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Studies of Alternative Ventilation Configurations to Mitigate Airborne Exposure Risks in Office Spaces

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I2SL Annual Conference and Technology Fair
Pittsburgh, PA

October 18, 2022 Session G1 3:30-4:00 PM

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Learning Objectives

- Reducing airborne exposure for office occupants should not only be viewed for the COVID-19 Pandemic, but also for common cold & flu season to create a safer and healthier office space year-round.

- Modification of size and location of return air grilles & changing directional flow of supply diffusers can be simple & offer a low-cost solution to reduce airborne exposure for occupants, given most general office areas have Heating, Ventilation, and Air Conditioning (HVAC) design of ducted supply & plenum return.

- Implementation of Computational Fluid Dynamics (CFD) can be used from a safety point of view for not only laboratory spaces but also common office areas & conference rooms.

- Validating the CFD model can be achieved with simple visual tools & purchase of expensive anemometers may not be required.

Agenda

- Learning Objectives
- Model
- Test
- Results
- Discussion

Model

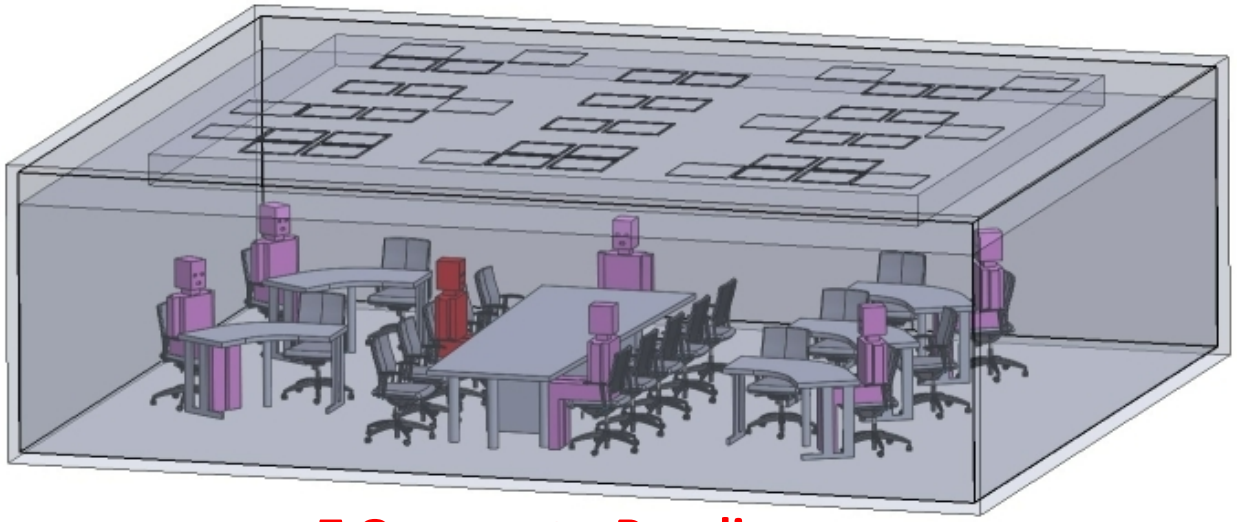
Conference Room #1

Approach

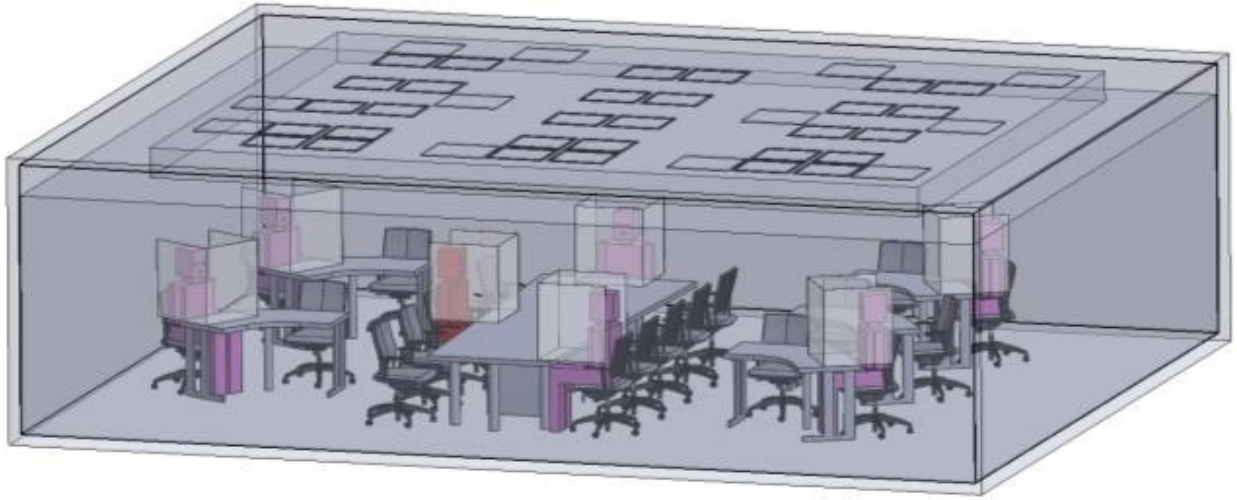
- Simulate steady state conditions using realistic boundary conditions
- Simulate expelled aerosol plume dispersion using water vapor
- Different configurations and scenarios were used to compare exposure risks
  - Social Distancing
  - Plexiglass Barriers
  - Redirect supply Airflow
  - Relocate/Centralize Return

Conference Room #1

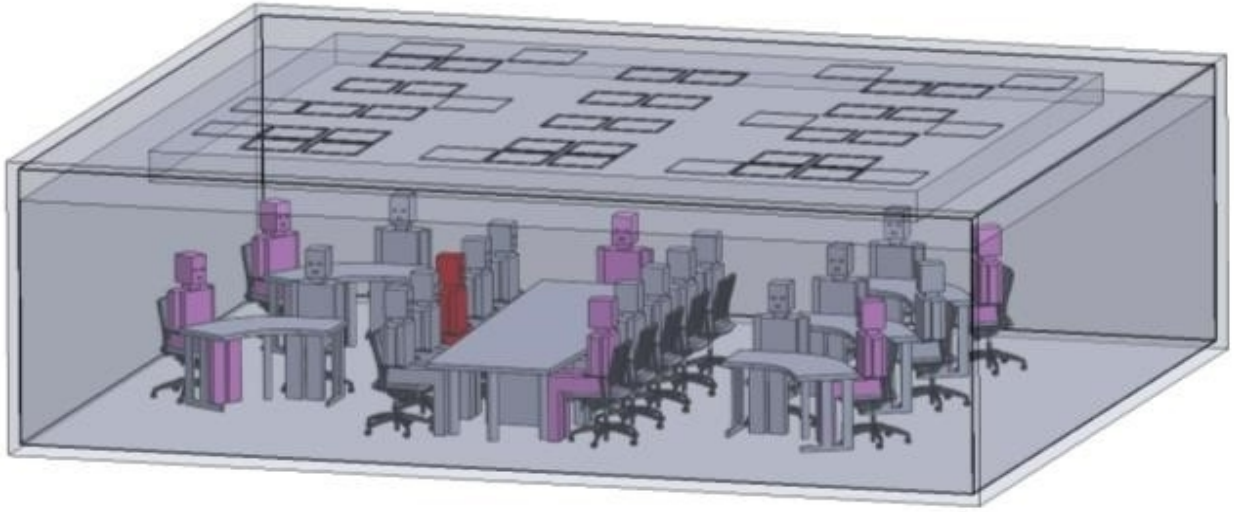
Model Configurations



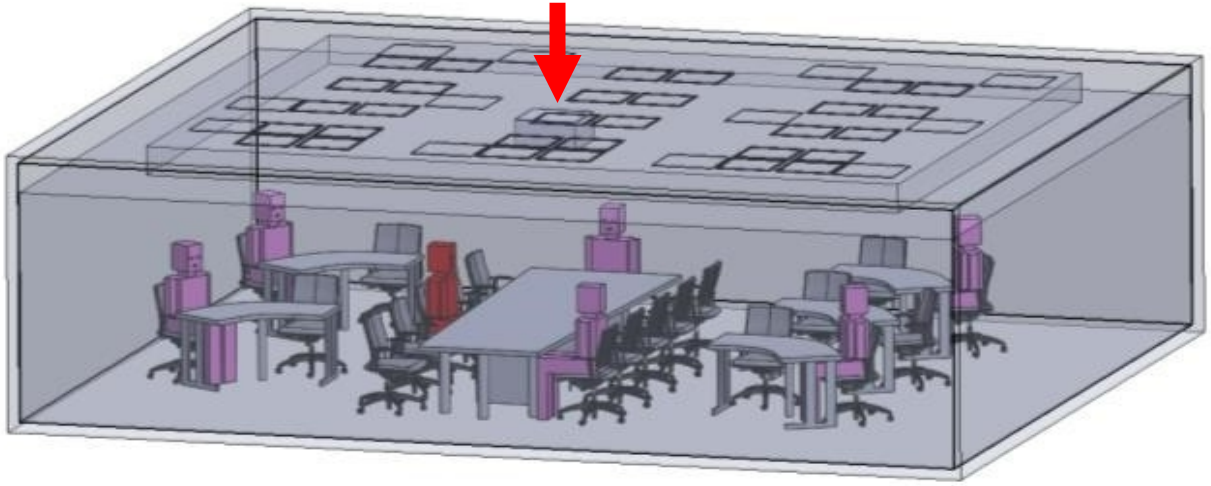
7 Occupants, Baseline



7 Occupants, Plexiglass Barriers

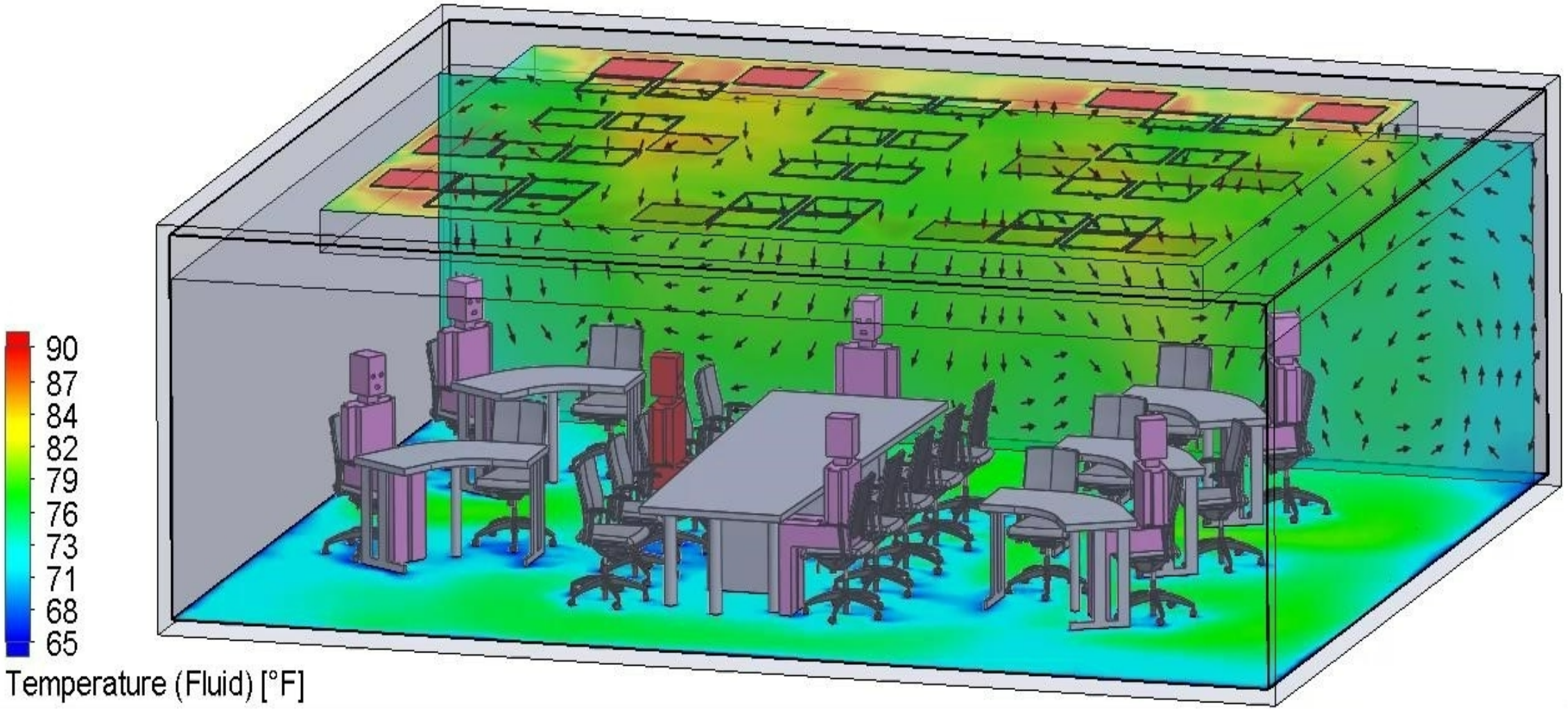


Full Occupancy



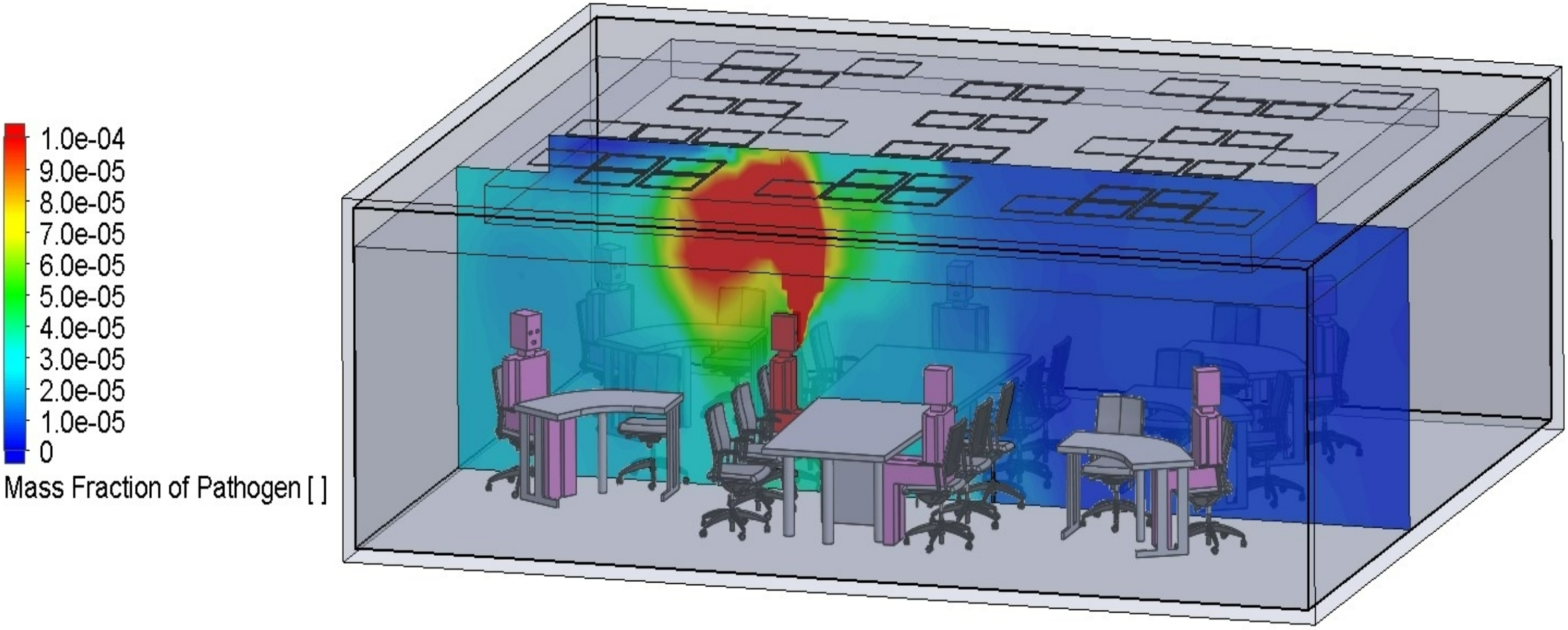
7 Occupants, Modified Central Return

7 Occupants, Baseline



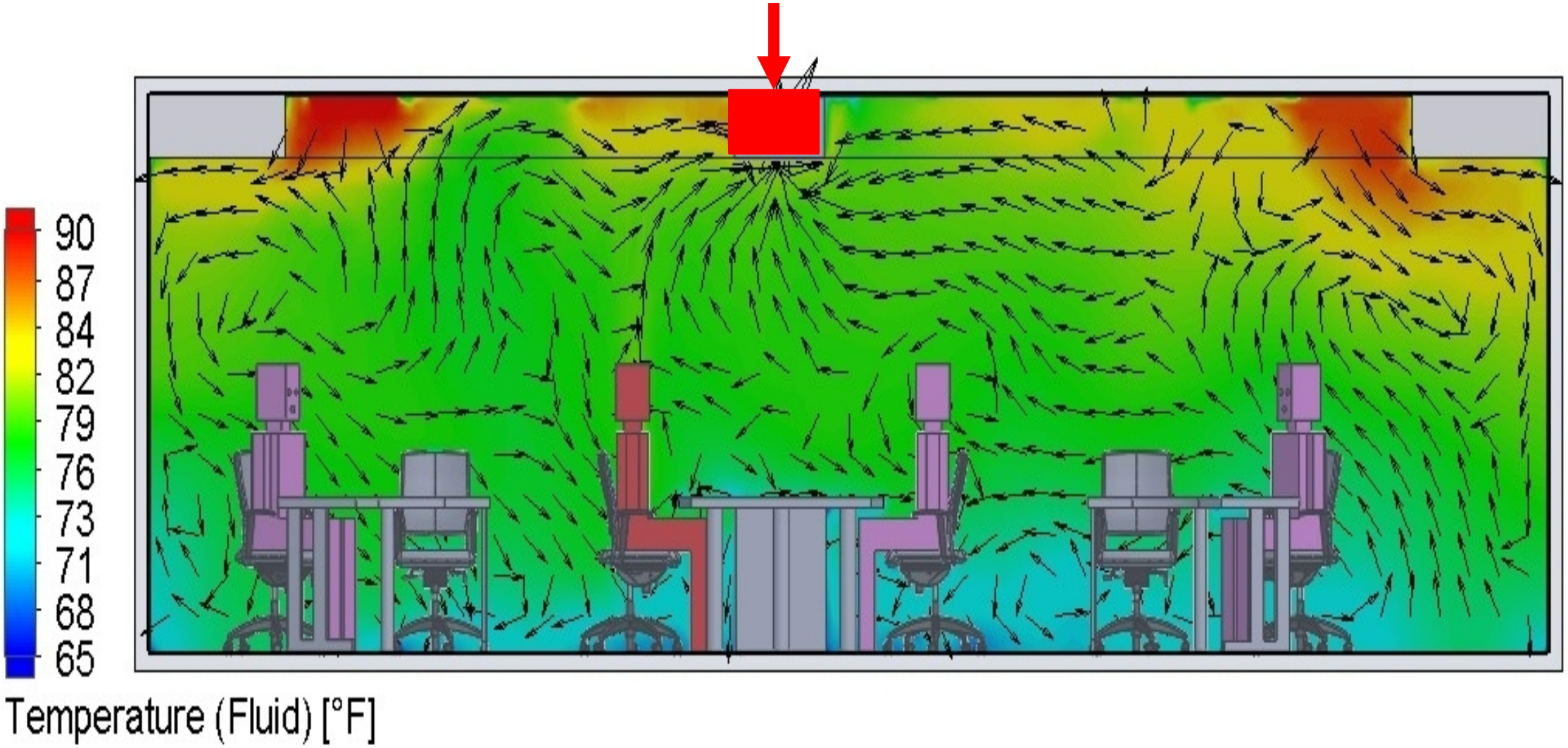
Simulated steady state temperatures and velocity in 2-D

Pathogen Simulation



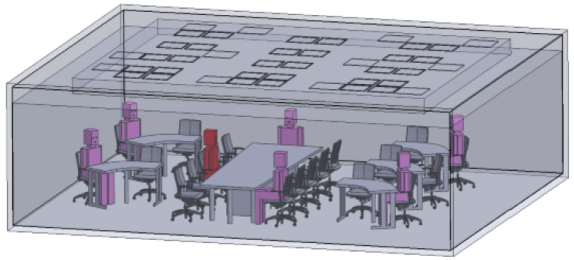
Simulated pathogen distribution after several minutes with original ventilation configuration during steady-state airflow and temperature

Modified Central Return

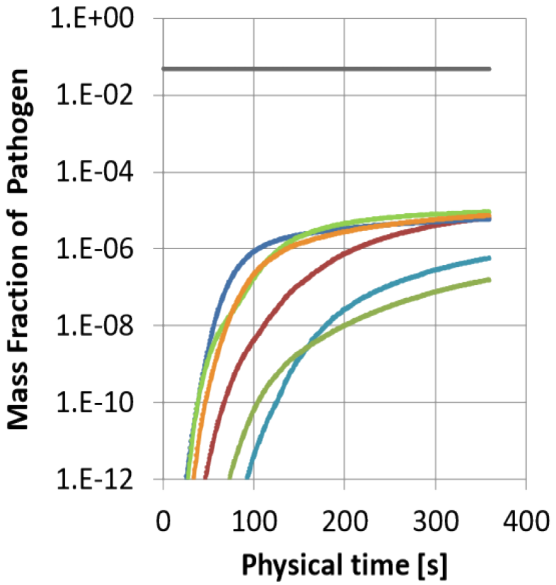


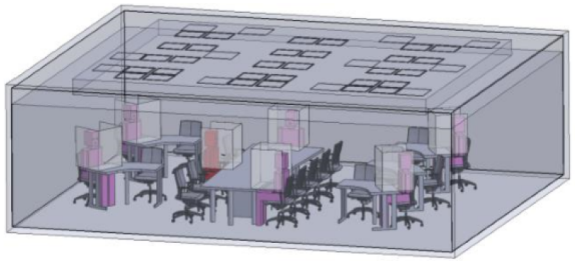
Simulated steady state temperatures and velocity in 2-D

Results

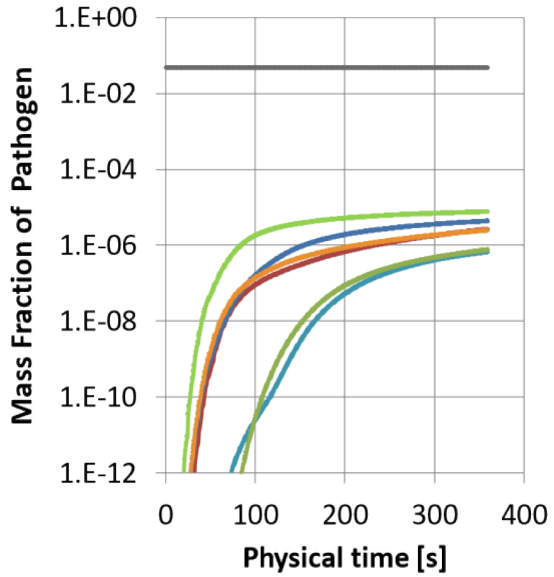


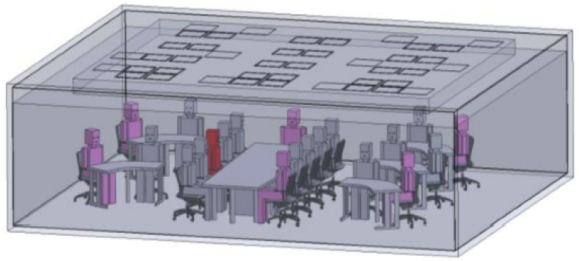
7 Occupants



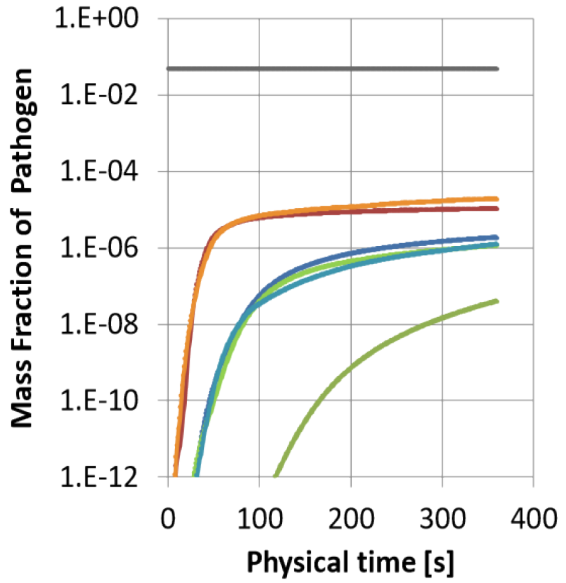


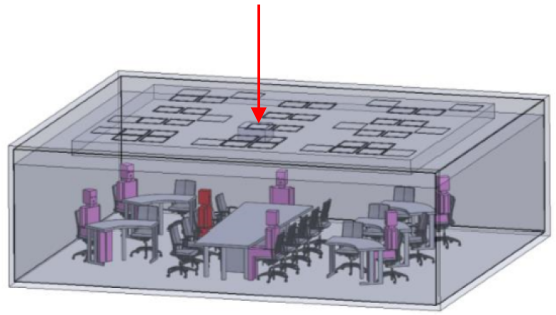
Plexiglass



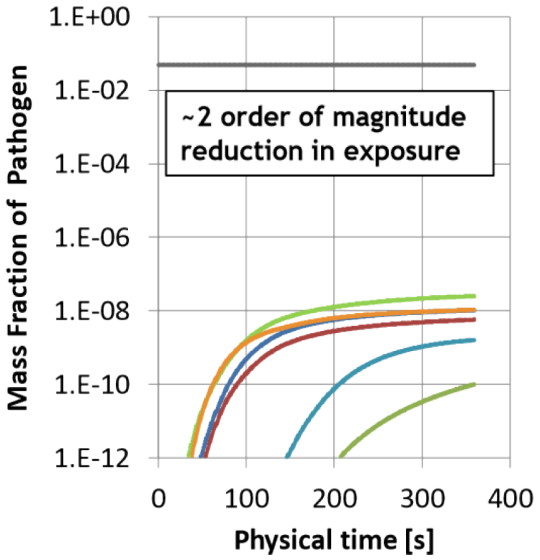


Full Occupancy





Modified Return



Test

Conference Room #2

Approach

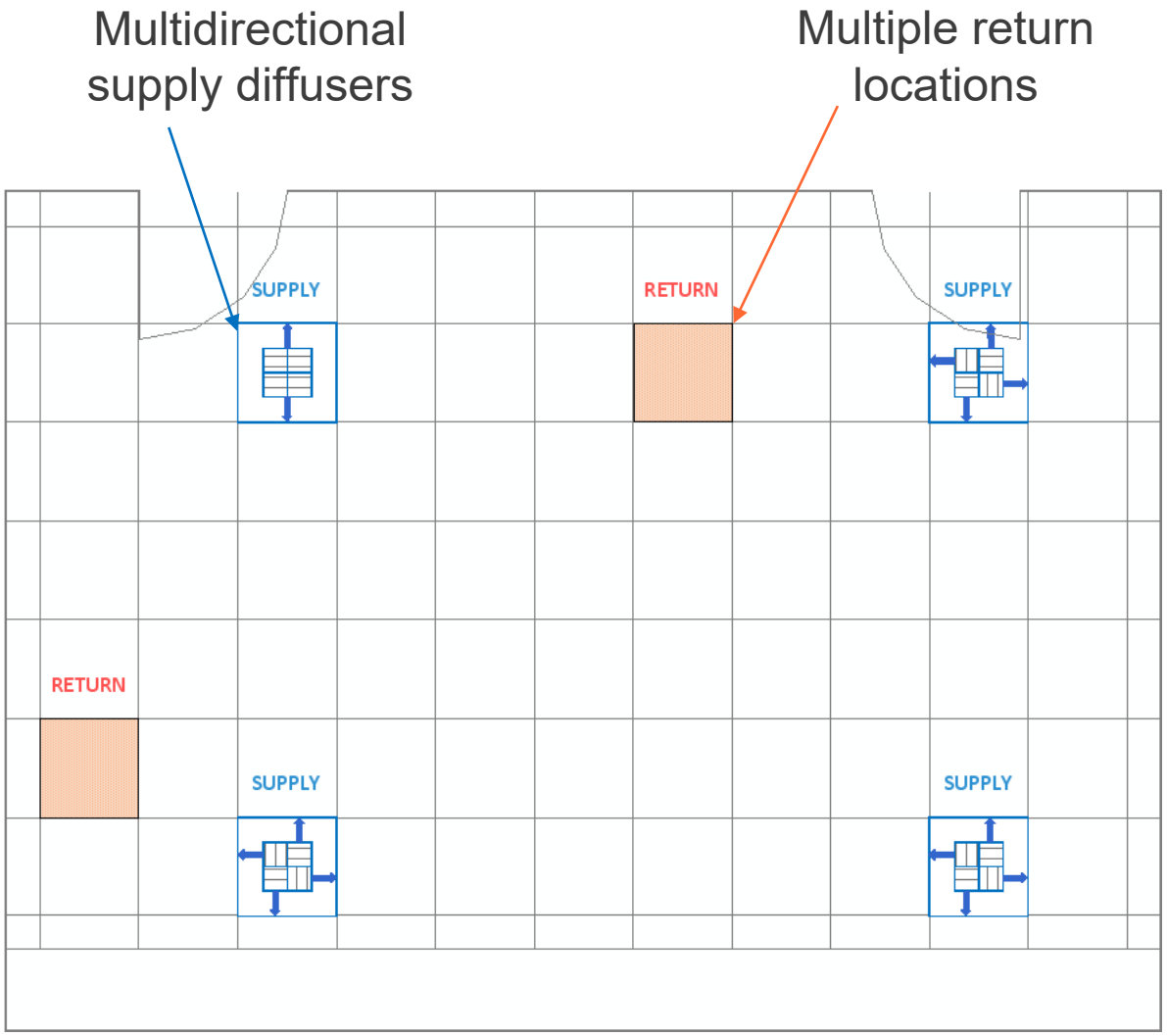
- Analyze conference room HVAC configuration
- Determine test methods
- Select instrumentation and tools
- Generate test plan
- Prepare for test day

Conference Room #2

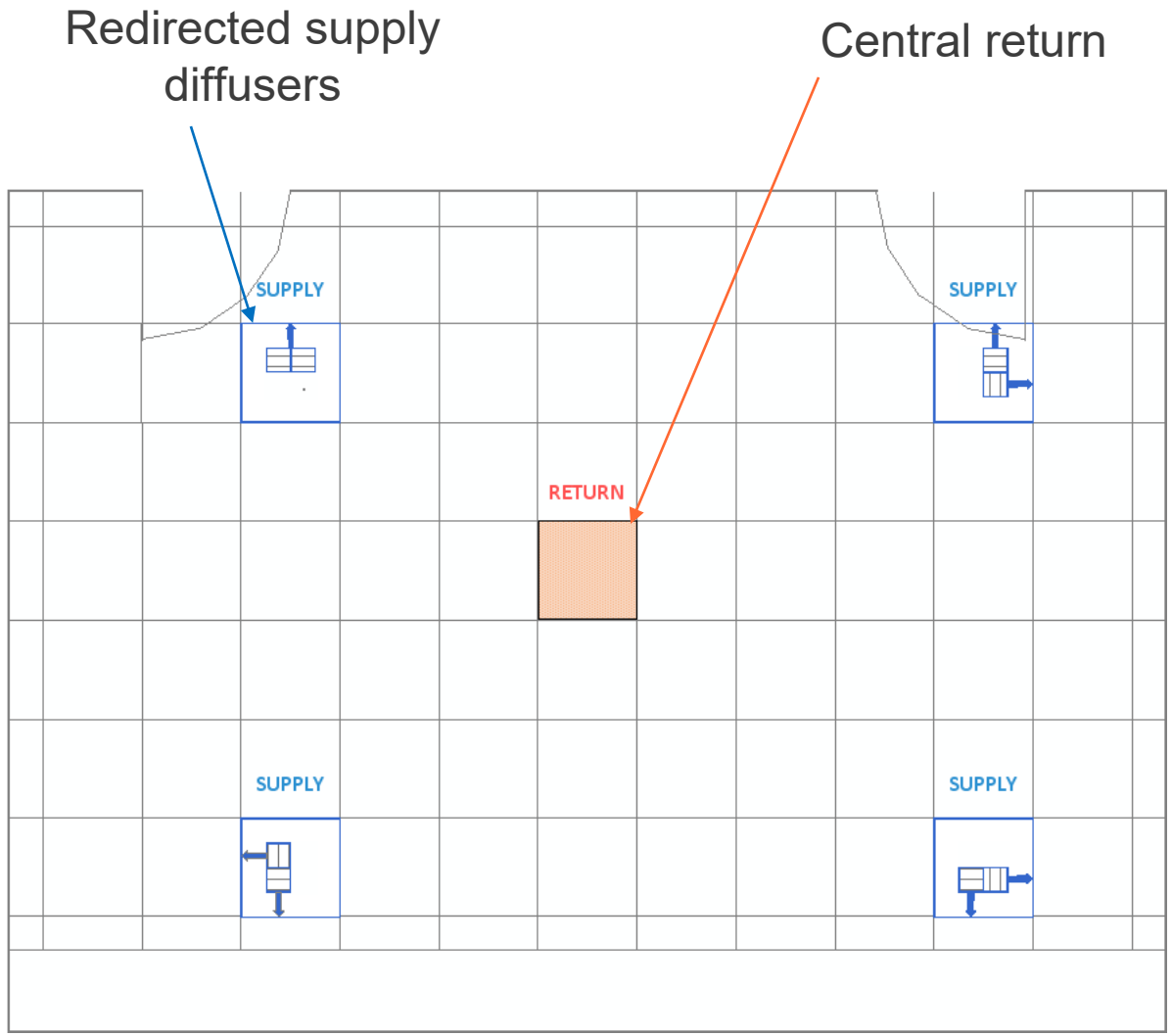
Diffuser Modifications

Test Setup

Test Configurations



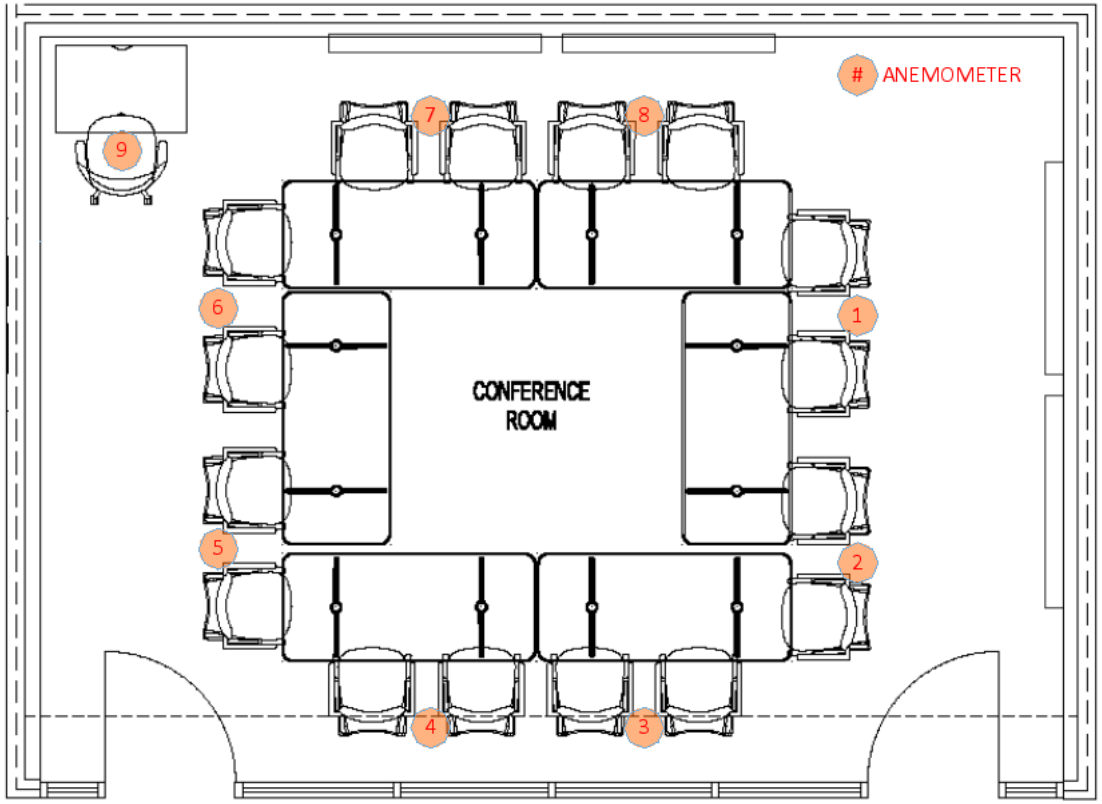
Original Configuration



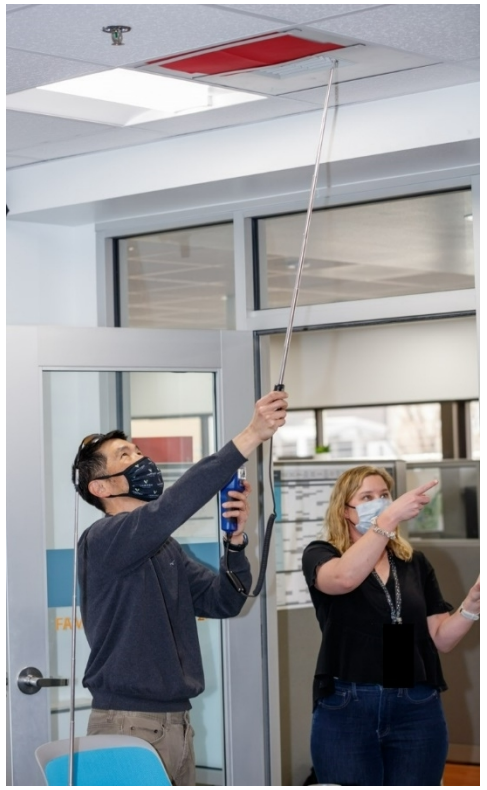
Modified Configuration

Anemometer Testing

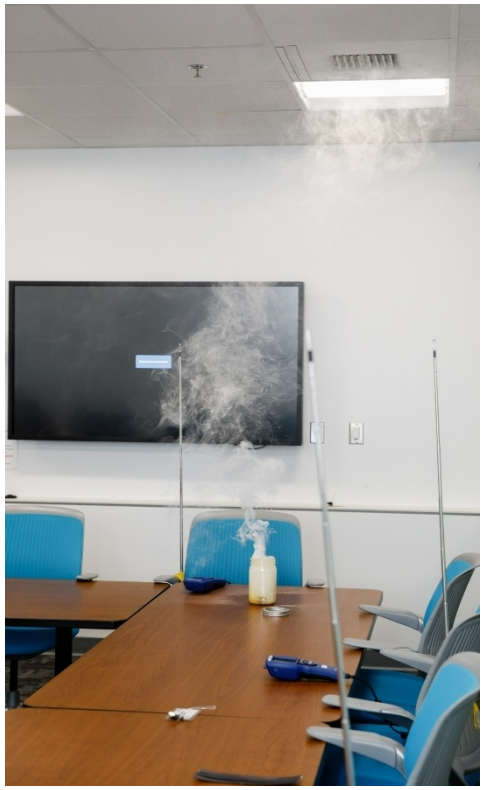
- Anemometers placed to gather velocity data for comparison with model (9 Locations)
- Documented airflow readings at each diffuser
- Crucial tool for model validation



Anemometer Placement



Airflow Measurements



Anemometers in Action

“Calibrated” Tissue Test

- Easy visual aid
- Verification of air movement
- Direction of airflow “Flag in the Wind”

Tissue Test, Redirected Supply

Tissue Test, Modified Return

Smoke Emitter Test

- Smoke Emitters
  - 90 second
  - 4 minute
- Visualize direction of airflow throughout the room

Smoke Emitter in Action

Smoke Emitter Placement

Fog Purge Test

- Puffs of smoke
  - Observed airflow currents
  - Obvious draw to the return air vents
  - Visualized room conditions
- Fog out conditions
  - Filled room with smoke
  - Fog dissipation over 12 minutes
  - Noticeable changes between configurations
  - Observations were complete with 6+ people
- Best visualization tool

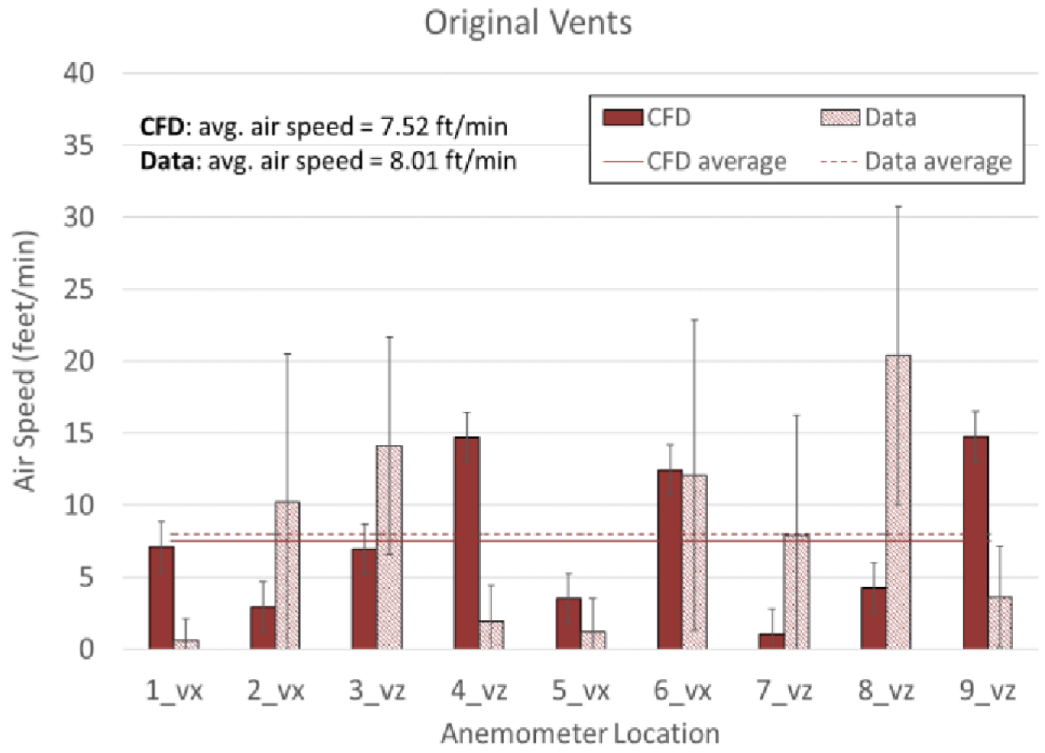
Fog Machine in Action

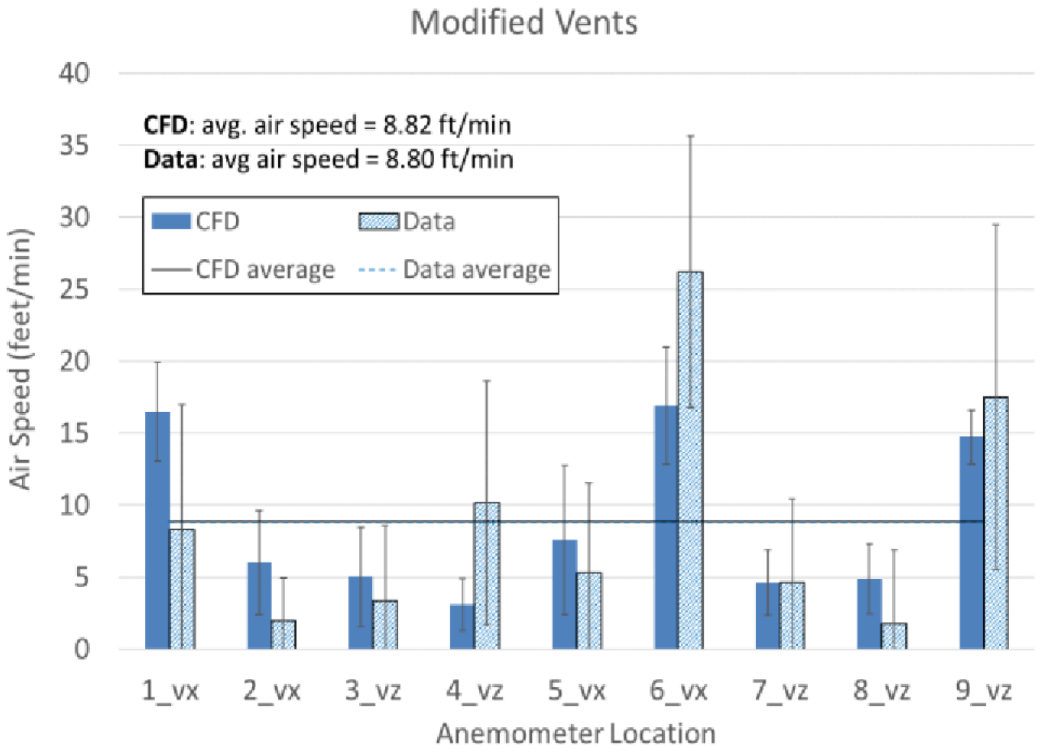
Results

Empirical vs. Model Data

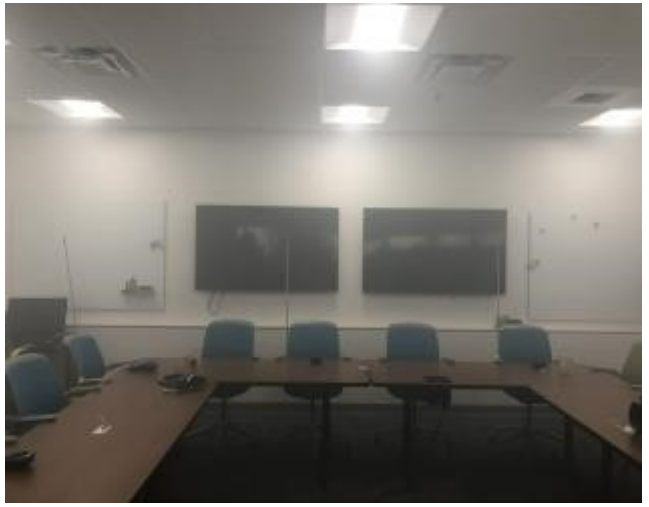
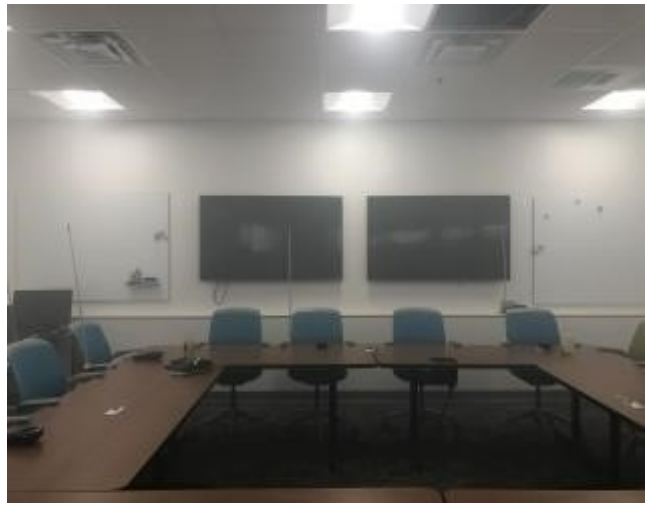
Model Validation

- Empirical data were placed in CFD Model
  - Airflow and velocities at supply and return
- Simulated measurements at locations similar to anemometer test (9 Locations)
  - Velocities were within 6% of actual original and 0.2% for modified
- Compared air speeds provided confidence in model and simulation methods





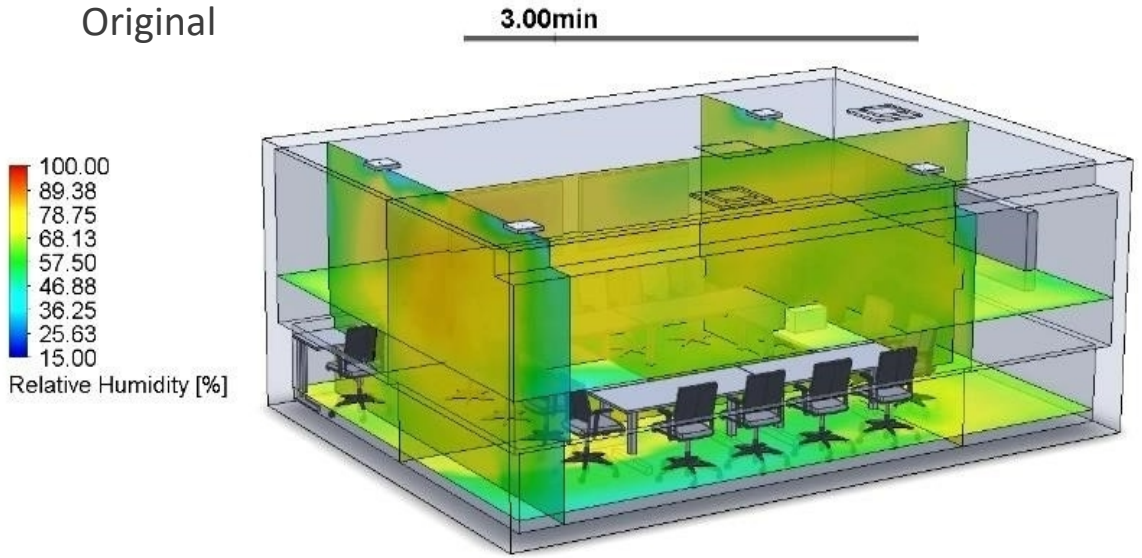
Fog Purge Timelapse

	0 min	4 – 5 min	11 – 12 min
Original Configuration			
Modified Configuration			

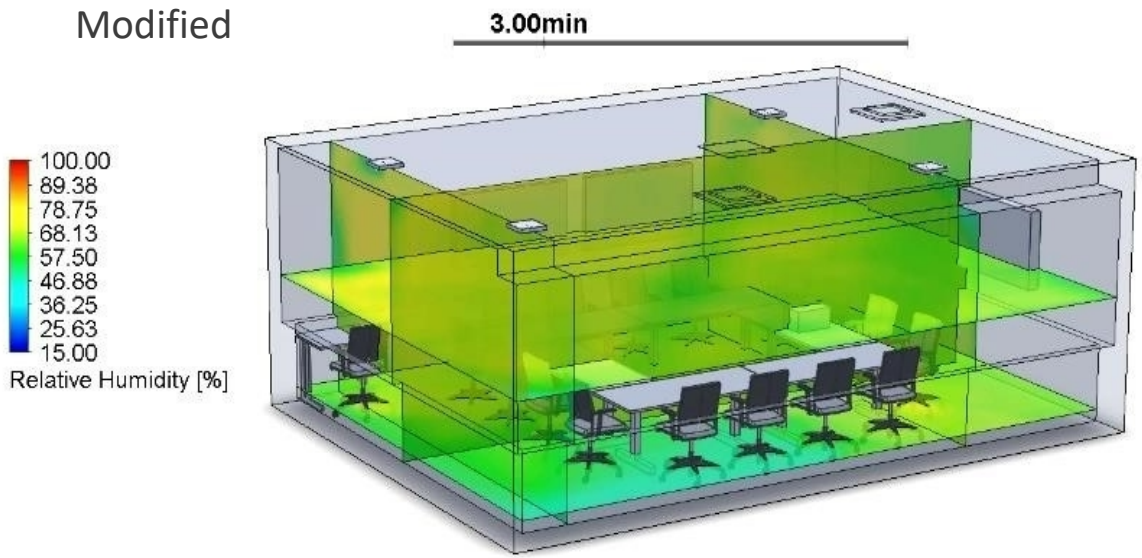
Time lapse photos during fog purge testing using smoke machine

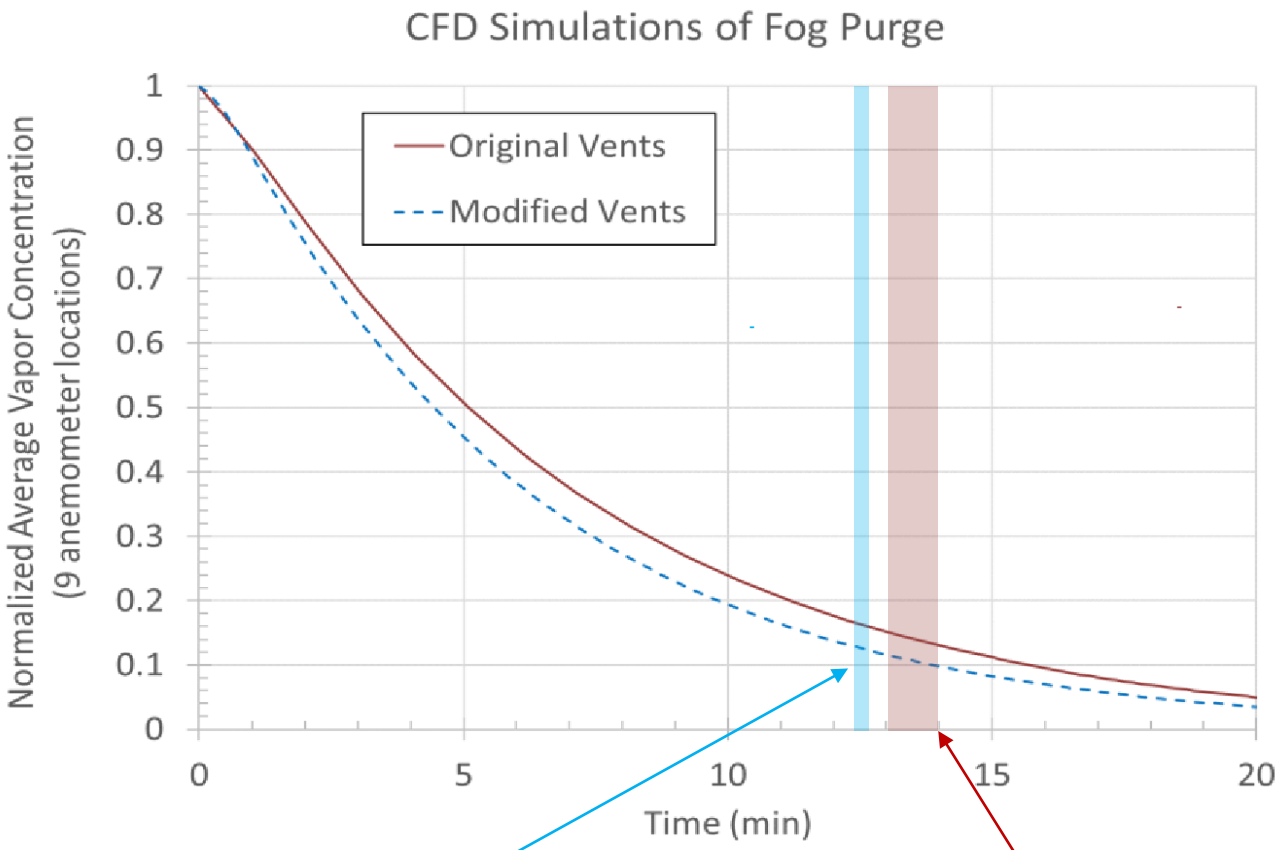
Fog Purge Simulation

Original



Modified





Reported time to "clear out" fog-filled room with modified vents ~12.5 minutes

Reported time to "clear out" fog-filled room with original vents ~13-14 minutes

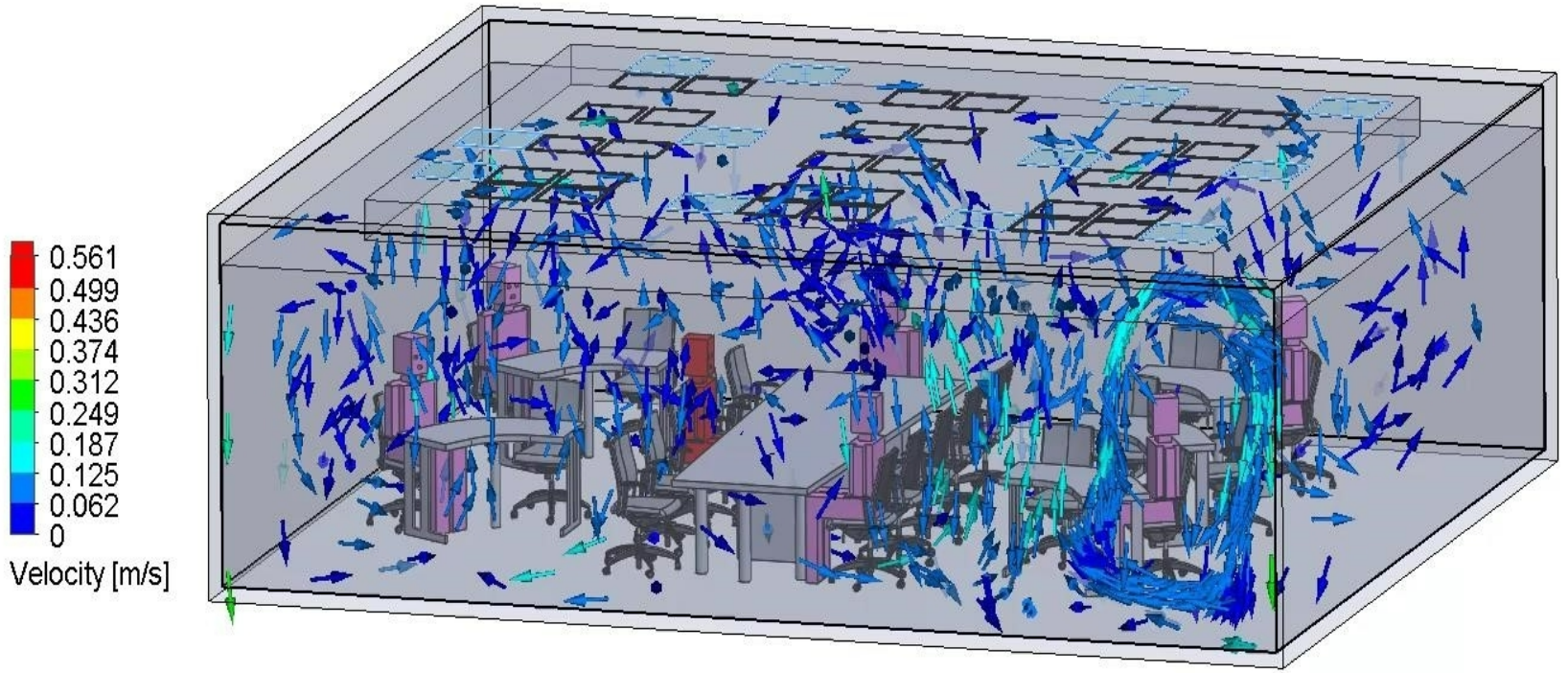
Fog purge simulation uses water vapor as the fog medium

Discussion

Observations and Lessons Learned

Observations

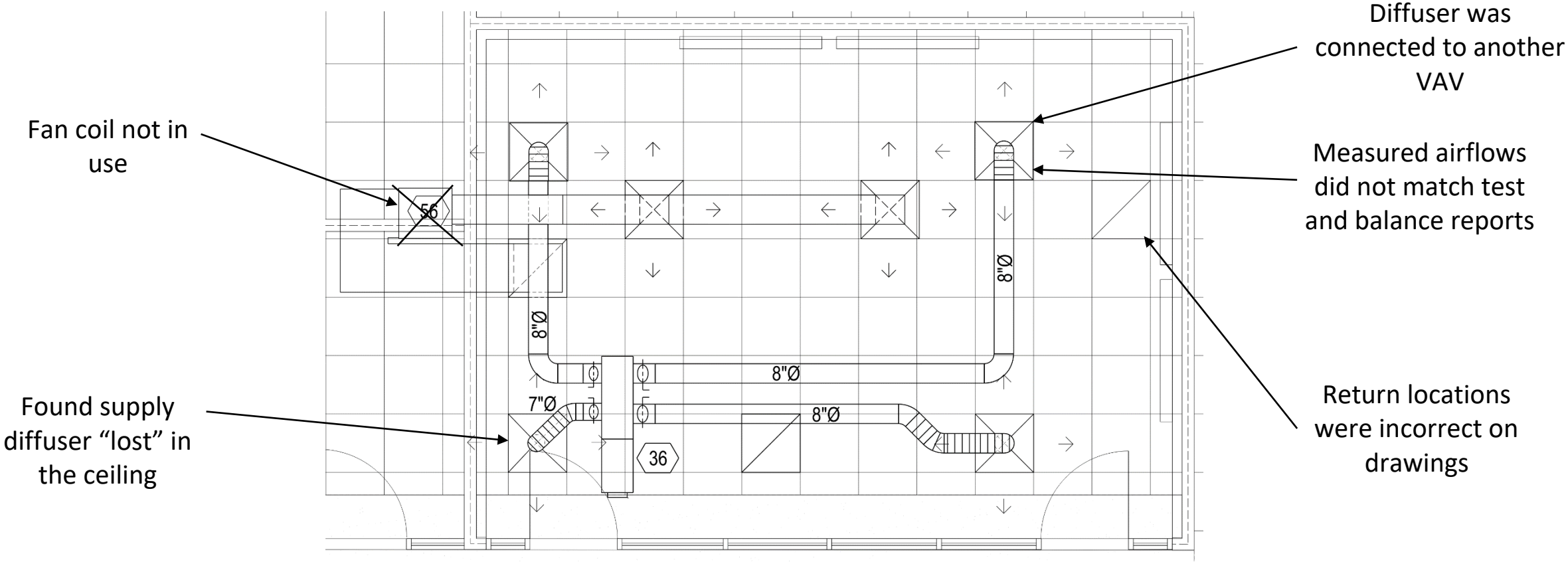
- Small modifications improve ventilation effectiveness
  - Can be applied to future space designs
  - Sweeping airflow may improve air exchange
  - Effective to minimize risks of transmission
- CFD Simulation
  - Characterized the general airflow patterns and exposure risks
  - Compare against tests from measured air velocities and air-change effectiveness



Simulated steady-state flow field in room Conference Room #1

Lessons Learned

- Do not assume drawings match in-field installation
- Place cameras/people strategically for testing
  - Beneficial to discern airflow in the space
- Validate supply & return airflow rates
  - Field airflow measurements were contrary to building design criteria
  - Test & balance is an important validation tool



Conference Room #2 HVAC Configuration

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By: Casiano Armenta, Roberto Armijo, John Garcia, Clifford Ho, Nicole Naber

Technical Report: https://www.osti.gov/biblio/1827490

Questions?

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Nicole Naber: nnaber@sandia.gov