# Modeling TCCs in a Cargo Compartment

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By: Andrew Ferraro

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Federal Aviation Administration

# Introduction

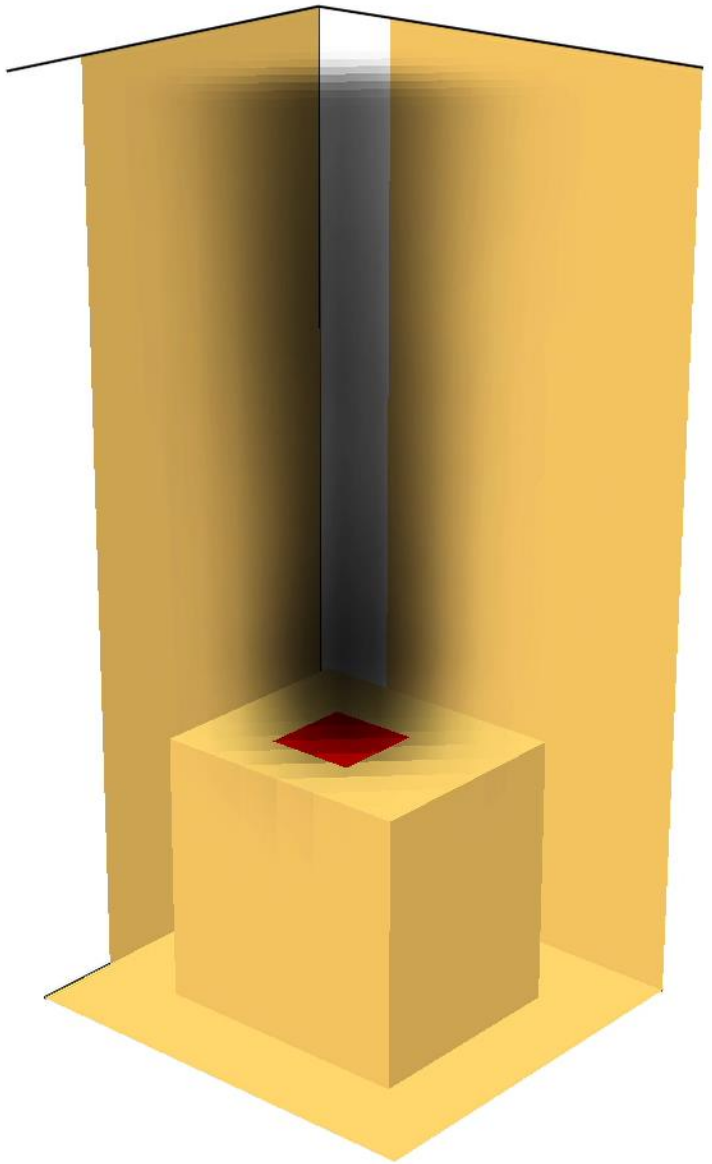
- Smoke detection in aircraft is a critical safety feature
- Any changes should be understood and accounted for
- “Active” or temperature-controlled cargo containers (TCC) are any containers with integrated fans, usually for internal refrigeration cycles

# Previous Work

- Effects of Cargo Loading and Active Containers on Aircraft Cargo Compartment Smoke Detection by David Blake (2009)
  - Boeing 727 aft compartment
  - Forced air smoke detectors
  - Different active container fan locations
  - Tests with mixed containers
  - Concluded “active containers did not have a consistent influence”
  - DOT/FAA/AR-09-52

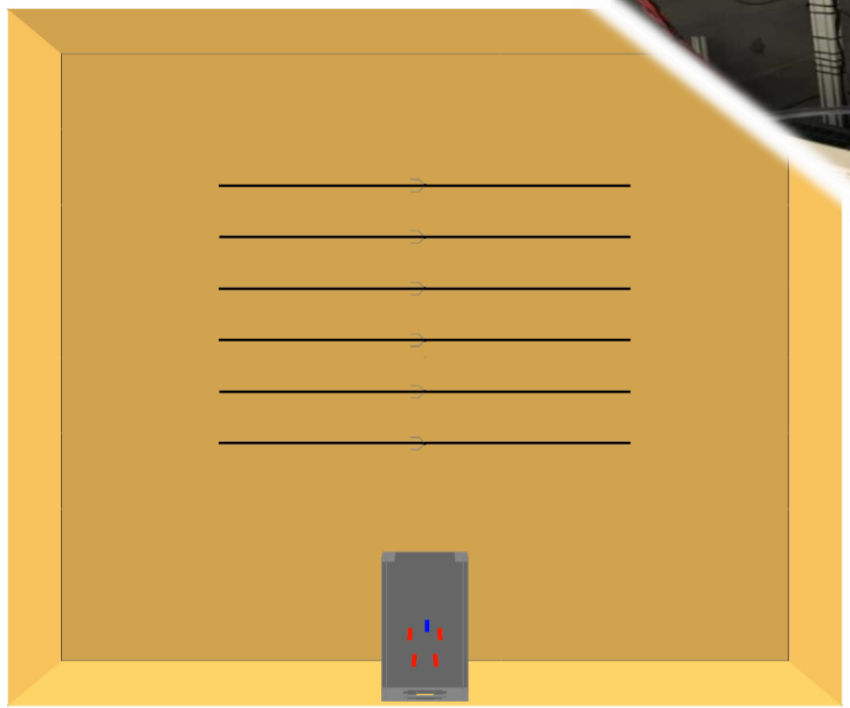
# Fire Dynamics Simulator

- FDS is a CFD model of fire driven fluid flow
- Numerical Navier-Stokes and Large Eddy Simulation
- Here is an example sim called “Fire Tornado”



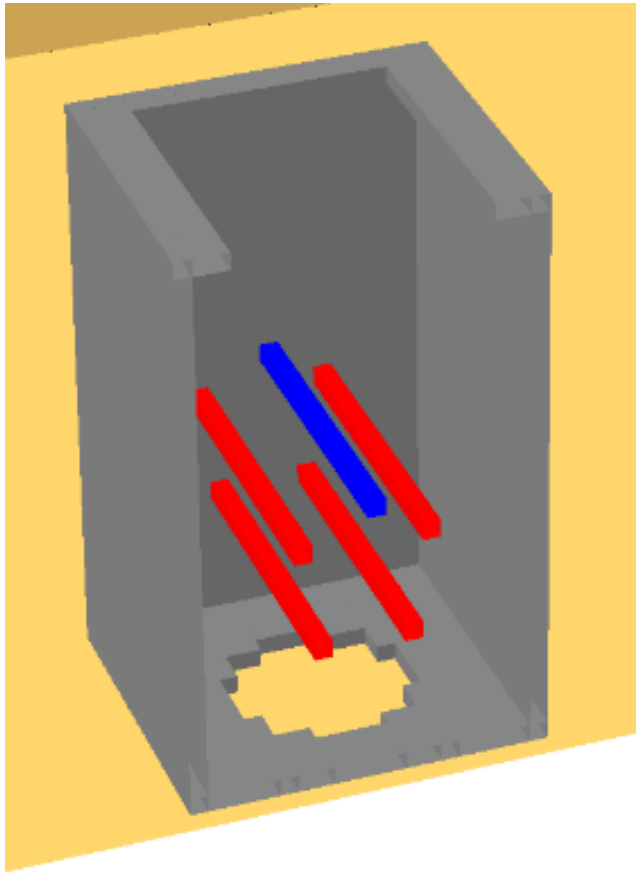
# Altitude Chamber in FDS

- Known baseline for FDS in sealed test cell
- Oil vapor smoke generator
- Six laser obscuration meters
- Multiple tests to match previous results
- Tune variables in the simulation



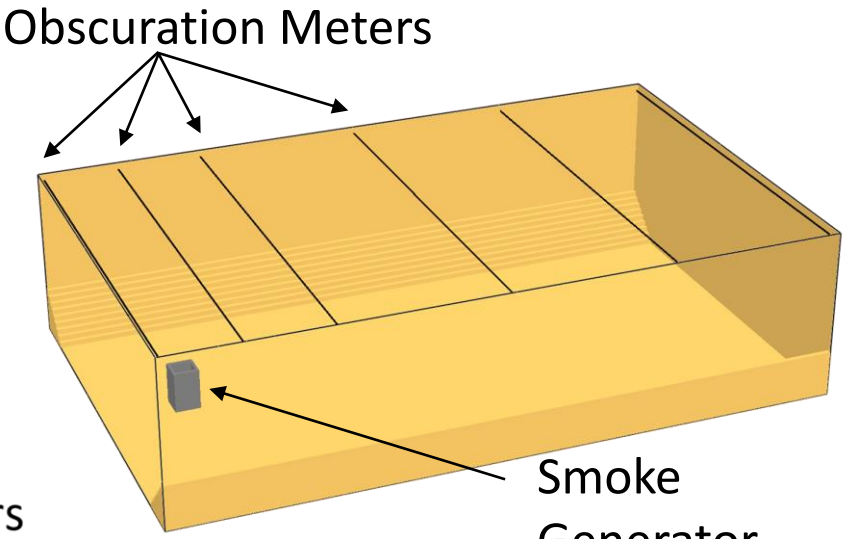
# Smoke Generator in FDS

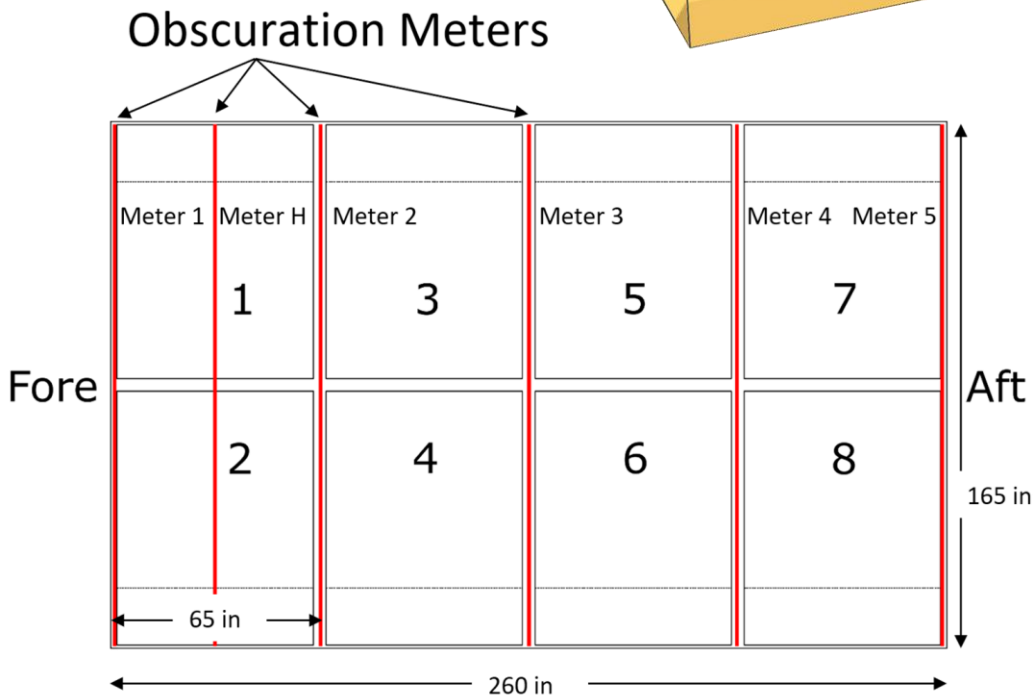
- Oil vapor smoke generator
- Smoke generator chimney creates convection current
- Heater bars in red – 640W of power total
- Smoke emitter in blue
- Gap between floor to allow airflow upwards



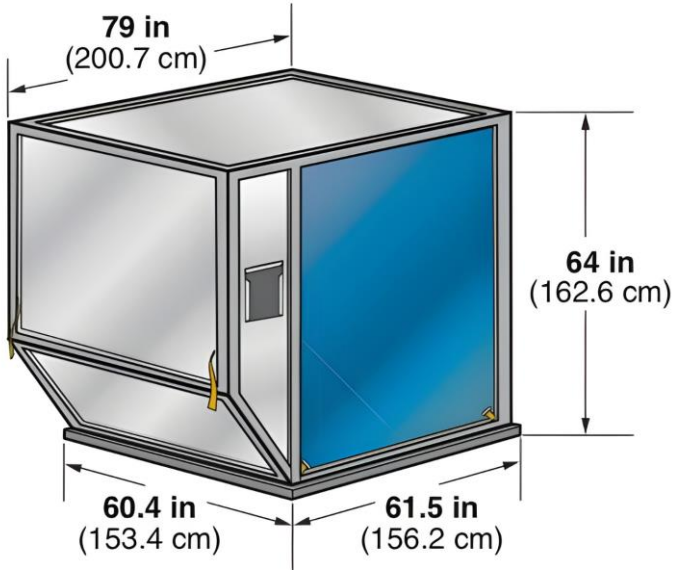
# DC-10 FDS Model

- Modified DC-10 in the Full-Scale Fire Test Facility
- Modeled after 22ft long cargo section
- Fits eight LD3 containers



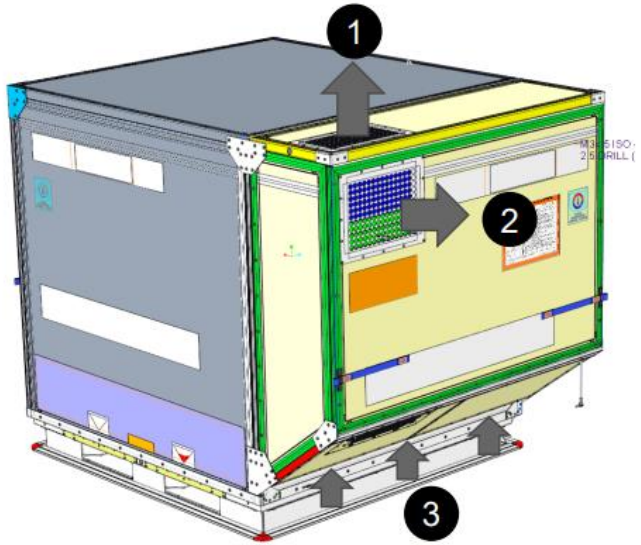



# Containers



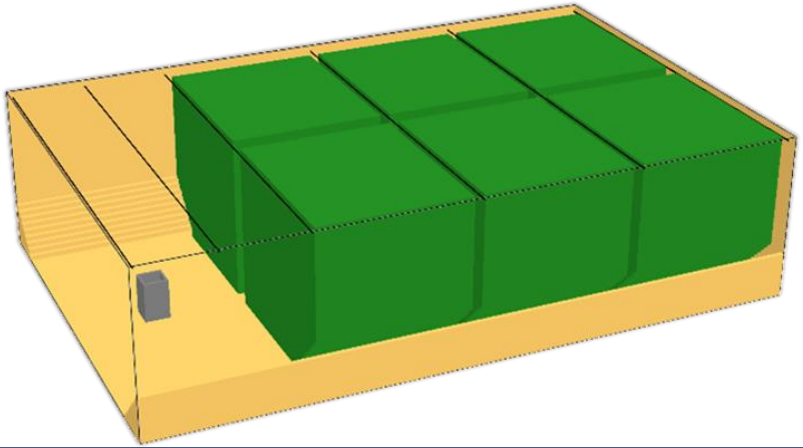

## LD3

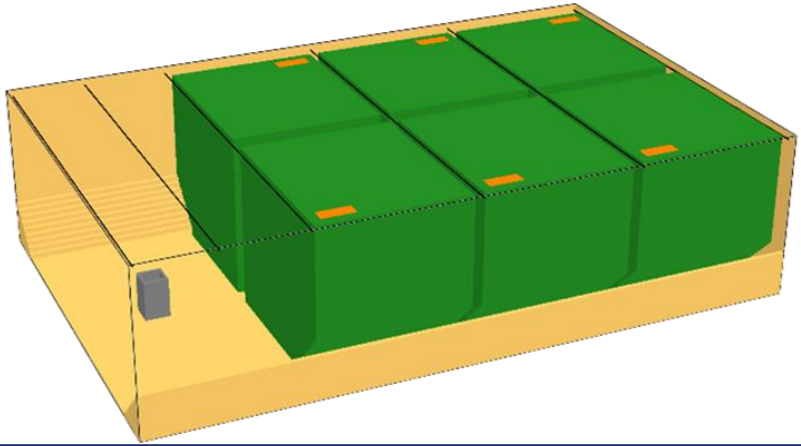
- Canvas door
- Sealed from smoke



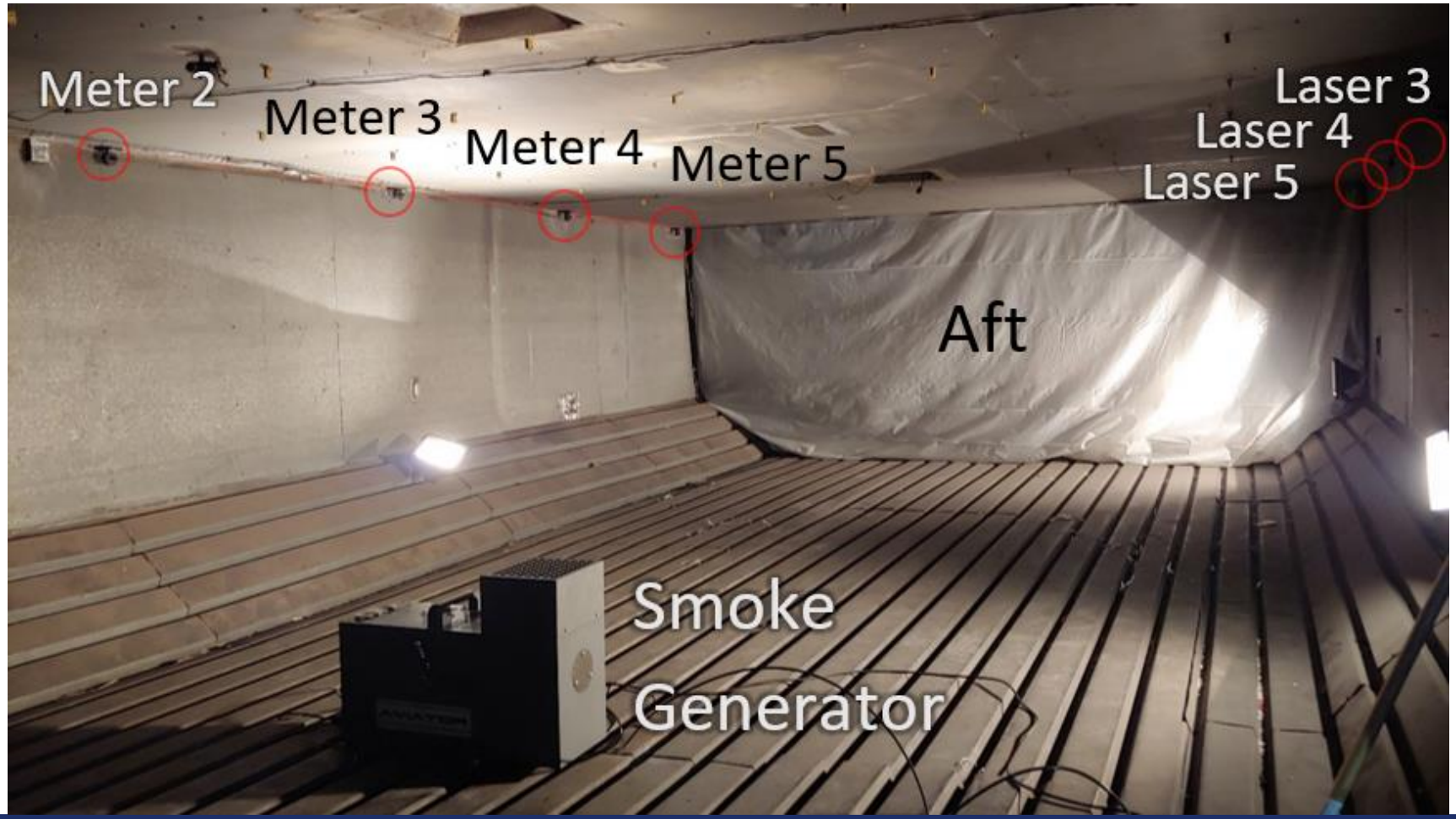

## TCC

- Sheet metal with vents
- Same size as LD3s





# DC-10 Test Setup



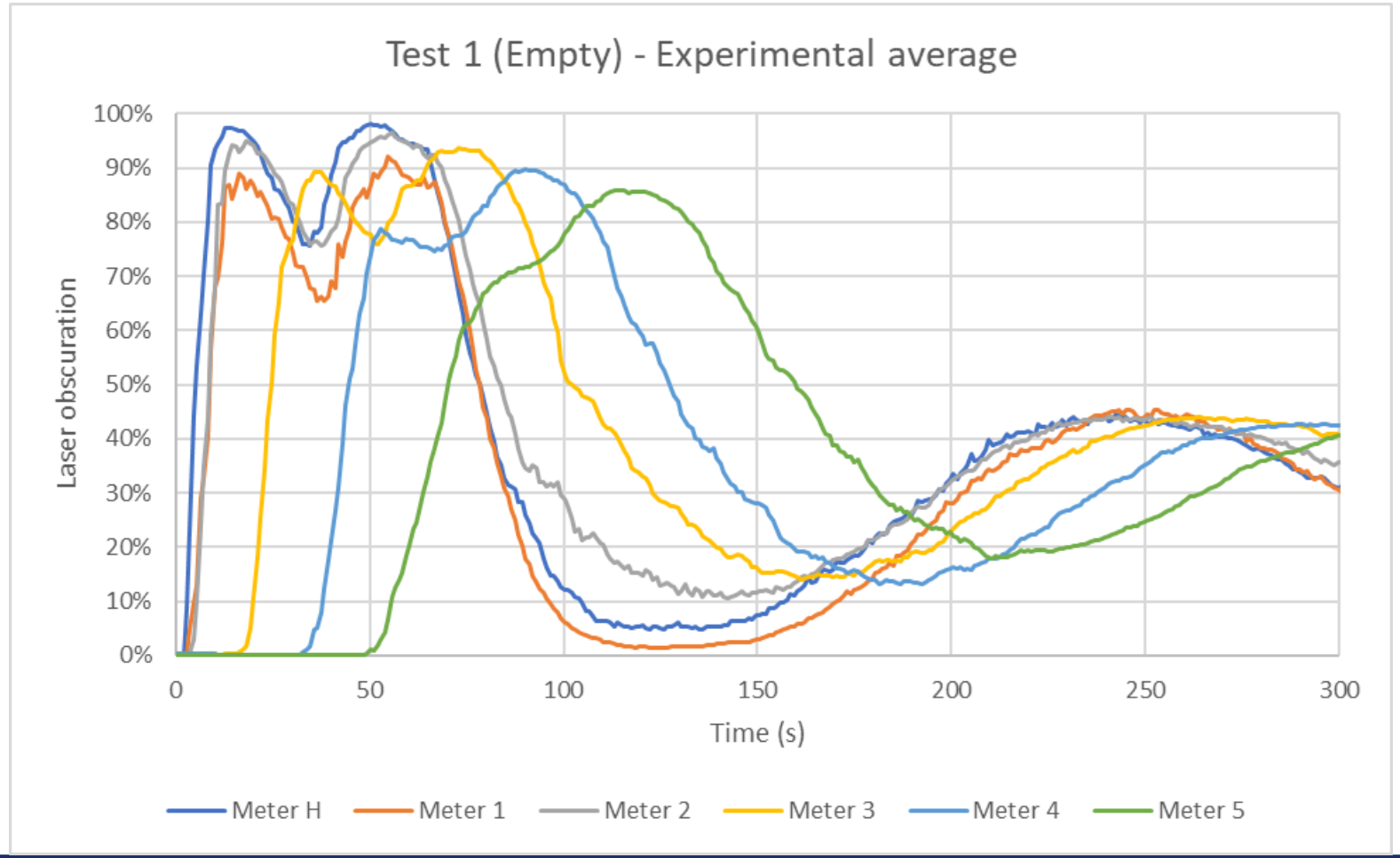
# DC-10 Testing

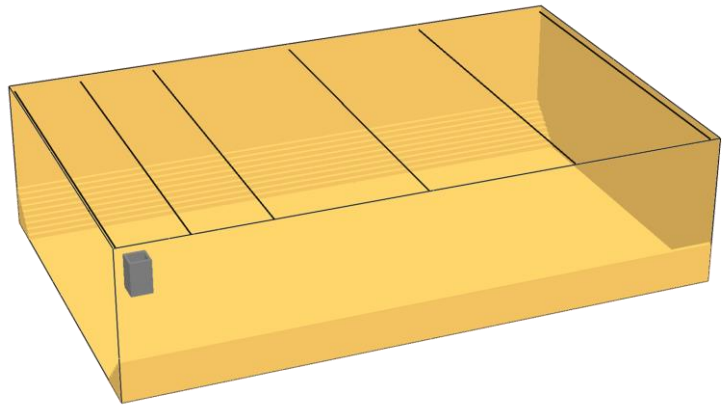
# Mock Temperature-Controlled Container

# Smoke Detection Criterion

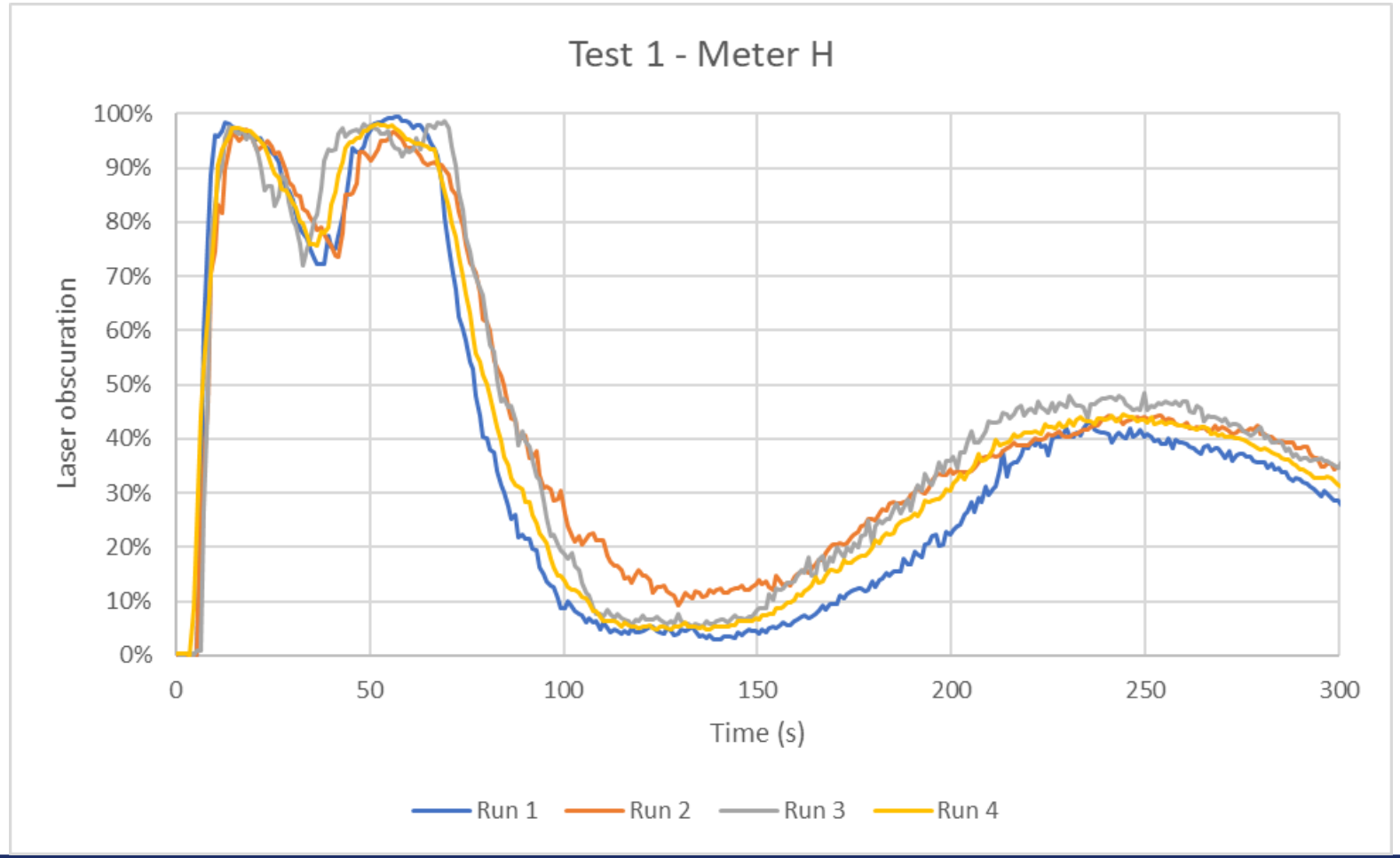
- Meggitt model 604
  - Light transmission 94-96%
- Equivalent light obscuration across test cell is 42-57%
- Smoke detection at 10% light obscuration chosen

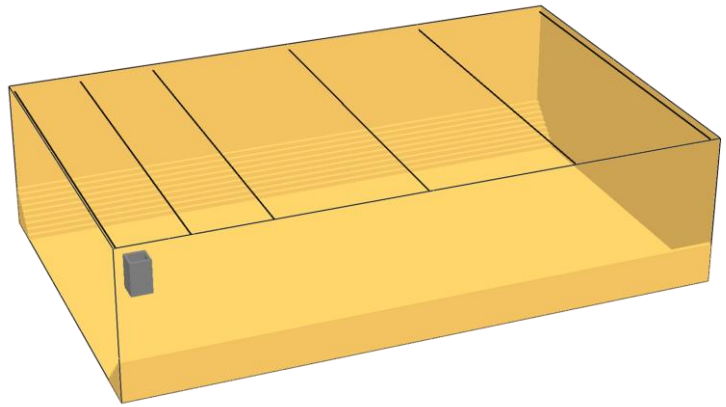
# Experimental Results – Test 1



# Experimental Results – Test 1

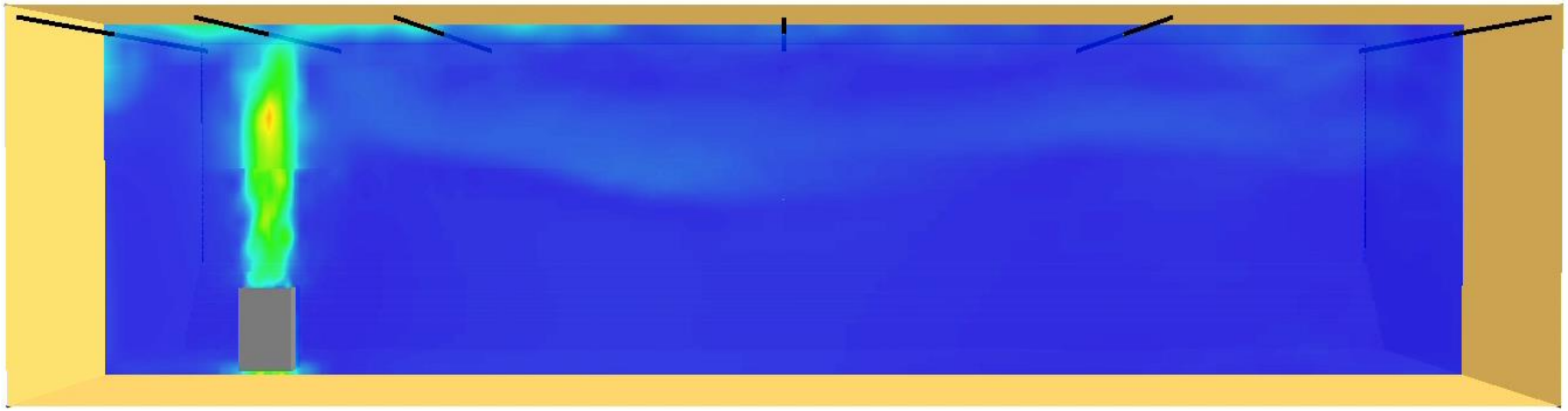


# Simulated Results – Test 1

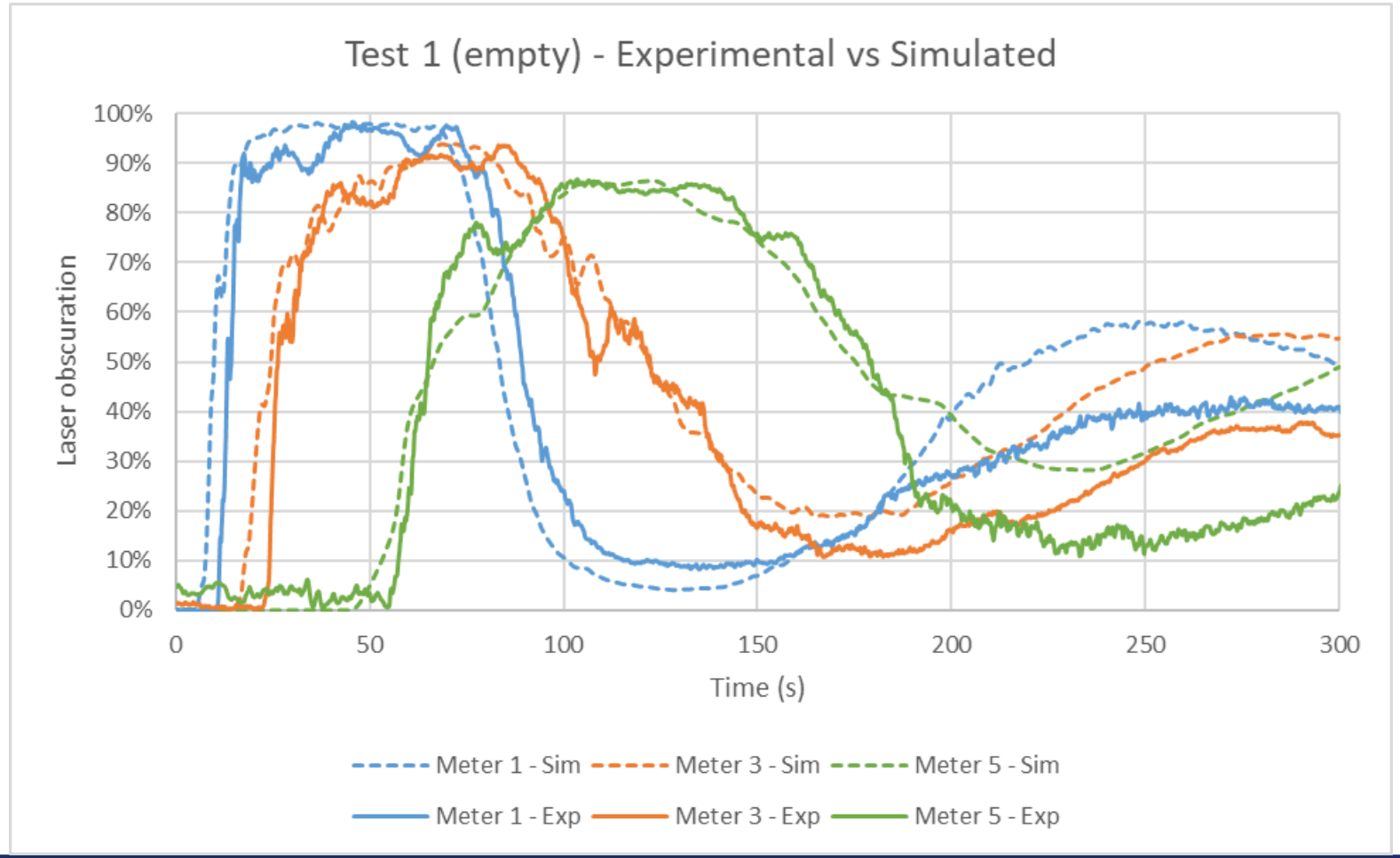
- Convection current forms on ceiling towards aft
- Returning current ~2ft below ceiling towards front
- Cycle of ~200 seconds

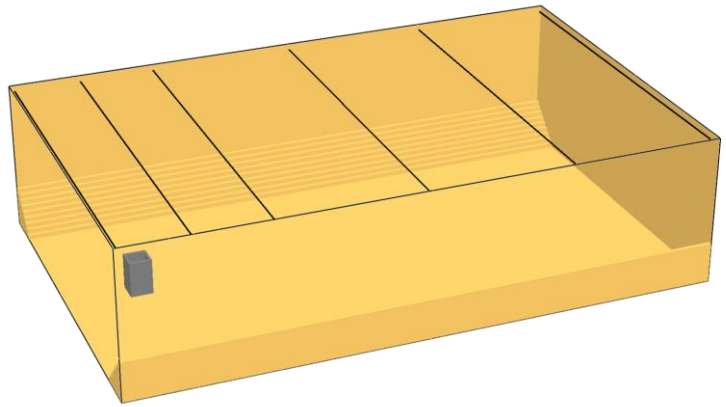
Fore



Aft

# Experimental vs Simulated



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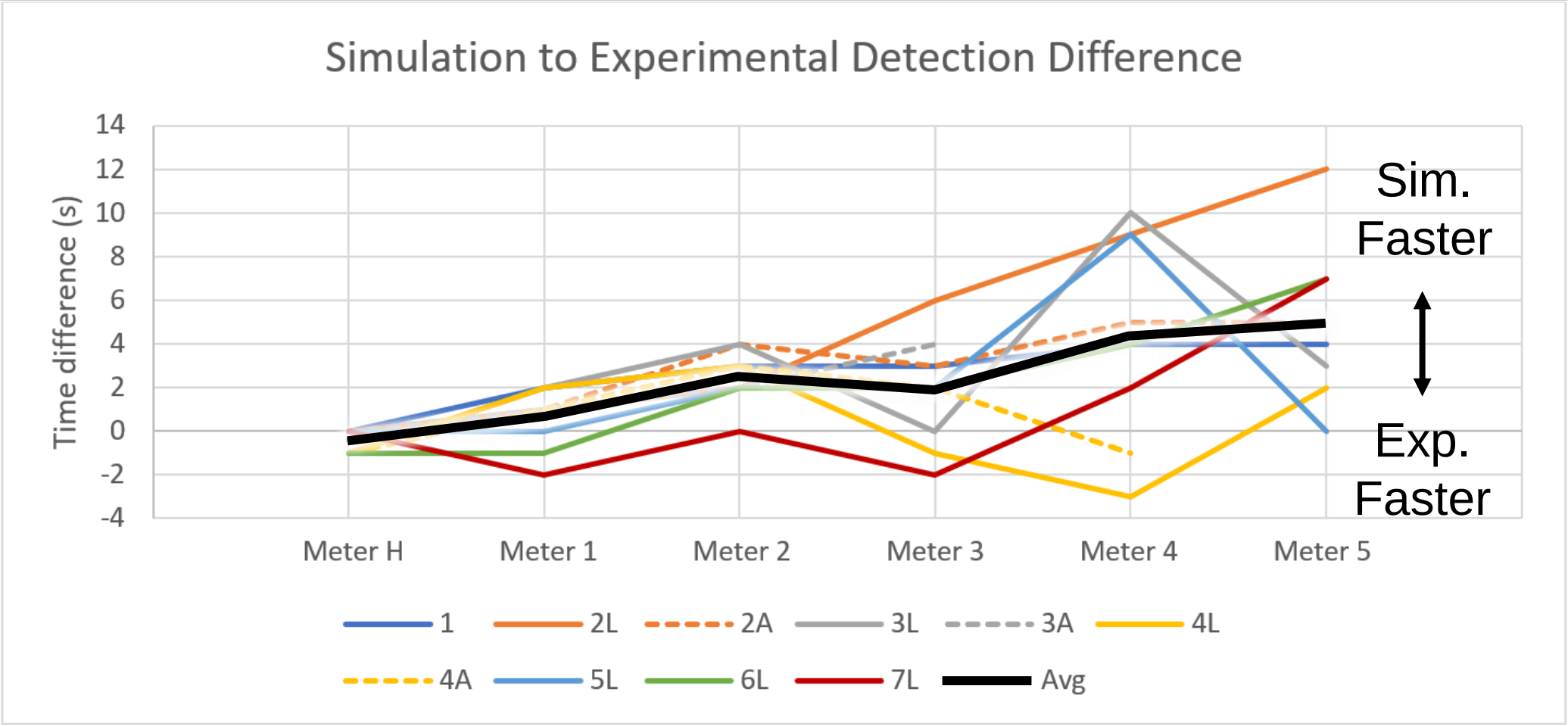
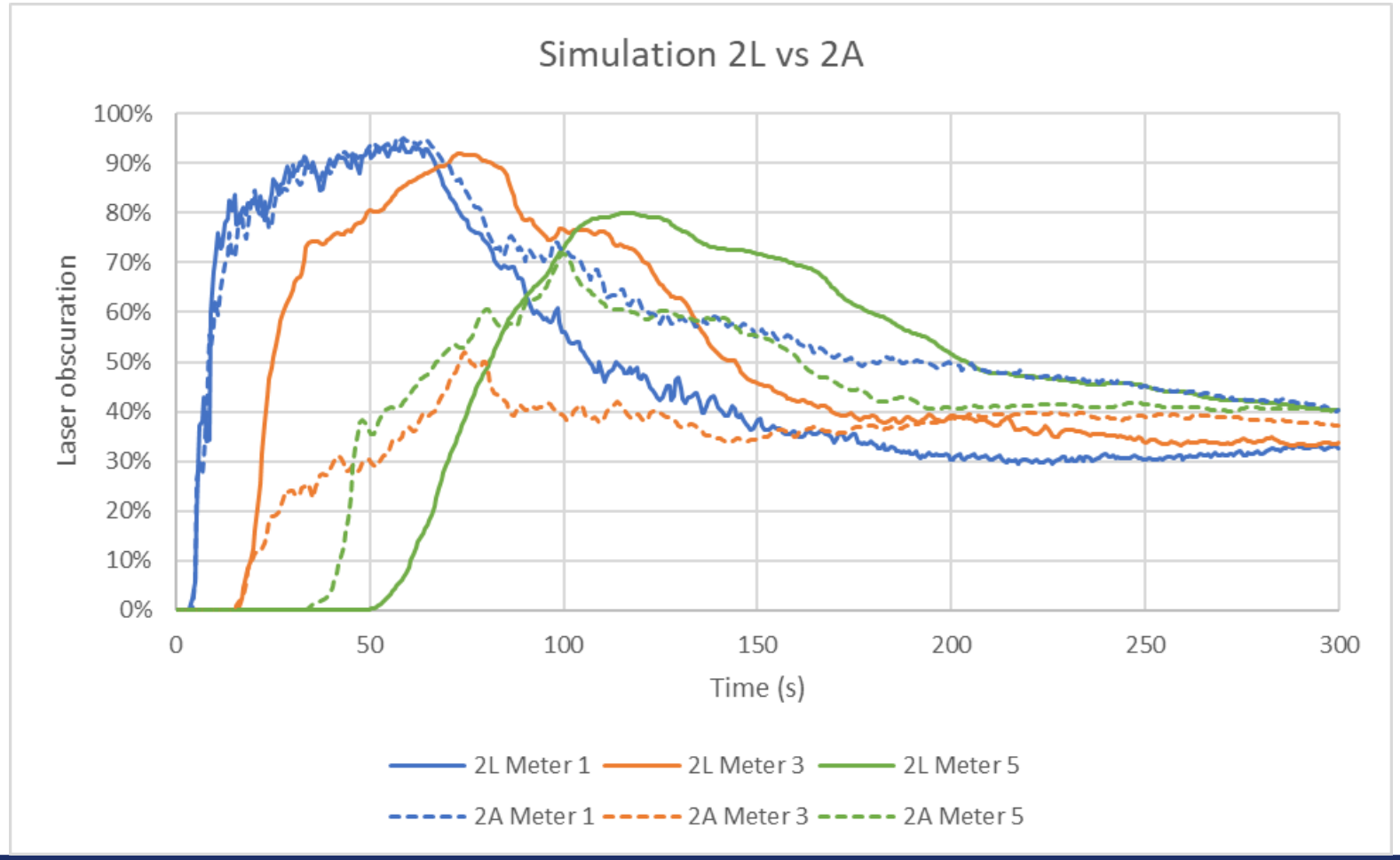
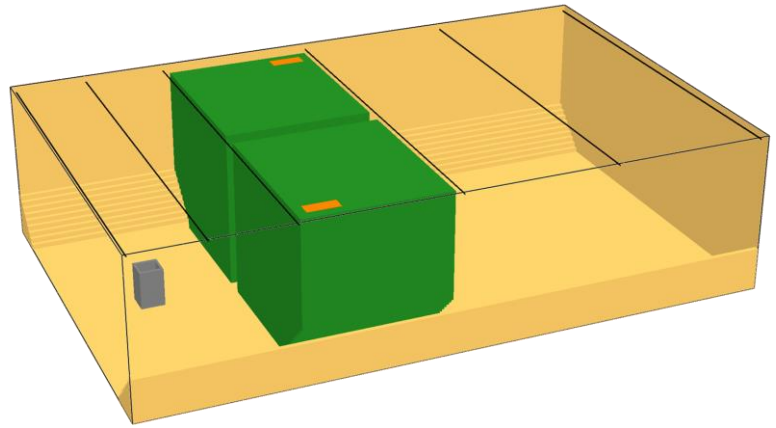


# Active Cargo Containers



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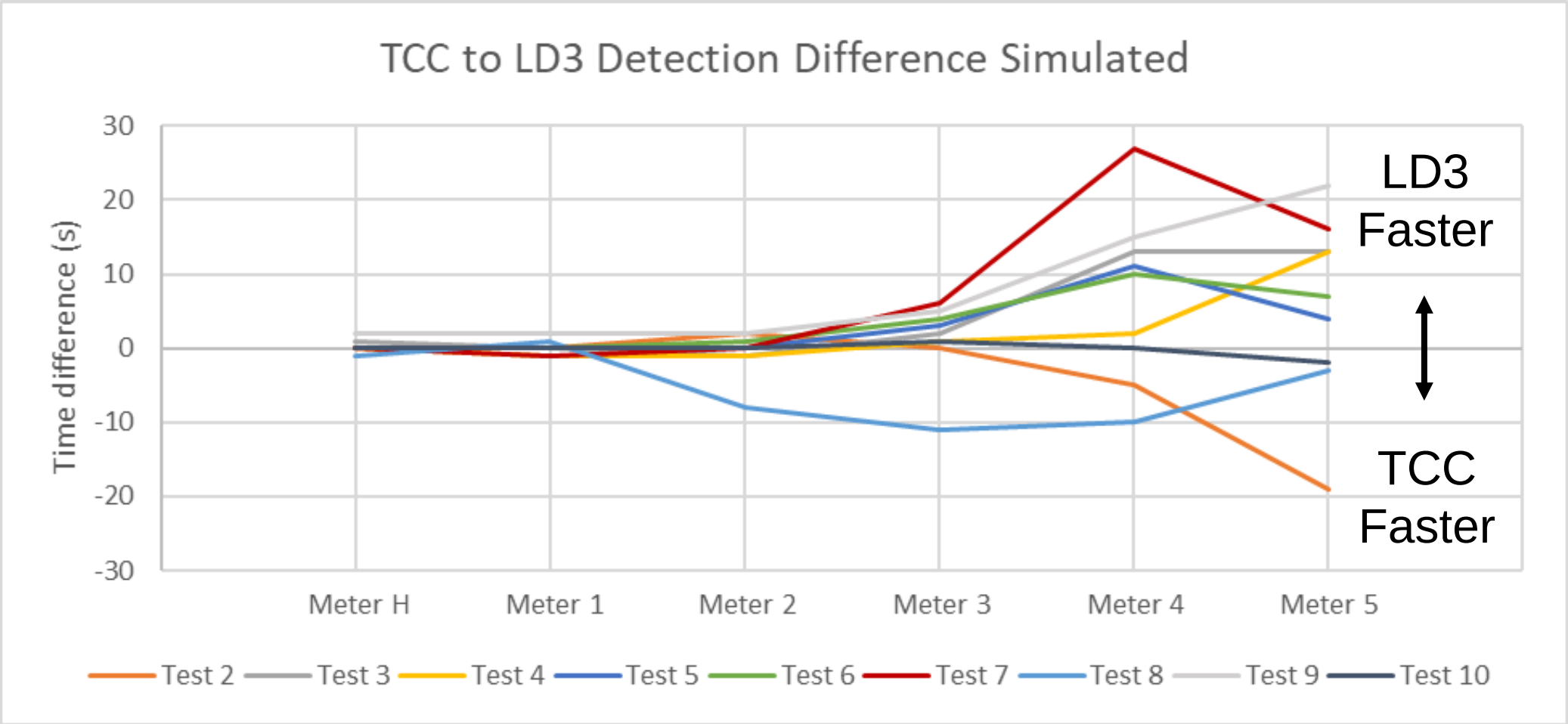
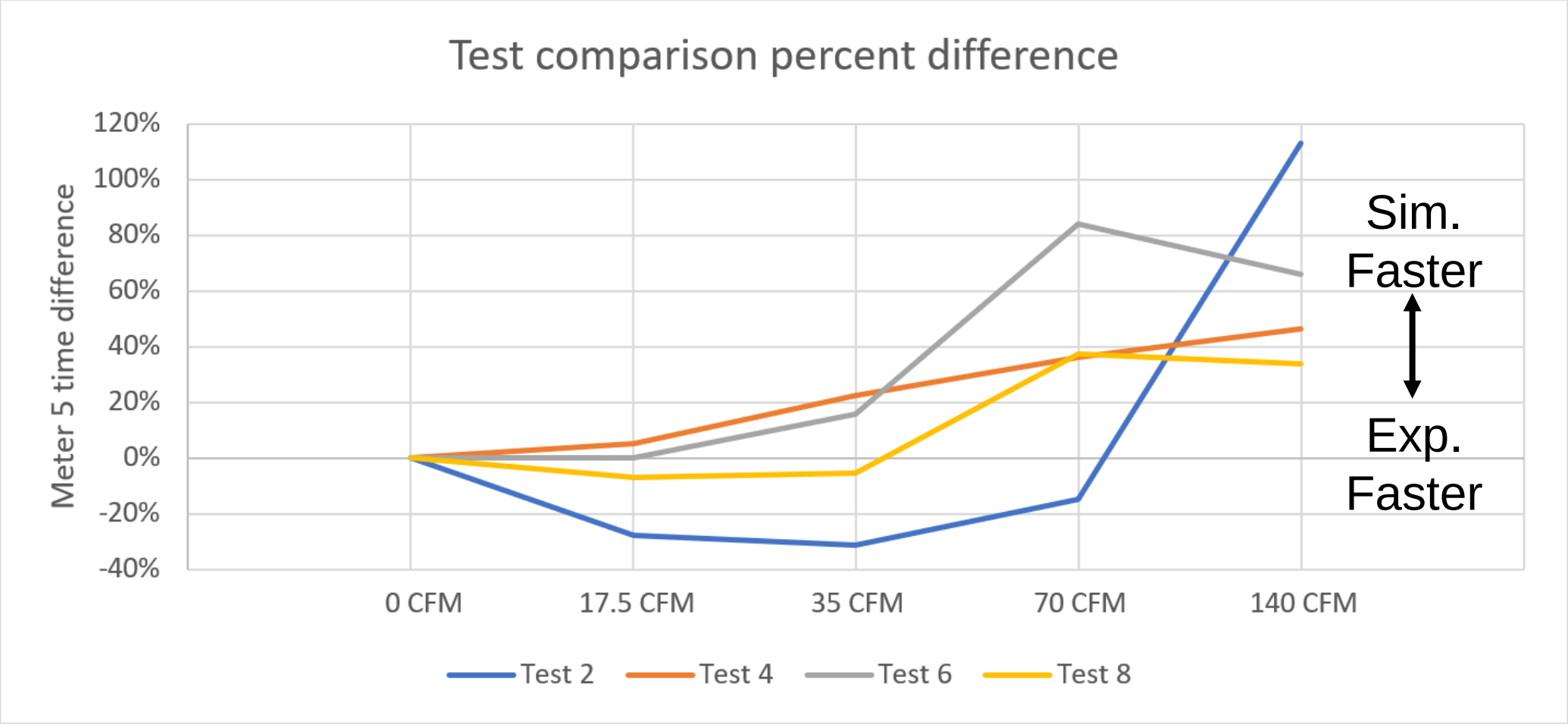


# Maximum Velocity



# Conclusion

- Fire Dynamics Simulator as a replacement for physical testing
  - Can model smoke at aircraft scale
  - Convection currents with low error
  - Minimal bias over minutes of simulation
- The effect of active cargo containers on aircraft smoke transport
  - TCCs with airflow of 17.5 and 35 CFM had an inconsistent effect on smoke detection time
  - Above 70 CFM, detection time increases
  - No correlation between detection time and number of containers
  - Recommend to keep TCC airflow below 70 CFM

# Future Work

- Refinement of the model
  - Light scattering & more accurate mass extinction coefficient
  - Tune smoke for accuracy in long tests
  - Mesh optimizations
- Other variables
  - Vent heat flux
  - Different vent size/shape
  - Different cargo compartment shape

# Thank you

DOT/FAA/TCTT-22/30

Andrew Ferraro
andrew.ferraro@faa.gov
(609) 485-5773