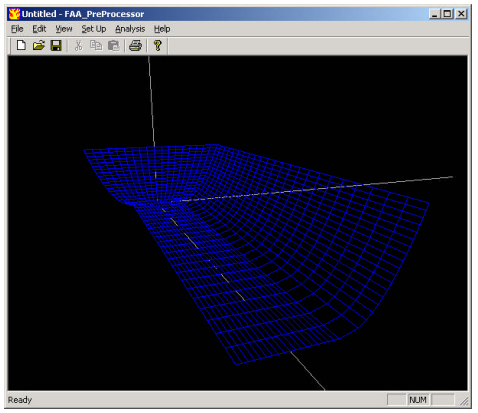
Software Design

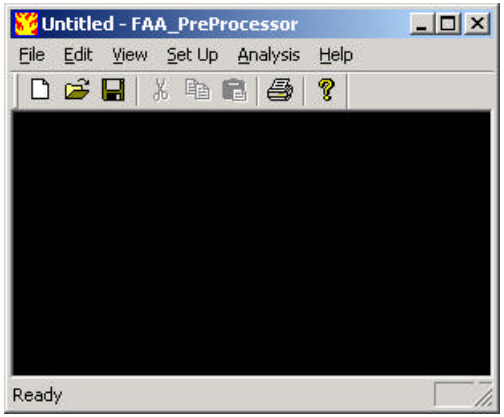


Pre-Processor

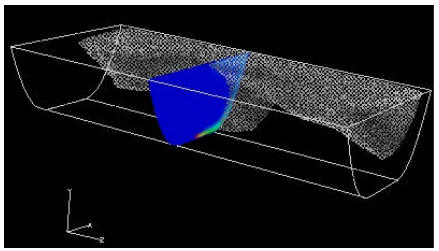
Graphical
User Interface

Analysis Module

Post-Processor

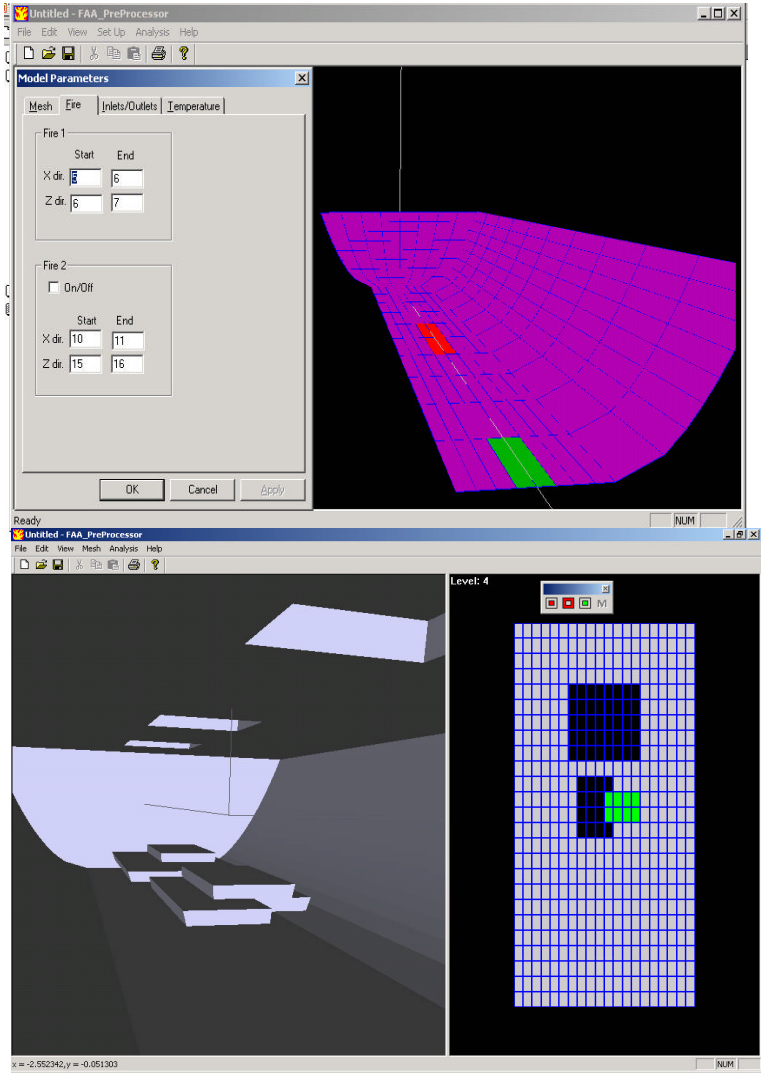


$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}(\rho u_j) = S_m^p$$



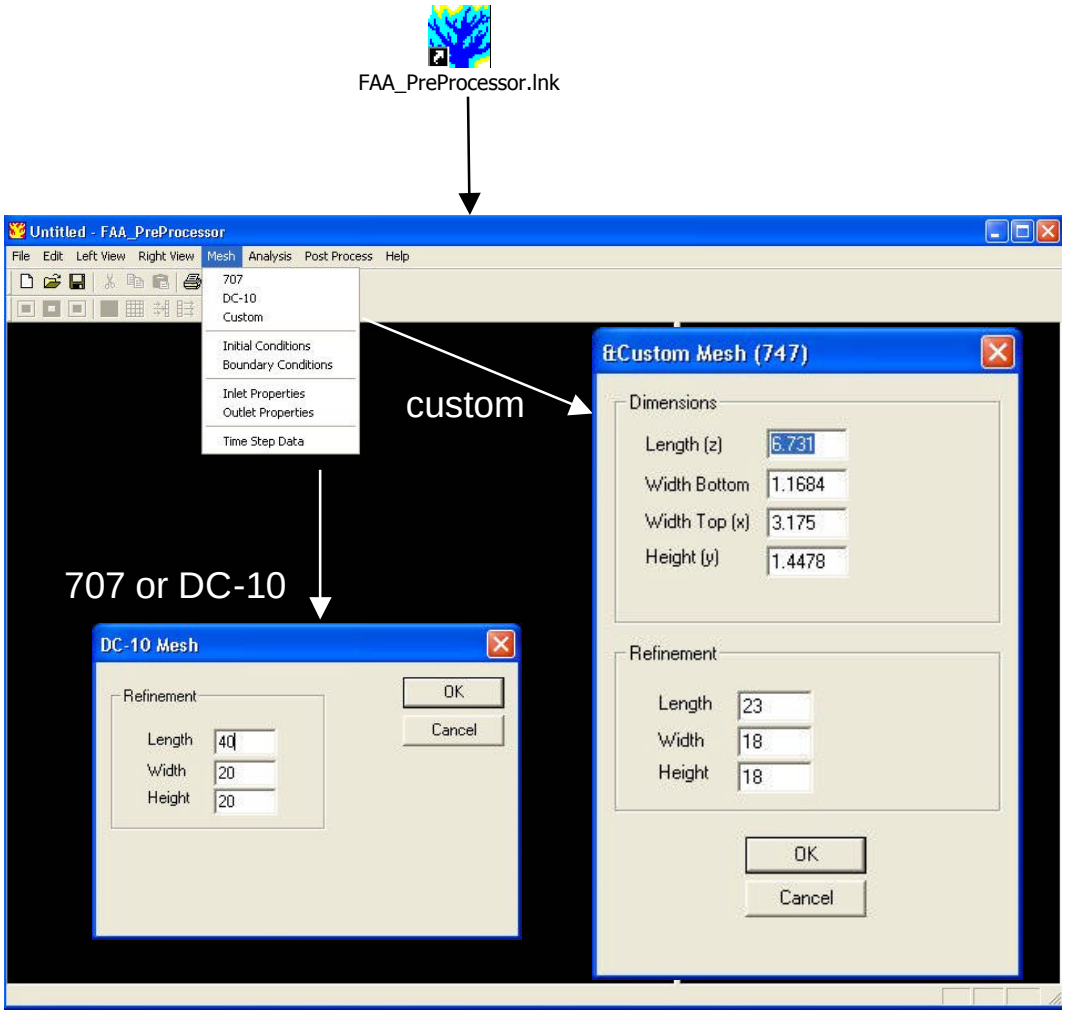
Pre-Processor Overview

- Provide models for different aircraft
  - Boeing 707, 727, 747, etc.
  - User defined
- Capabilities
  - Refine mesh
  - Enter fire(s) location and type
  - Enter ventilation velocities and locations
  - Enter compartment temperature and pressure
  - Add obstacles and recessed areas
- Instantaneous visual feedback

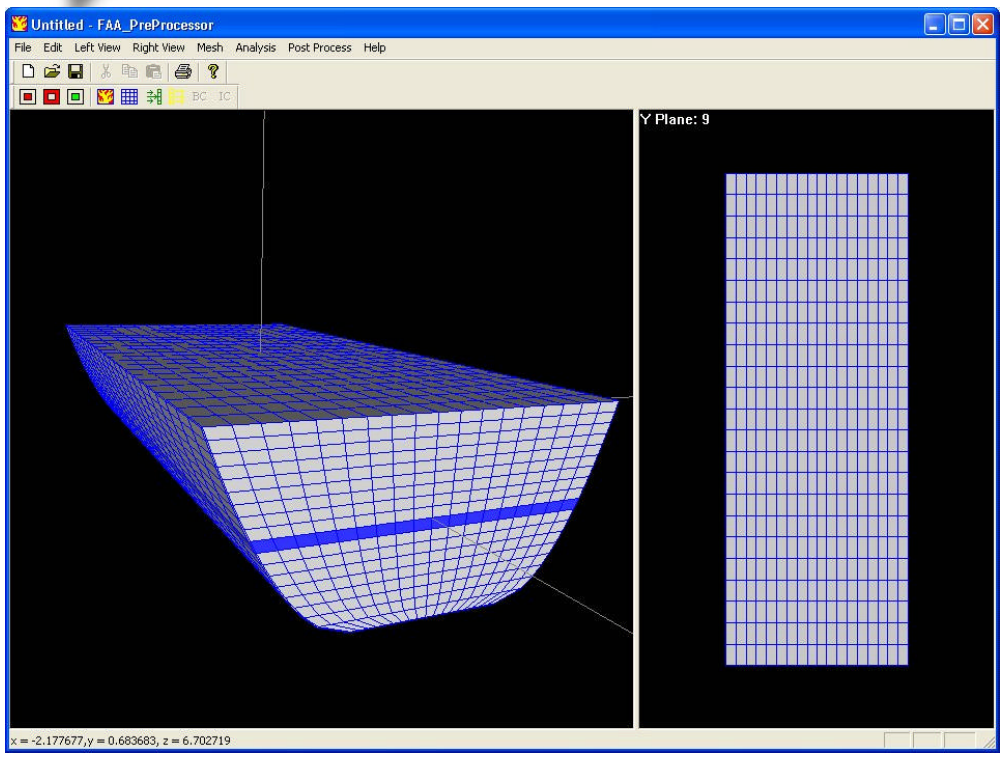


Running a Simulation
Compartment and Mesh Specification

- Execute the Pre-Processor
- Select the type of compartment
  - 707
  - DC-10
  - User Defined
- Input the dimensions
- Enter the mesh size - # of nodes

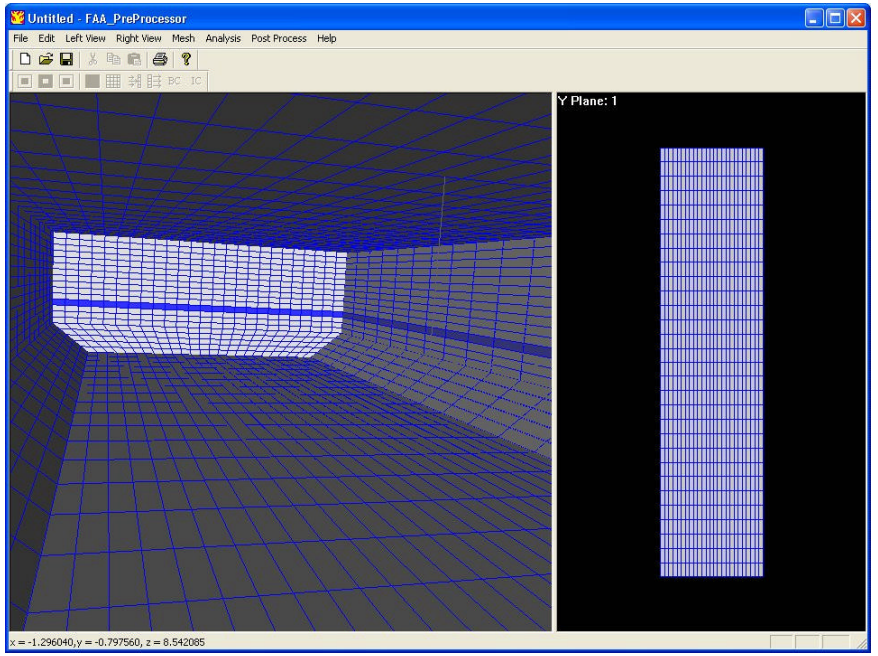


Running a Simulation
Created 707 and DC-10 Meshes



- Automatically generated 707 mesh
- Curvature captured by mesh
- Right side of screen shows selected plane

- Automatically generated DC-10 mesh
- Internal view of compartment



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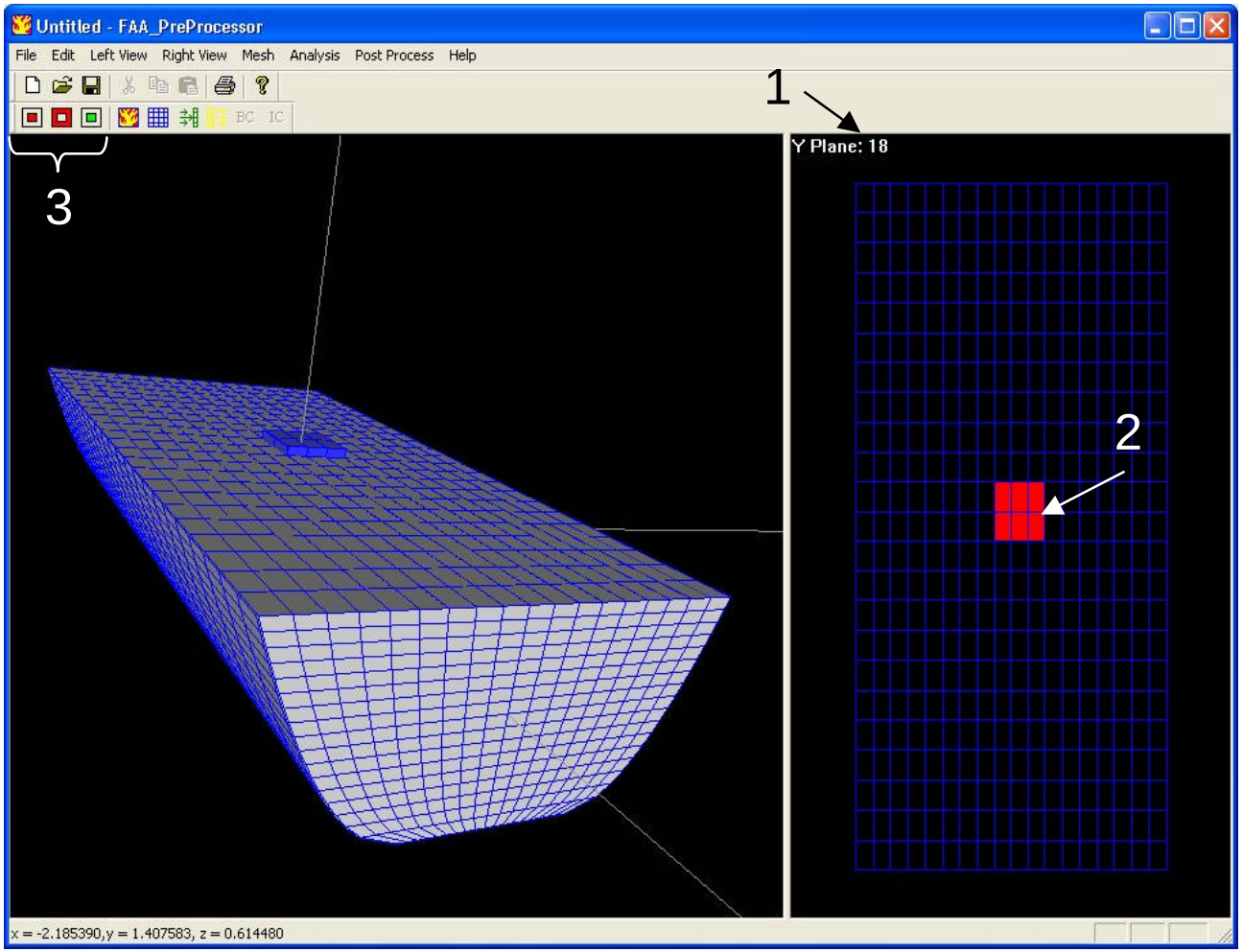
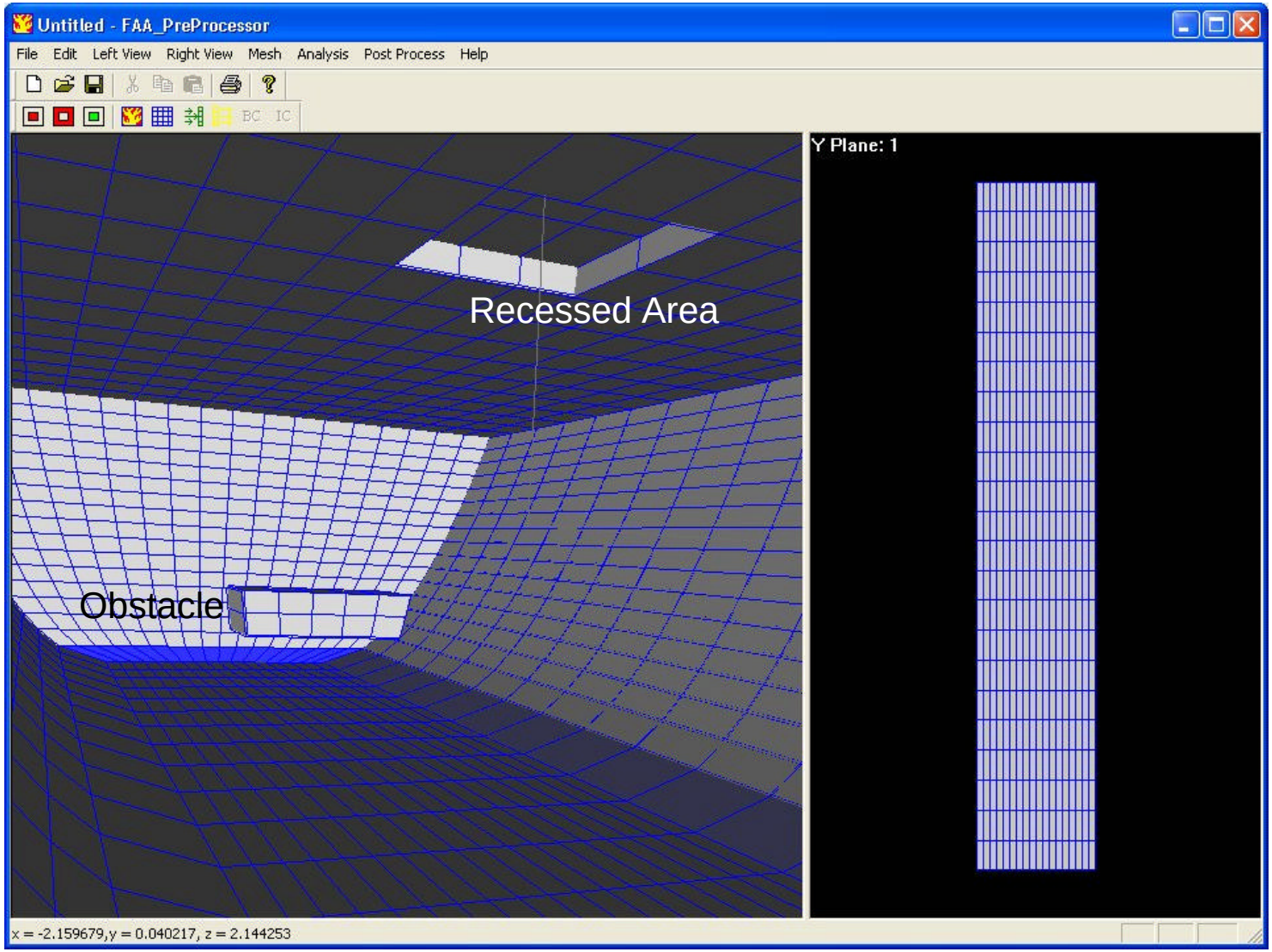
Running a Simulation
Recessed Area Specification

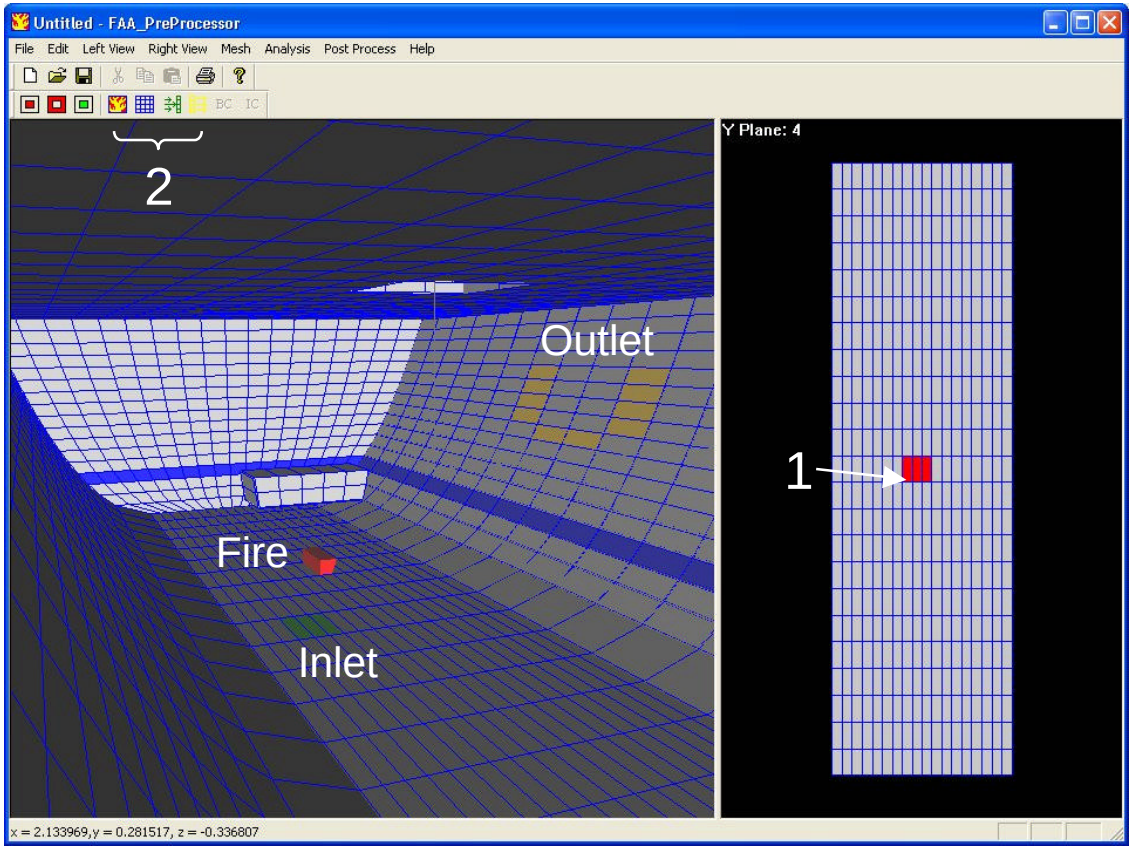
1. Advance to selected Y-plane
2. Select desired cells
3. Perform operation using buttons



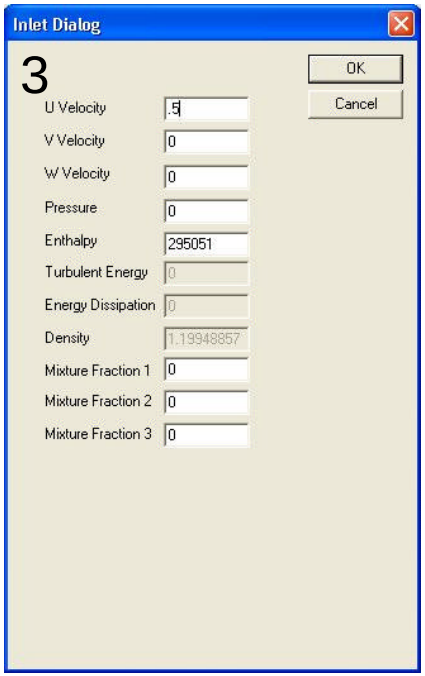
Running a Simulation
Obstacle Specification



Running a Simulation
Ventilation and Fire Specification



1. Select cells
2. Enter type of cell (inlet, outlet, fire) – cell colored to denote type
3. Use table to enter ventilation properties
4. Fire properties in file



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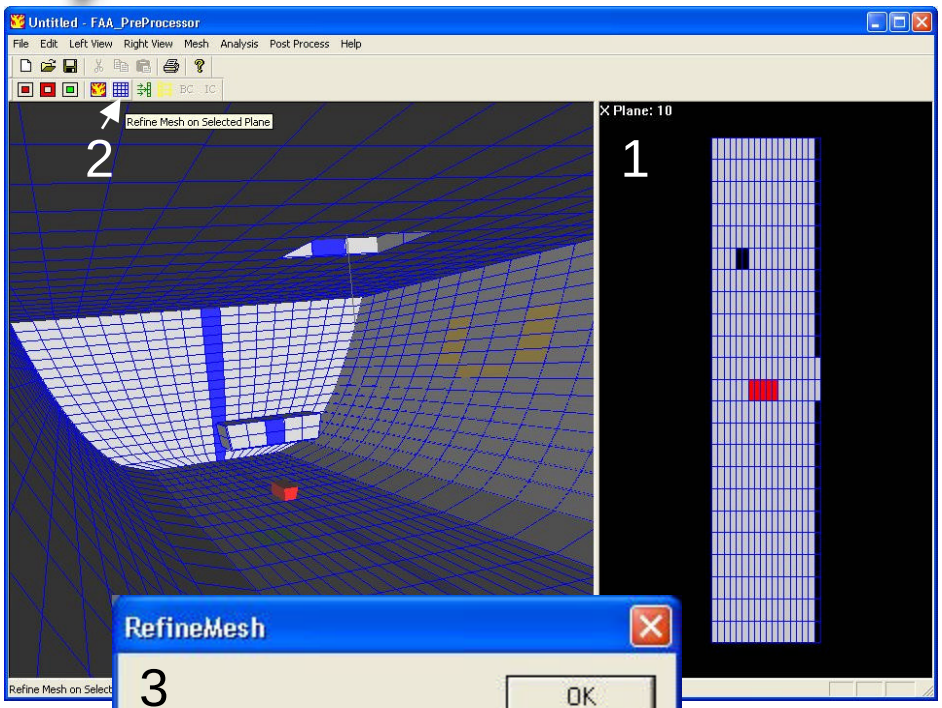
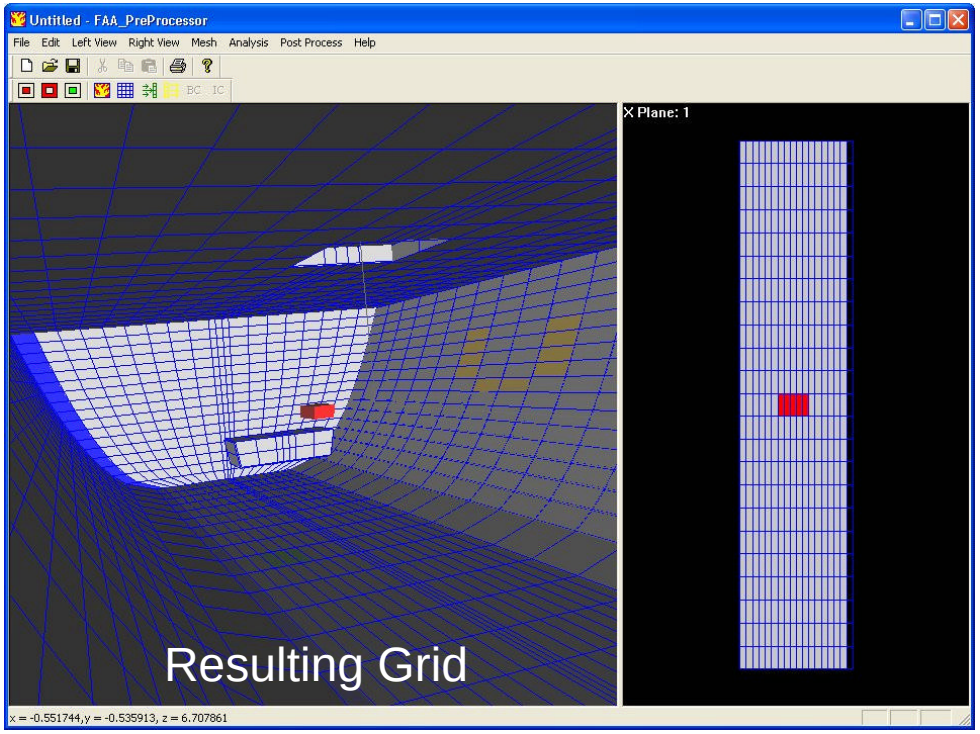
Running a Simulation
Mesh Refinement Specification



1. Select the plane for refinement
2. Use refinement tool
3. Enter level of refinement



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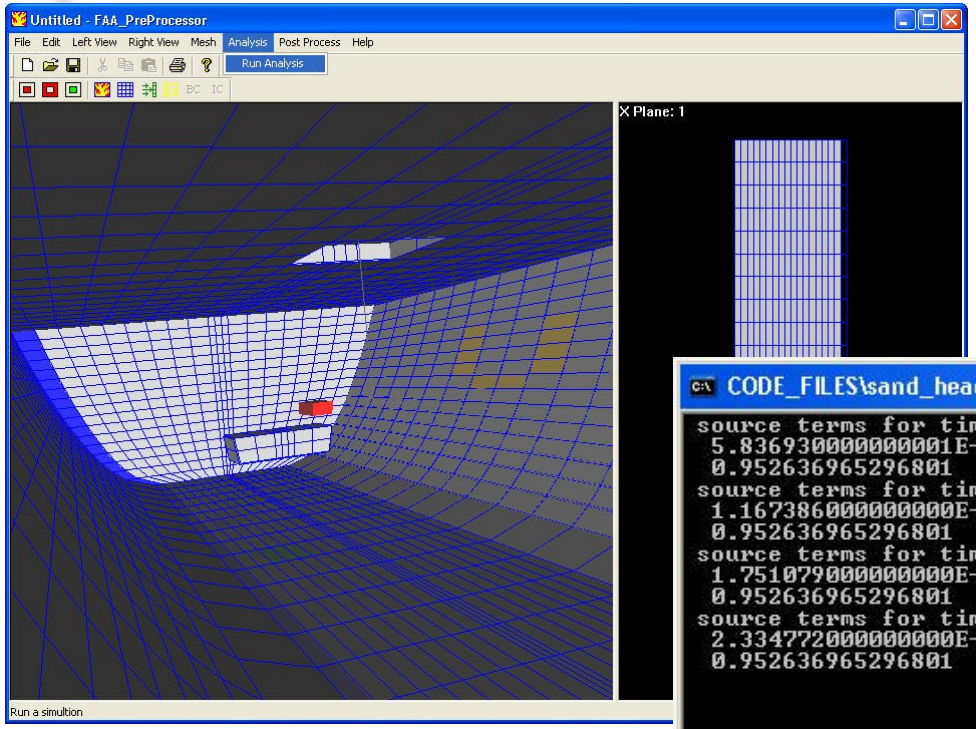
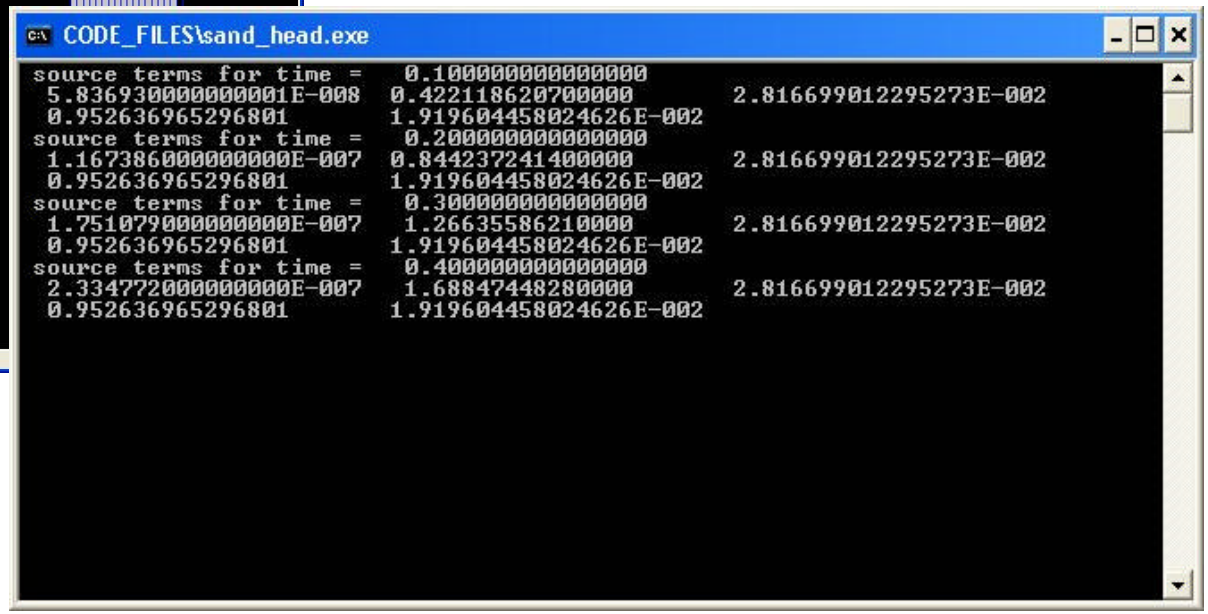
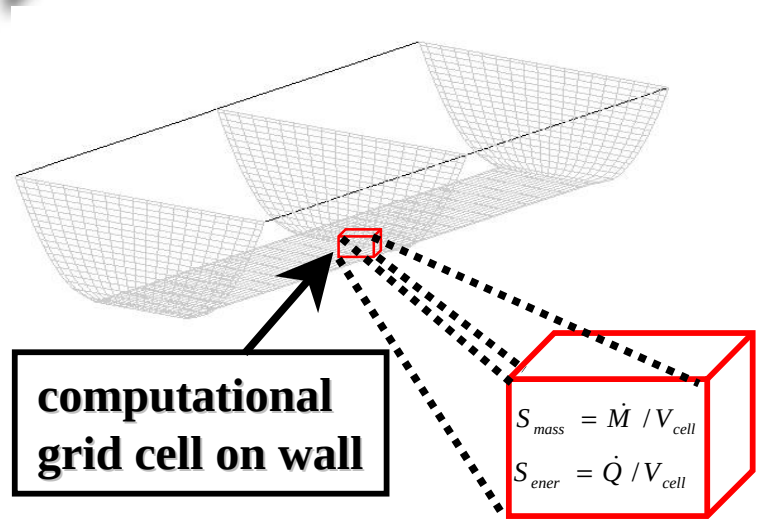
Running a Simulation
Running the Analysis Code

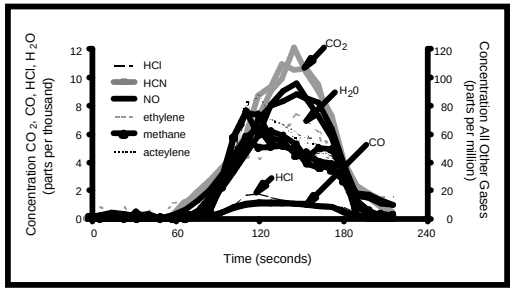


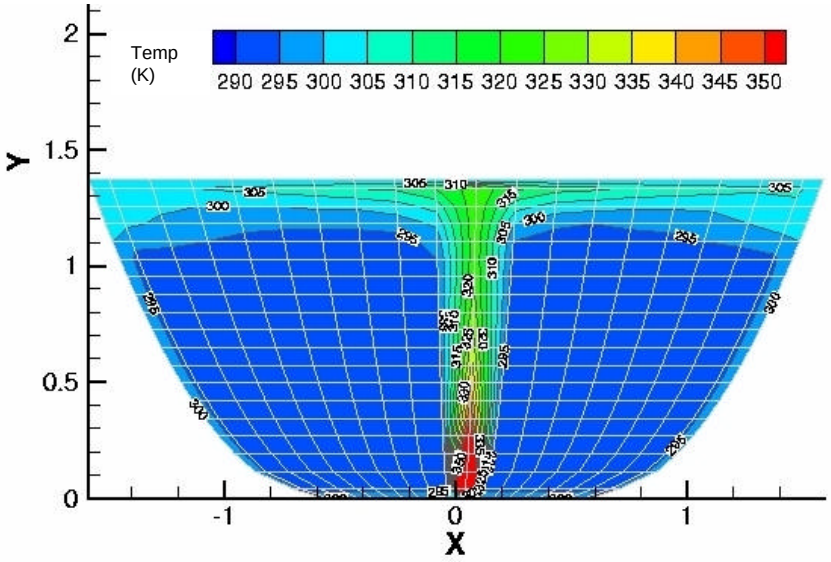
- Analysis - - - Run Analysis
- Status monitored on screen



Smoke Transport Analysis Code







- Curvature of compartment is resolved on grid
- HRR, MLR are time varying inputs (as measured in FAA experiments)
- Species tracking: presently soot, CO, and CO_2 but addition of more or different species possible
- Simulation time = 1 hour per minute of real time
- Validated using FAA full-scale experiments

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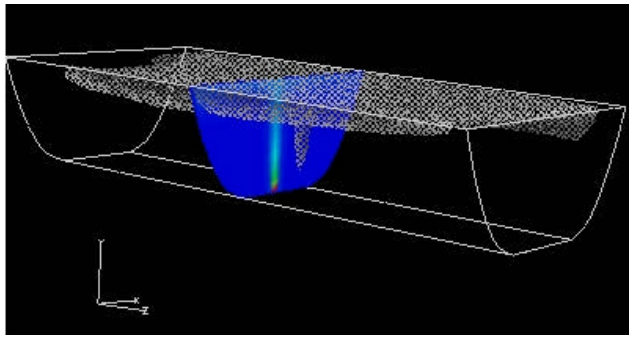
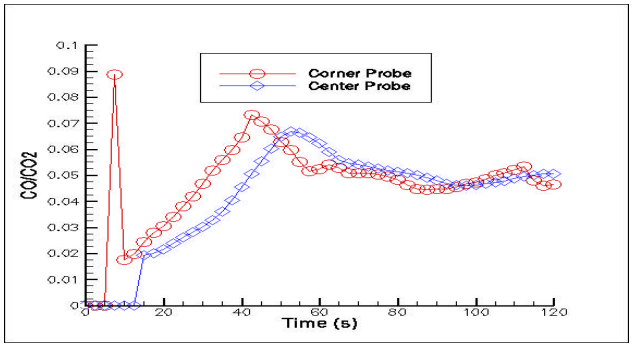
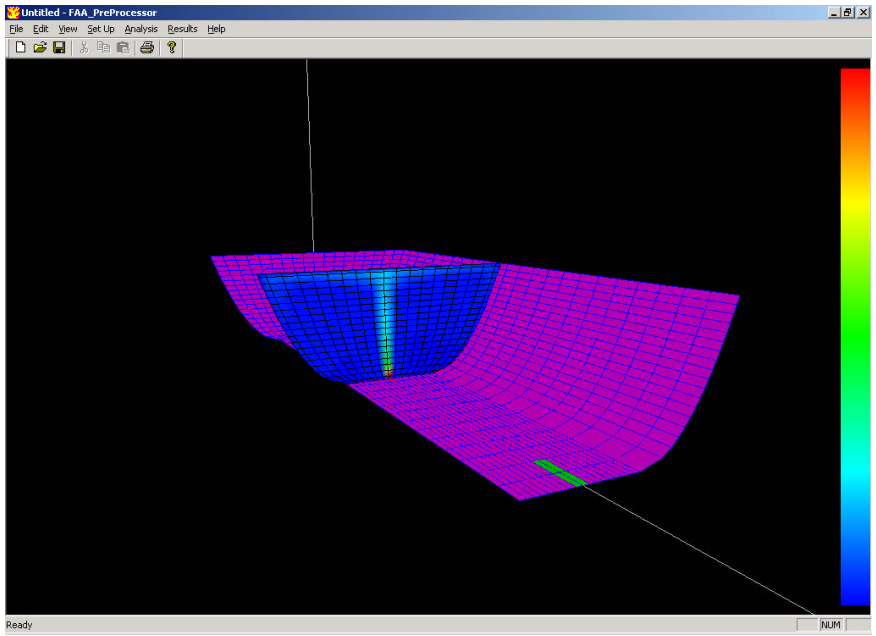
Post-Processor

Allow users to manipulate data in a variety of ways

- contour plots
- time history of field variables
- 3D smoke visualization in time







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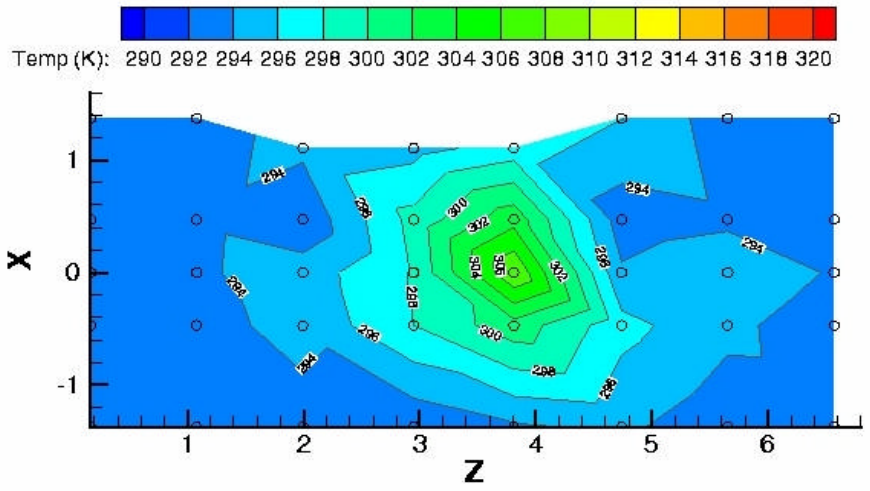
Code Validation Metrics

- Thermocouple temperature rise
  - 0 - 60 seconds
  - 0 -120 seconds
  - 0 -180 seconds
- Light transmission
  - 30 and 45 sec (ceiling and vertical)
  - 60 sec (vertical - high, mid, low)
  - 120 sec (vertical - mid and low)
  - 180 sec (vertical - mid and low)
- Gas species concentration rises
  - 0 - 60 seconds
  - 0 -120 seconds
  - 0 -180 seconds



Experimental ceiling temperature distribution at 60 sec

Status of FAA Full-Scale Validation Experiments

- 707 experiments completed
  - Baseline – center fire
  - Attached – sidewall fire
  - Corner – corner fire
  - Determined leakage ventilation had no impact on data
  - All 707 experiments were conducted without ventilation
- DC-10 experiments in progress
  - Ventilation validation
  - Three fire locations

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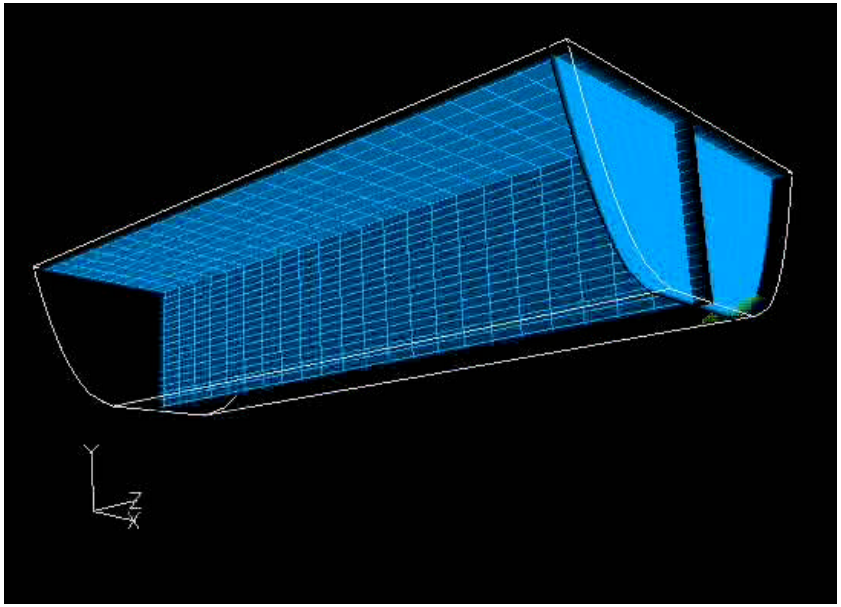
Future Activities

- Continue validation of the smoke transport code
  - Finish code modifications
  - 707 validation comparisons
  - DC-10 validation comparisons
- Release of code to small user community (Spring ’04)
  - Includes theory and users manual
- Revisions and final release of code (Feb ’05)



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