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Modeling Smoke Transport in Aircraft Cargo Compartments

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Albuquerque, NM

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Fire Safety Section

FAA Technical Center

International Aircraft Fire and Cabin Safety Conference

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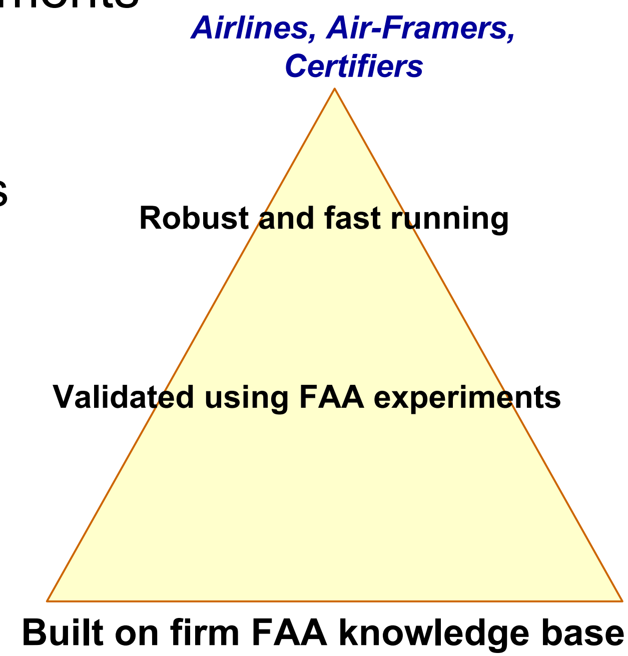
Modeling Smoke Transport in Aircraft Cargo Compartments

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 worst case 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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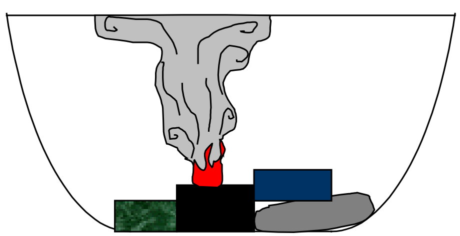
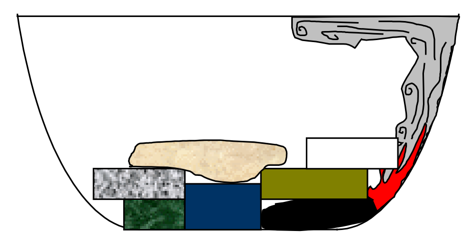
Insight into Physical Processes

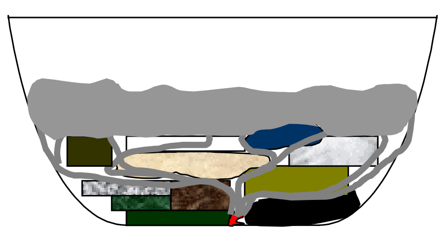
- FAA experiments helped identify four classes of cargo compartment fire scenarios
- Model capable of assessing these scenarios (curvature and packing issues addressed)



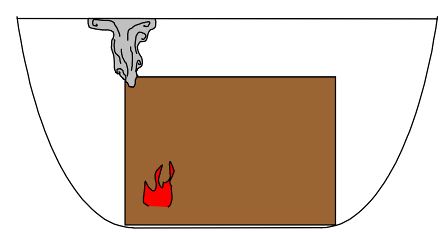
Buoyant Plume



Attached Flow



Diffuse Source



Containerized

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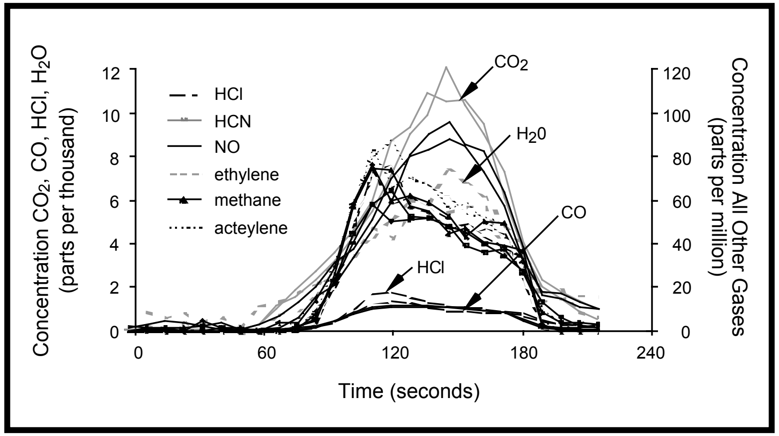
Experimental Research Supporting Code Development

FIRE SIGNATURES

- Characterization of particulate emitted from potential sources (flaming, smoldering, simulated)
- FAA calorimeter experiments for source heat release, mass loss, and species information



TRANSPORT

- Full-scale facility for validation experiments

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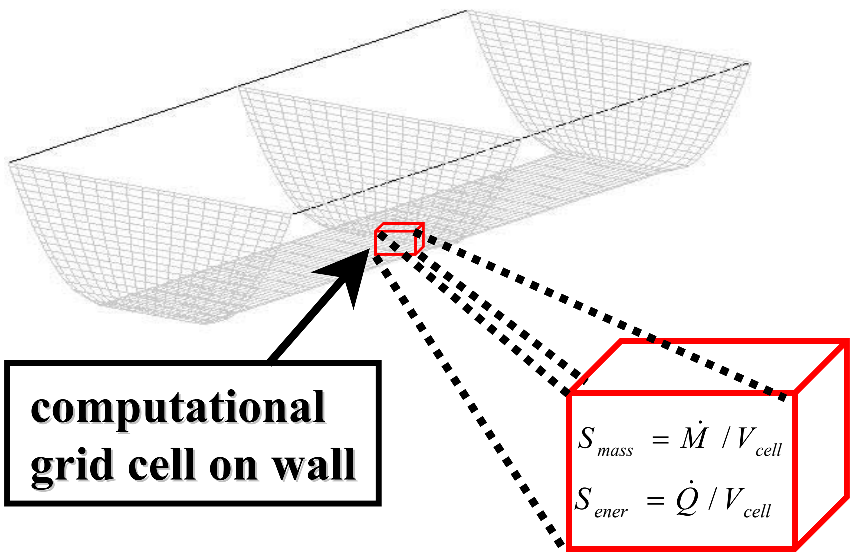
Smoke Transport Code Features



- Curvature of compartment is resolved on grid
- Arbitrary ventilation inlets and outlets can be specified
- Location and type of fire can be selected
- 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 on the order of hours

William J. Hughes FAA Technical Center

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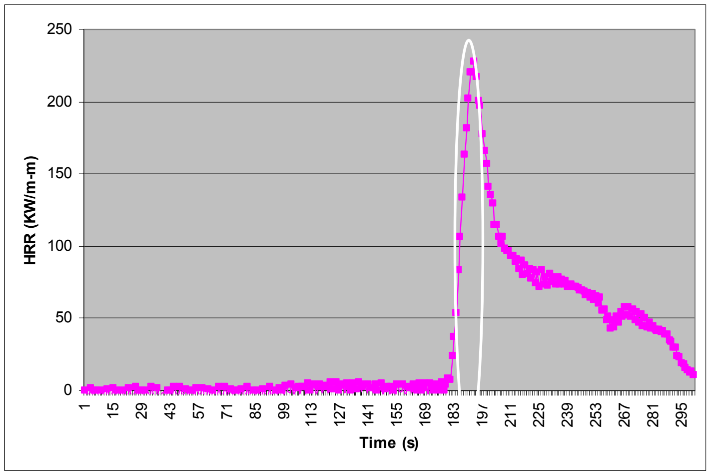
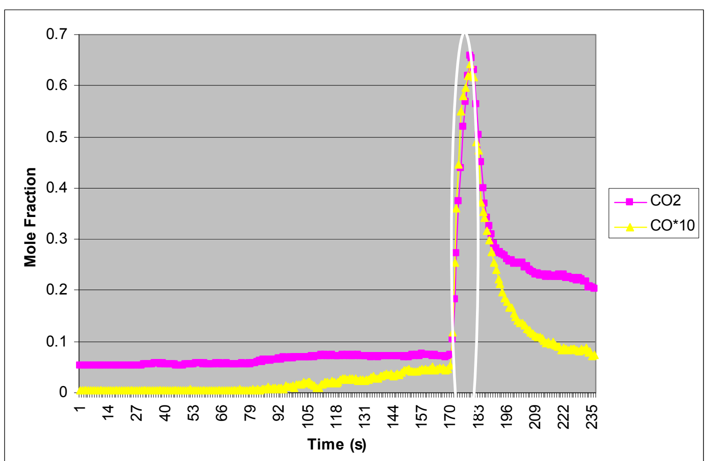
Smoke Transport Code Demonstration Calculations

- Buoyant Plume
  - 10 sec flaming fire in the center of sealed compartment
- Attached Flow
  - 120 sec flaming fire near wall of sealed compartment
- Dual Fire
  - arbitrary fire and ventilation locations

Smoke Transport Code Demonstration Calculation

Buoyant Plume Scenario





- Total flaming experiment time of 300 seconds
- Flaming heat release data (top)
- CO/CO2 composition (bottom)
  - Near constant uniform split $Y_{CO2} = 10{*}Y_{CO}$
- CFD simulation performed with time-varying heat, mass, and compositions completed for data points between 180 and 190 s
- Maximum HRR of 2.5 KJ/s

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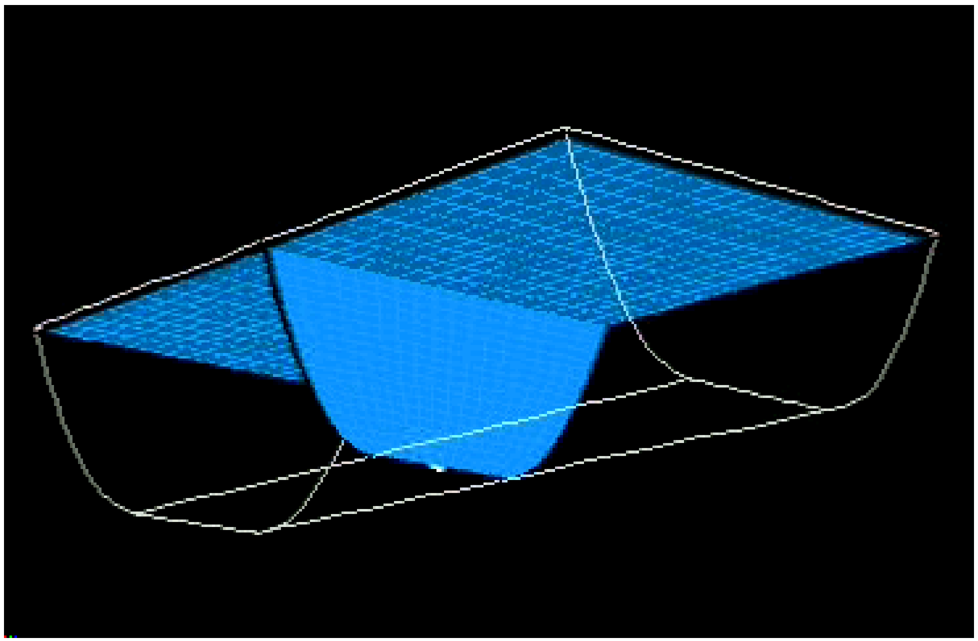
Smoke Transport Code Demonstration Calculation

Buoyant Plume Scenario



- Ten second simulation (1.7 hours of compute time for 10K grid points; Sun Ultra^2).
- Temperature profiles shown; walls are adiabatic
- No specified ventilation
- HRR, MLR are time varying as measured in FAA experiments
- Species concentrations (CO, CO_2, soot) - aids in sensor selection and placement

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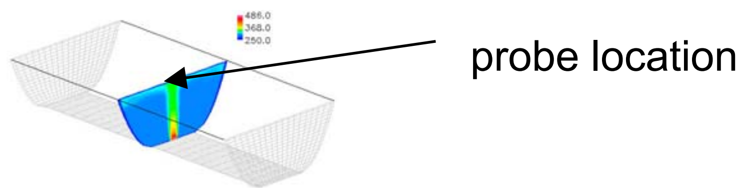
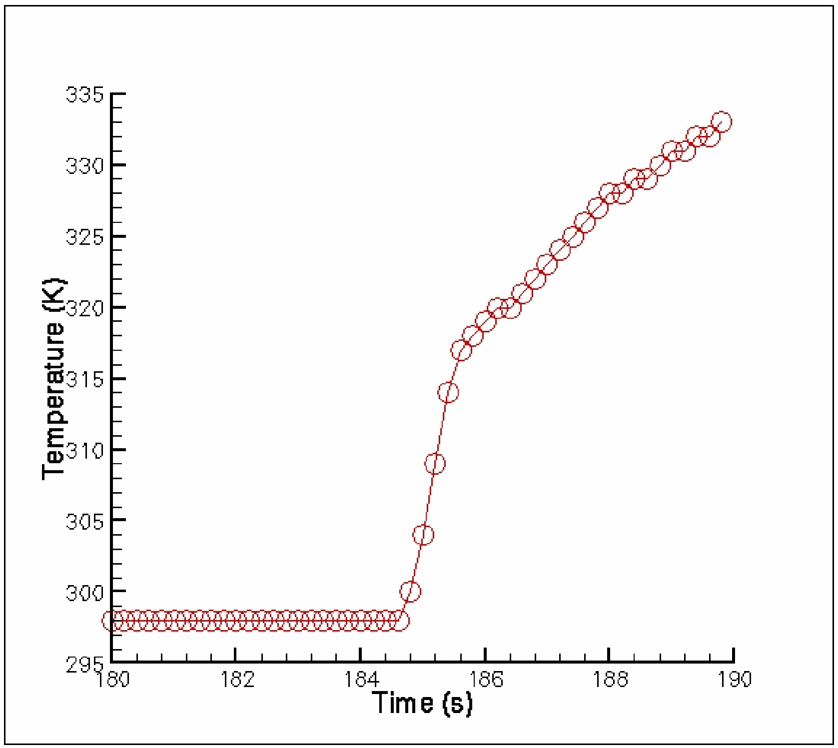
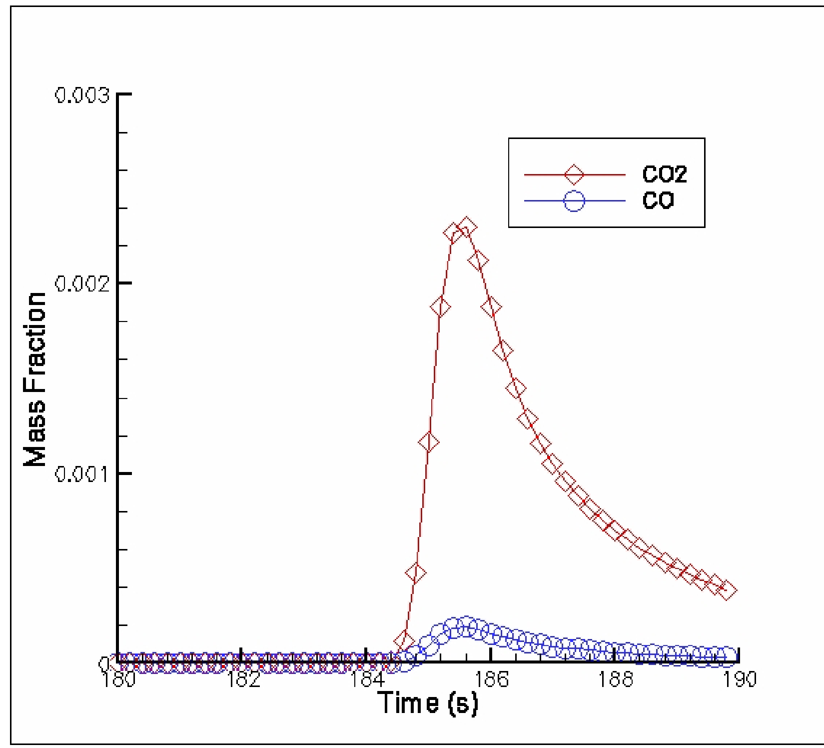
Smoke Transport Code Demonstration Calculation

Buoyant Plume Scenario







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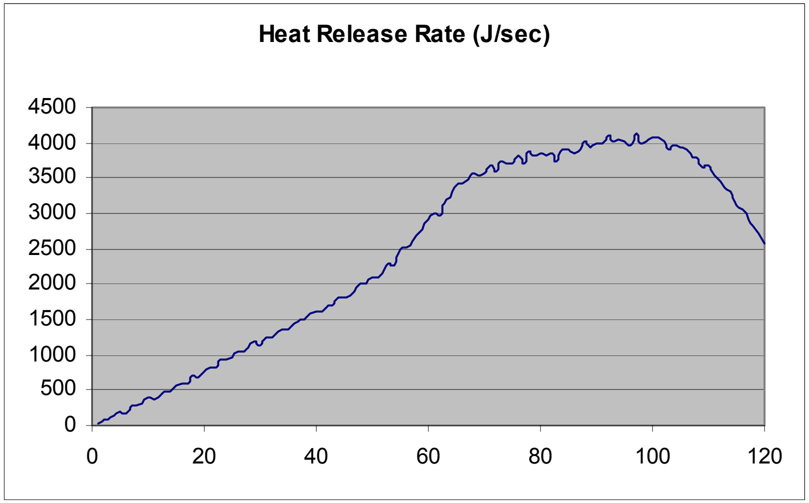
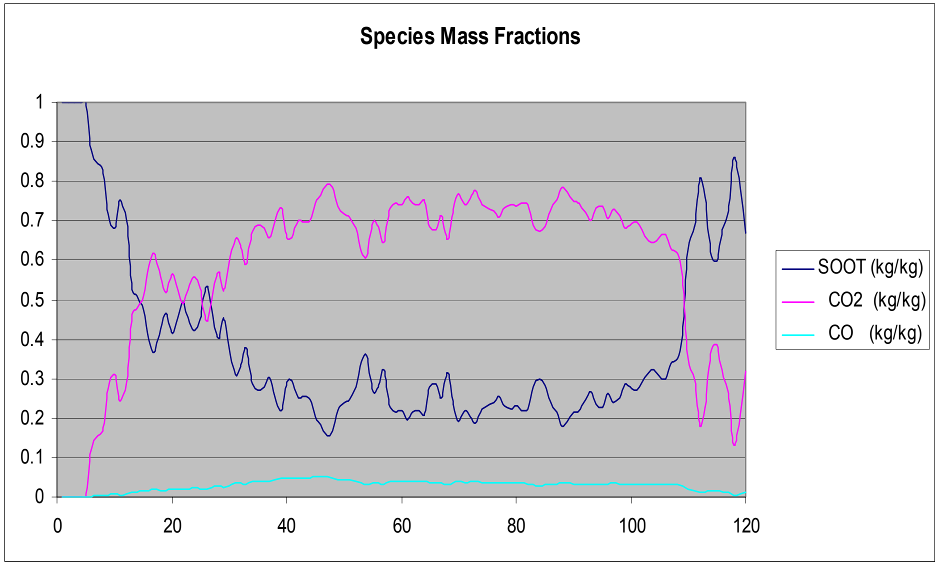
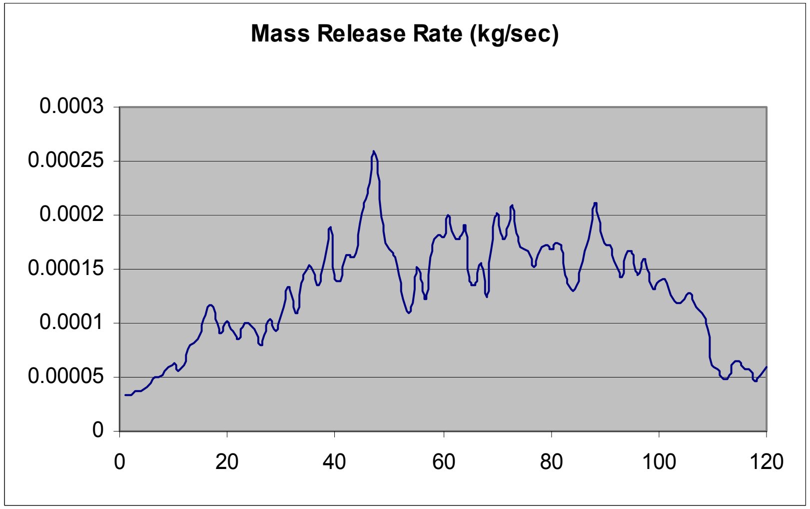
Smoke Transport Code Demonstration Calculation

Attached Flow Scenario

- Flaming source in forward in 707 cargo bay - attached flow
- Flaming experiment time of 120s
- CFD simulation performed with time-varying heat, mass, and compositions
- Maximum HRR of 4 kJ/sec







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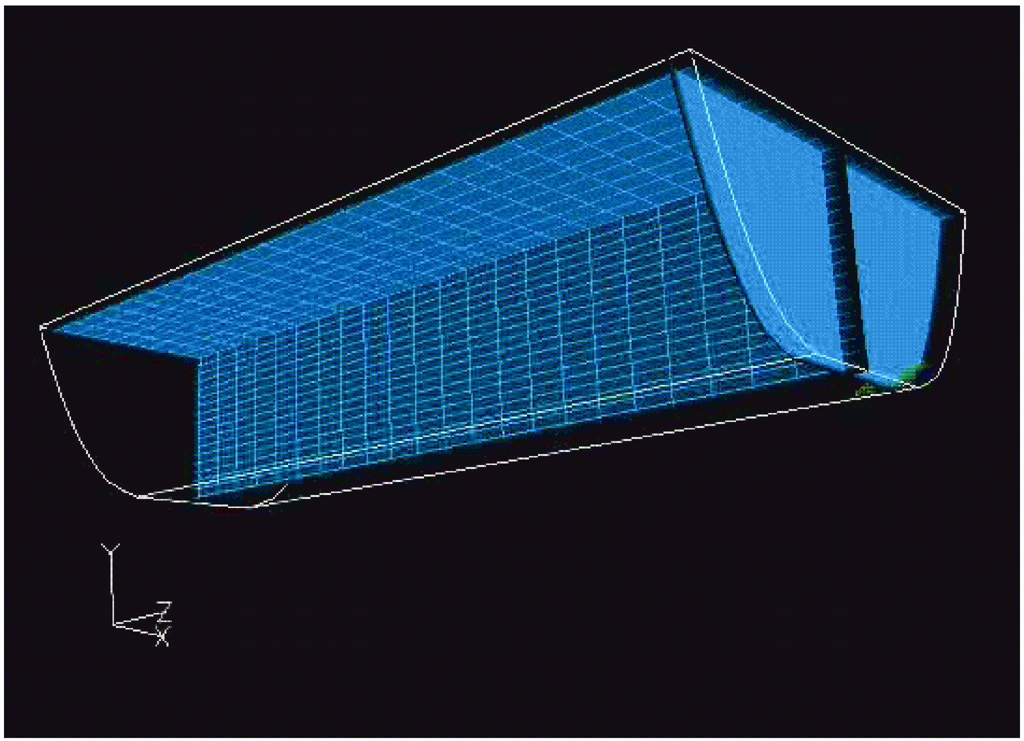
Smoke Transport Code Demonstration Calculation

Attached Flow Scenario



Soot Concentration

- 120 second simulation (~9 hours of compute time for 10K grid points; Sun Ultra^2).
- Walls are adiabatic
- No specified ventilation
- HRR, MLR are time varying as measured in FAA experiments
- Species concentrations (CO, CO_2, soot) - aids in sensor selection and placement

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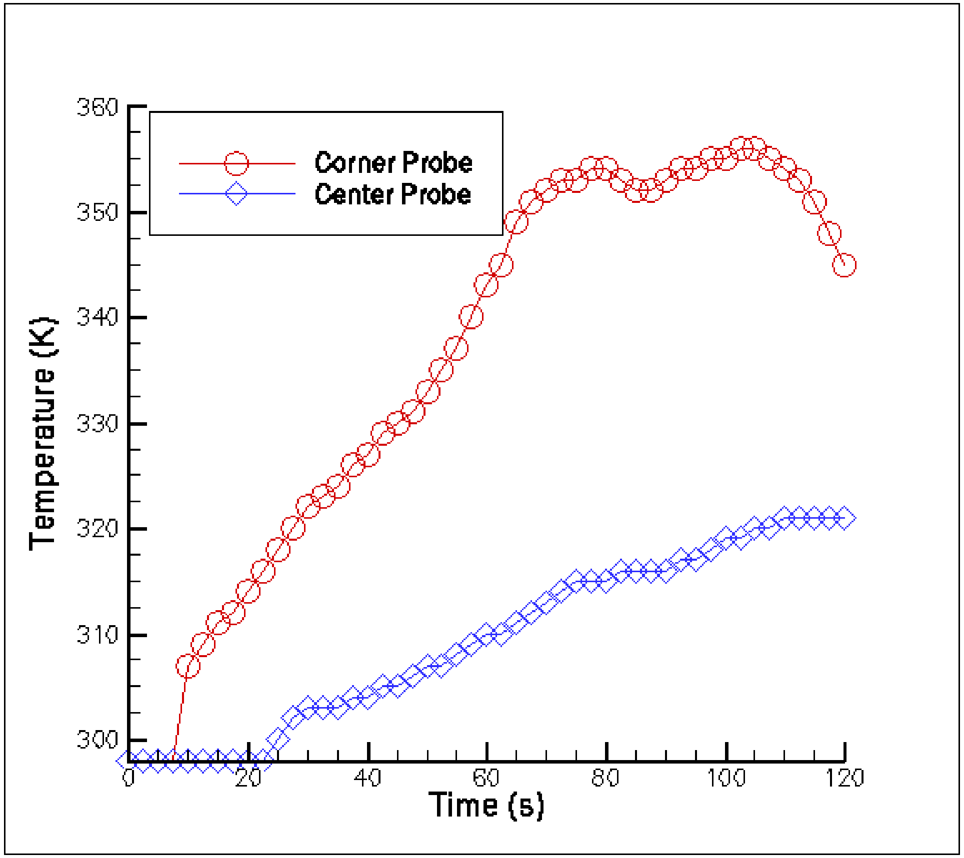
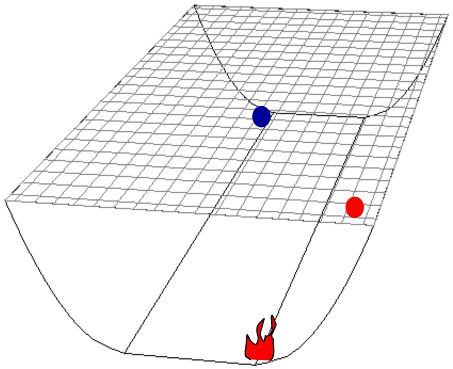
Smoke Transport Code Demonstration Calculation

Attached Flow Scenario -Temperature





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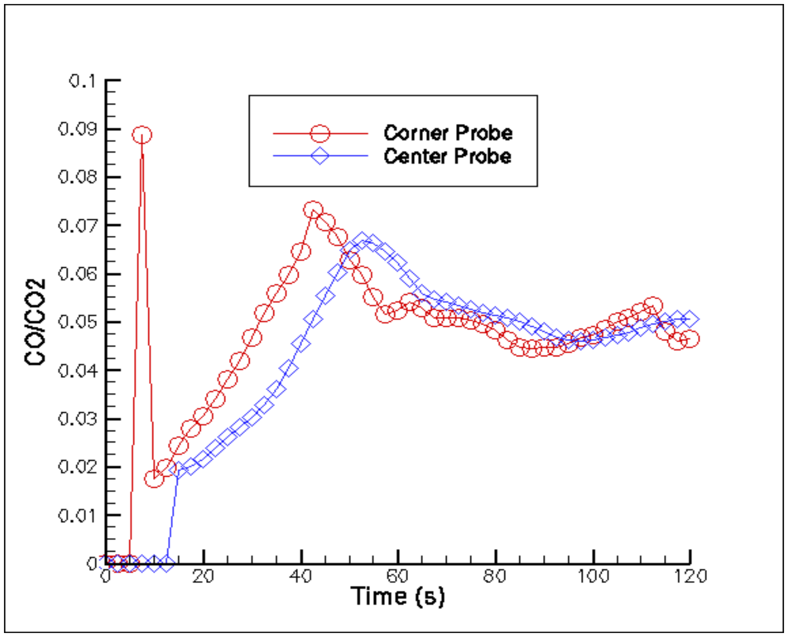
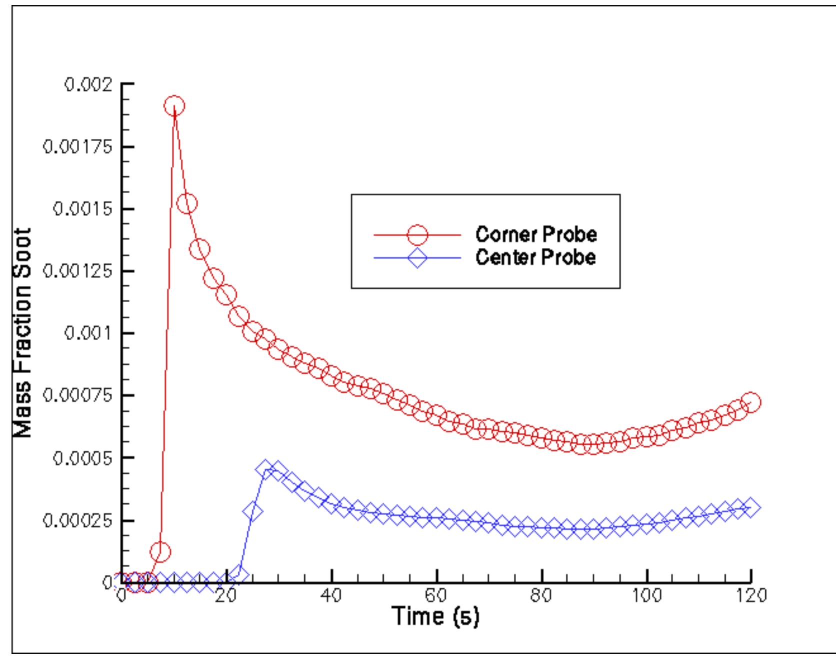
Smoke Transport Code Demonstration Calculation

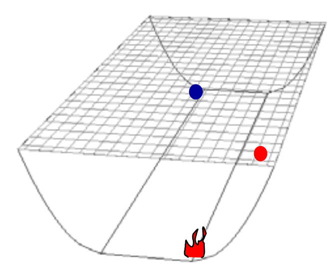
Attached Flow Scenario - Species





- CO/CO2 tracking could aid in sensor threshold selection and placement

- Soot concentration provides insight into particulate detectors



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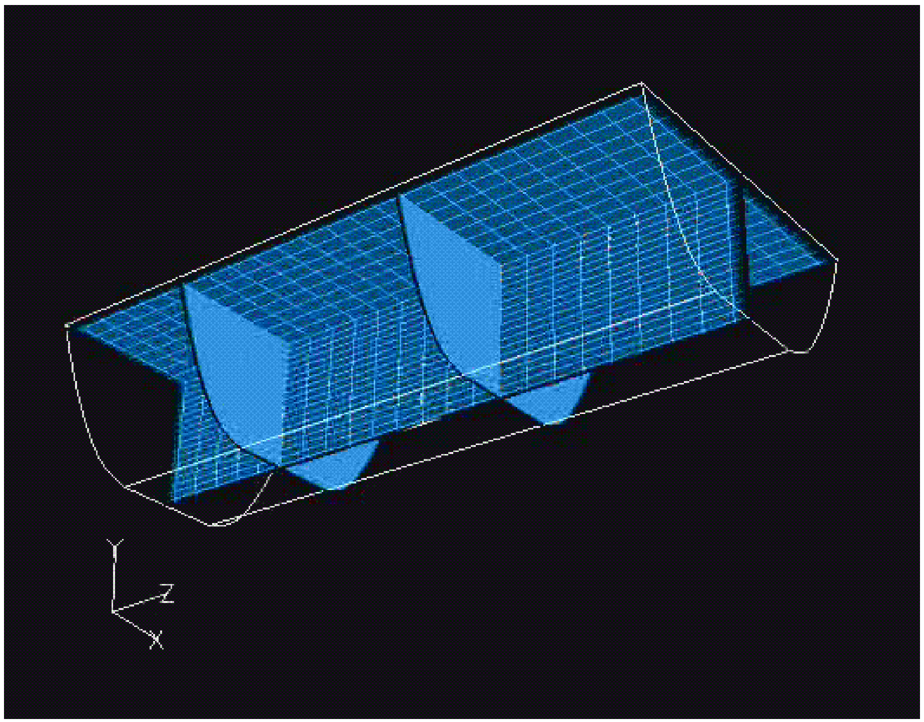
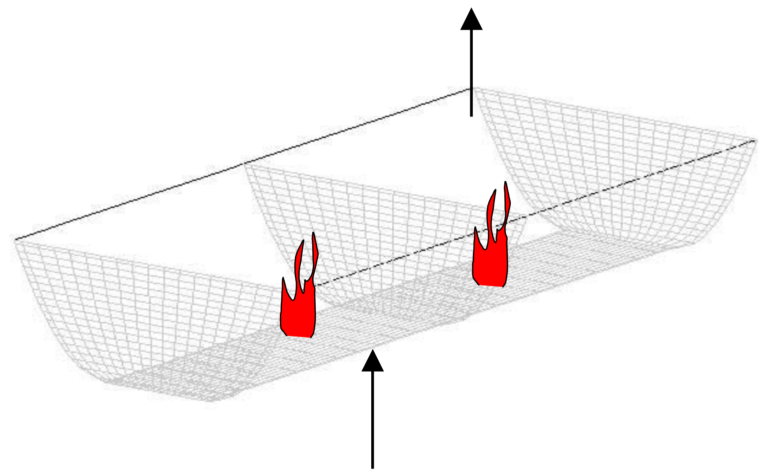
Smoke Transport Code Demonstration Calculation

Dual Source with Ventilation





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Future Activities

- Finalize plan to verify and validate the smoke transport code
- Implementation of clutter model for tightly packed compartments
- Verification and validation of the code using:
  - Method of manufactured solutions
  - Experimental data in literature
  - FAA full-scale experiments
- Release of alpha version (Oct ‘02)