CFD Modeling of Smoke Penetration into Pilot Deck in B727 Cargo Airplane

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HAIQING GUO

CFAR SERVICES

WILLIAM J. HUGHES TECHNICAL CENTER, NJ

Background

In 2010, a Boeing 747-44AF departed Dubai International Airport on a scheduled international cargo flight. Twenty two minutes into the flight, there was an indication of an on-board fire on the Forward Main Deck[1].

Due to the consistent and contiguous smoke in the cockpit region, the PF could not view the flight displays or the view outside the cockpit. The airplane crashed eventually and there were no survivors.

[1] General Civil Aviation Authority of the UAE, Uncontained cargo fire leading to loss of control inflight and uncontrolled descent into terrain, 2010.

Background

FAA B727 Experiments:

- Different types of batteries were tested (Lithium-ion, Lithium metal, mixed).
- Different locations were tested (FWD Cargo, Main Deck).
- Different ventilation conditions (pressurized, unpressurized, emergency mode).

FAA Smoke Generator to better understand the smoke transport.

In aircraft design, the pilot deck has a higher air exchange rate so the pilot deck pressure is slightly higher than that in the main deck. That will help keep the smoke away.

[2] Harry Webster, Full scale battery tests, 2013.

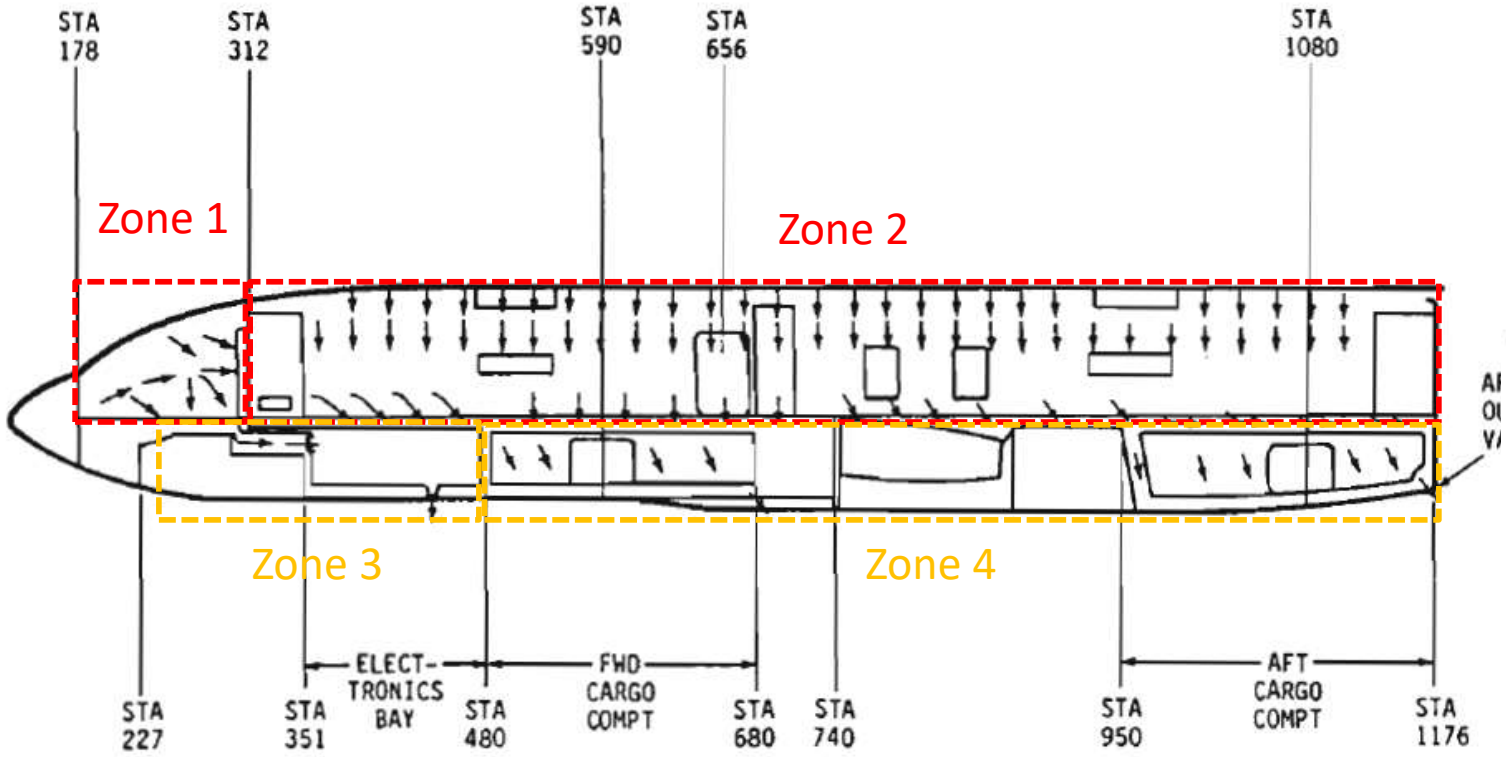
Objectives

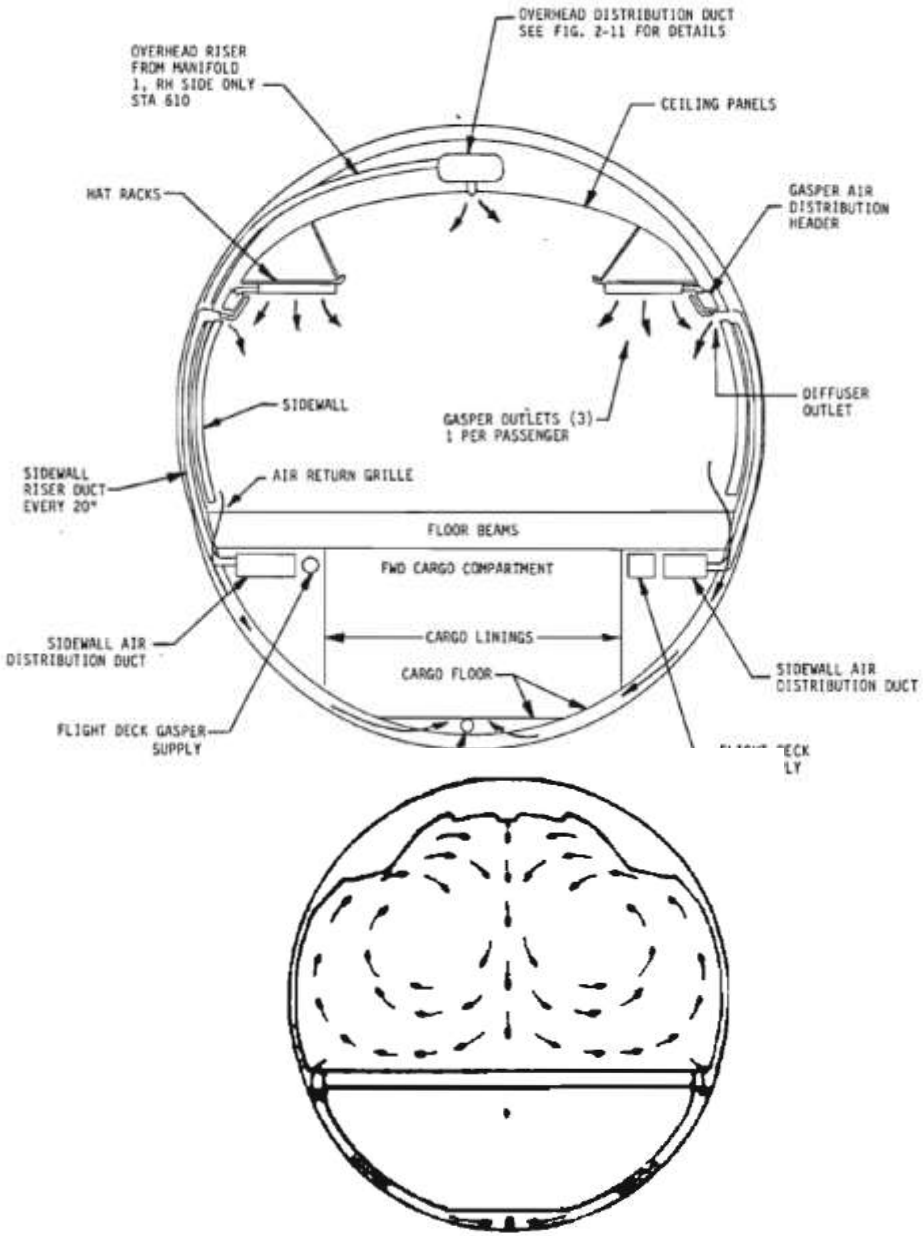
Use CFD tool to facilitate understanding on the smoke transport.

Better understand how the fire changes the pressure field and causes smoke penetration.

Focus: Main deck fire, unpressurized, emergency mode.

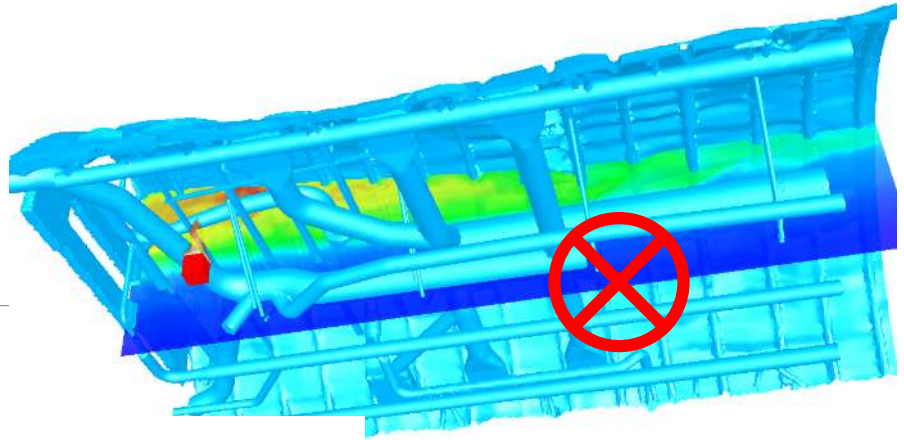
Flow Pattern in B727

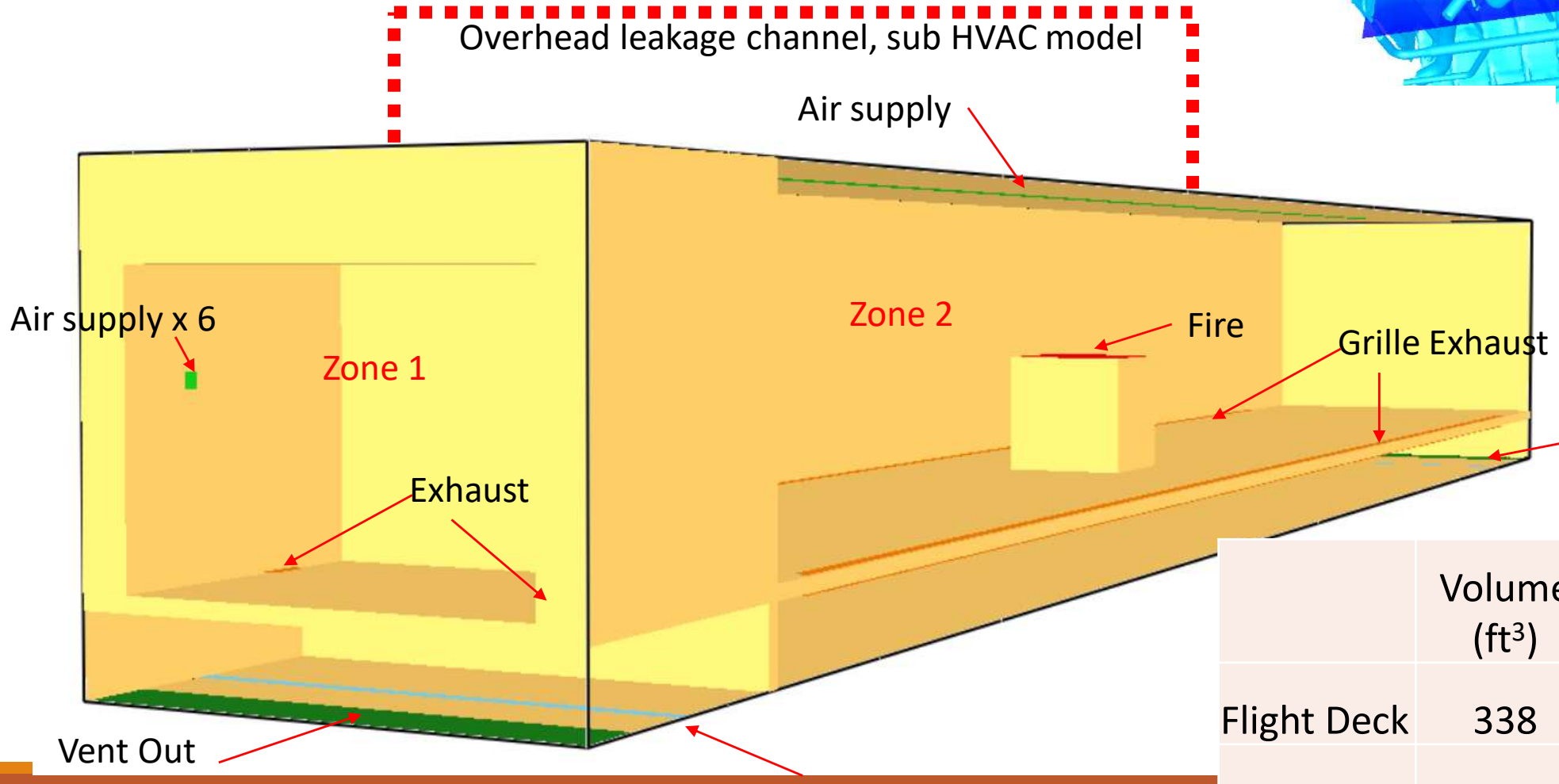




4 zones are treated as independent pressure zones.

CFD Model



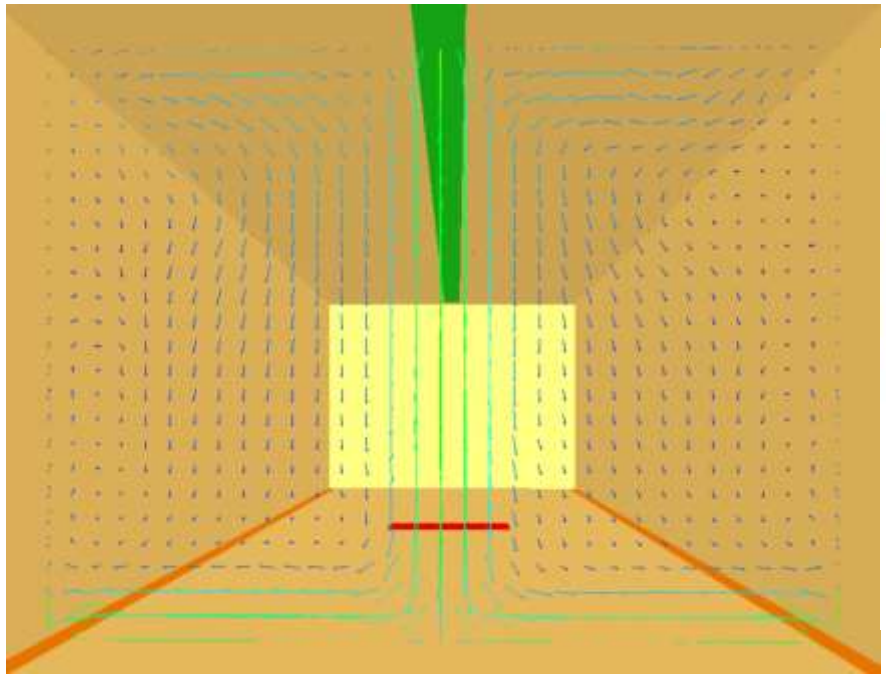


NIST'S Large Eddy Simulation tool Fire Dynamics Simulator with a HVAC -submodel.

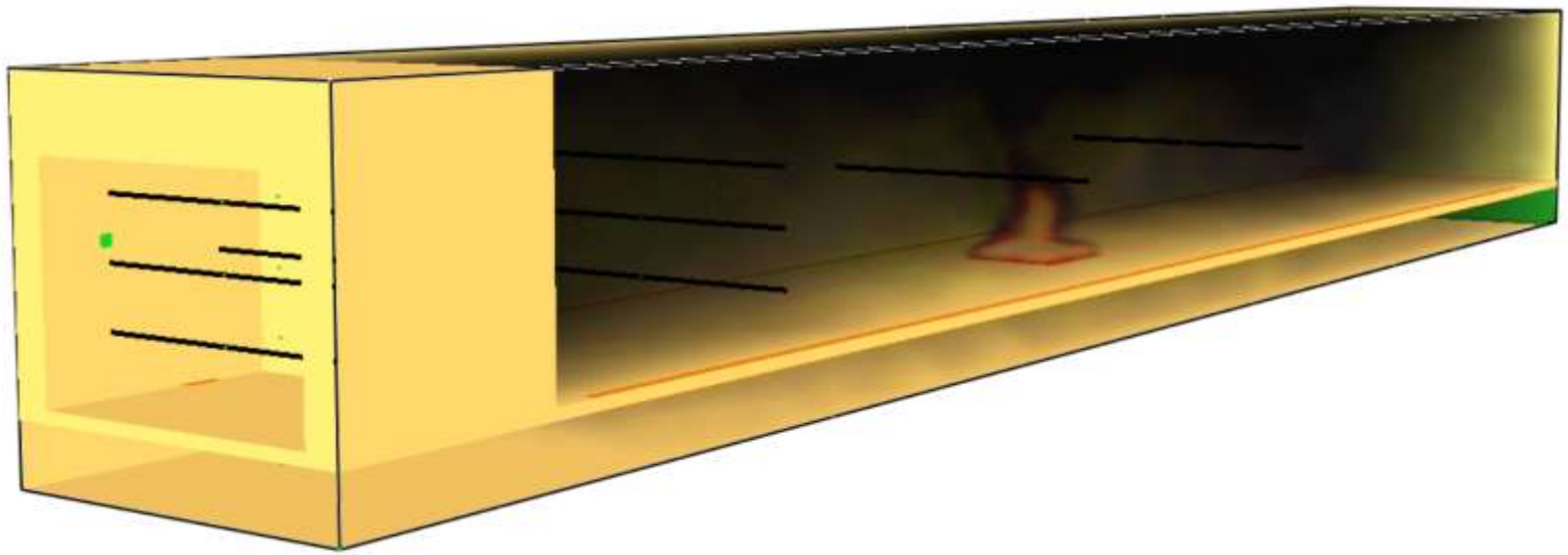
	Volume (ft^3)	Flow (ft^3/min)	Change (change/hr)
Flight Deck	338	197	35
Main Deck	5843	122	1.25

Account for leakage, and balance pressure

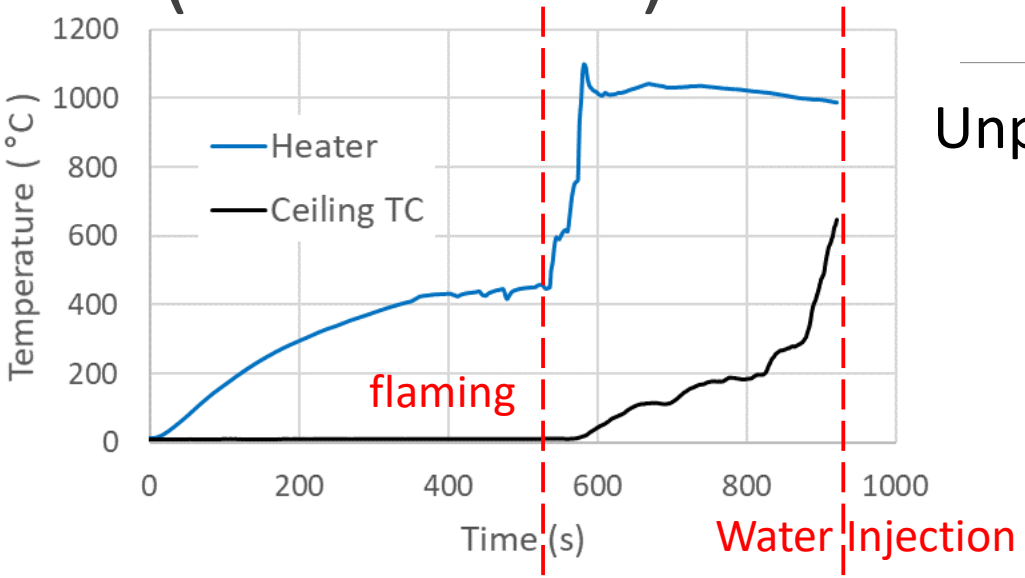
CFD Model

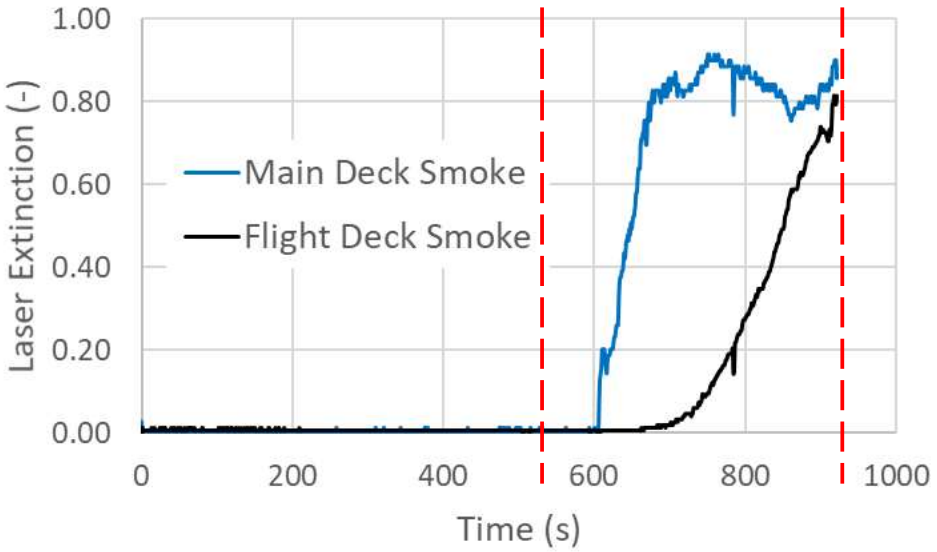


300 kW fire

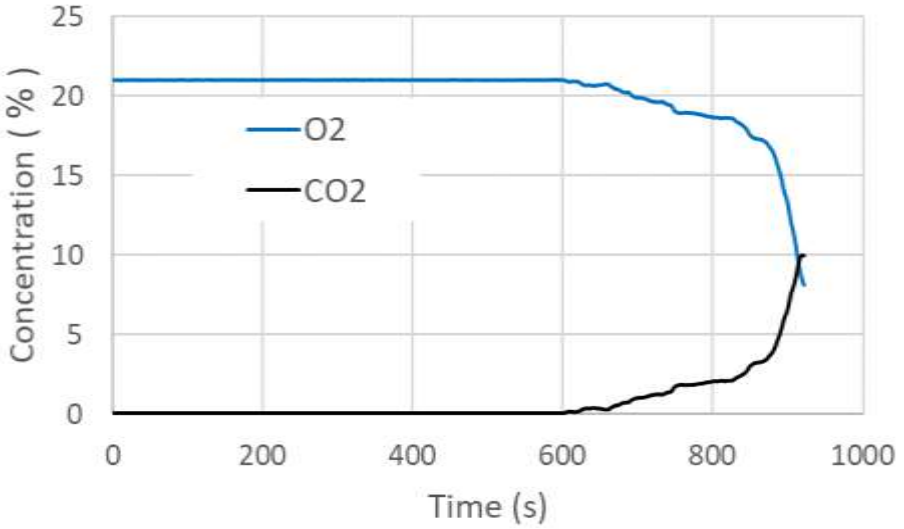


Previous Battery Fire Test Results (T130226)





Unpressurized, main deck, battery fire, emergency mode



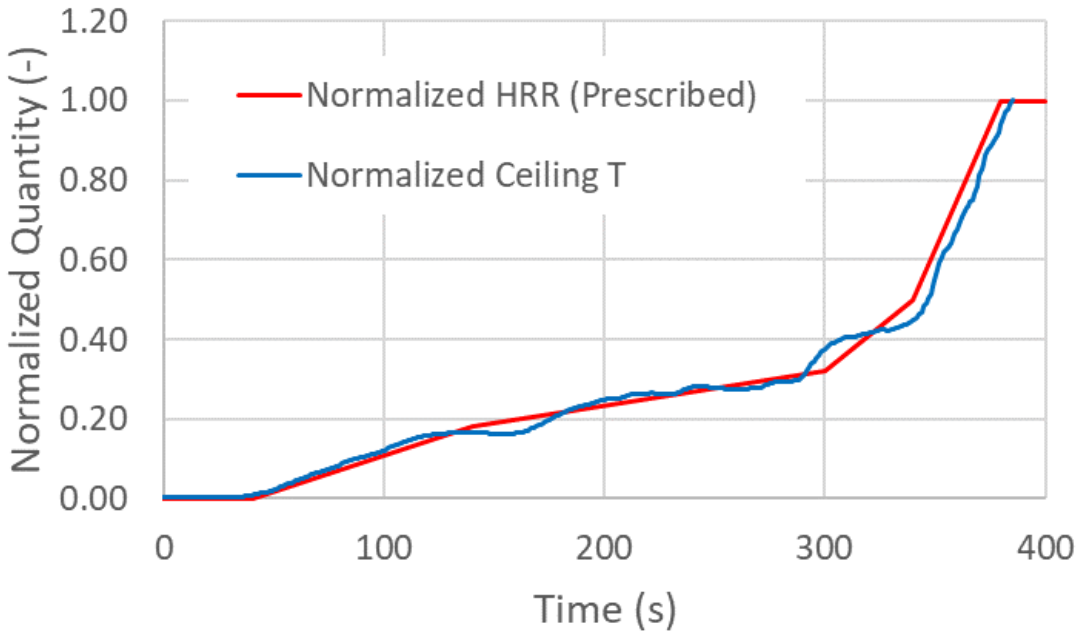
$\Delta H_{c,O2}$ = 13.1 kJ/g O_2 consumed

Perfectly stirred system

Q_c = 207 MJ

Fire HRR Input to Model

Assume the HRR profile follows the temperature profile.



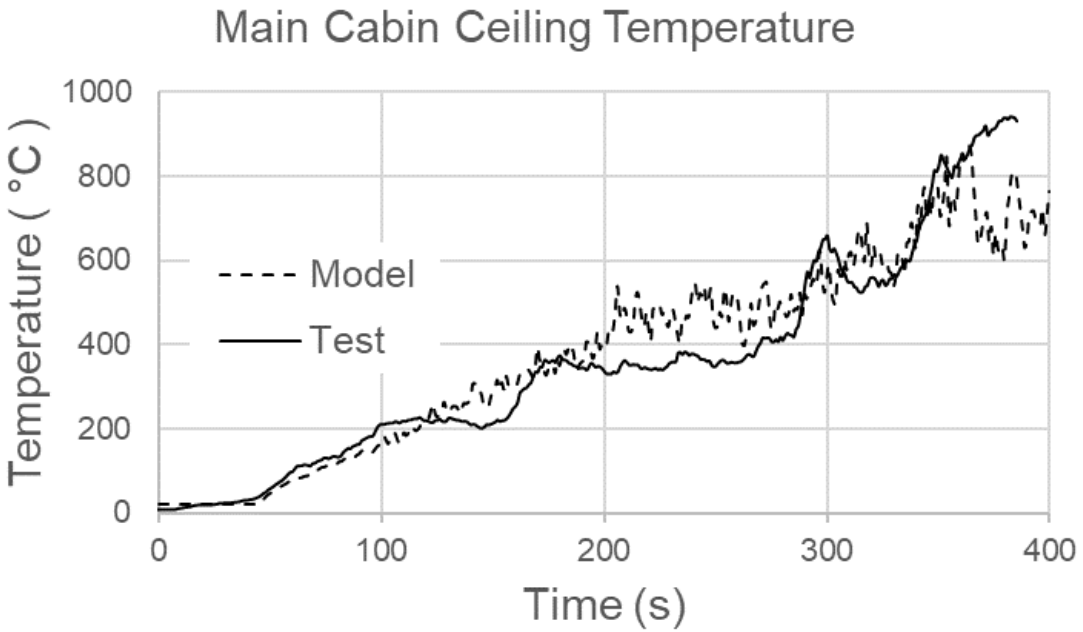
Total energy release = 207 MJ.

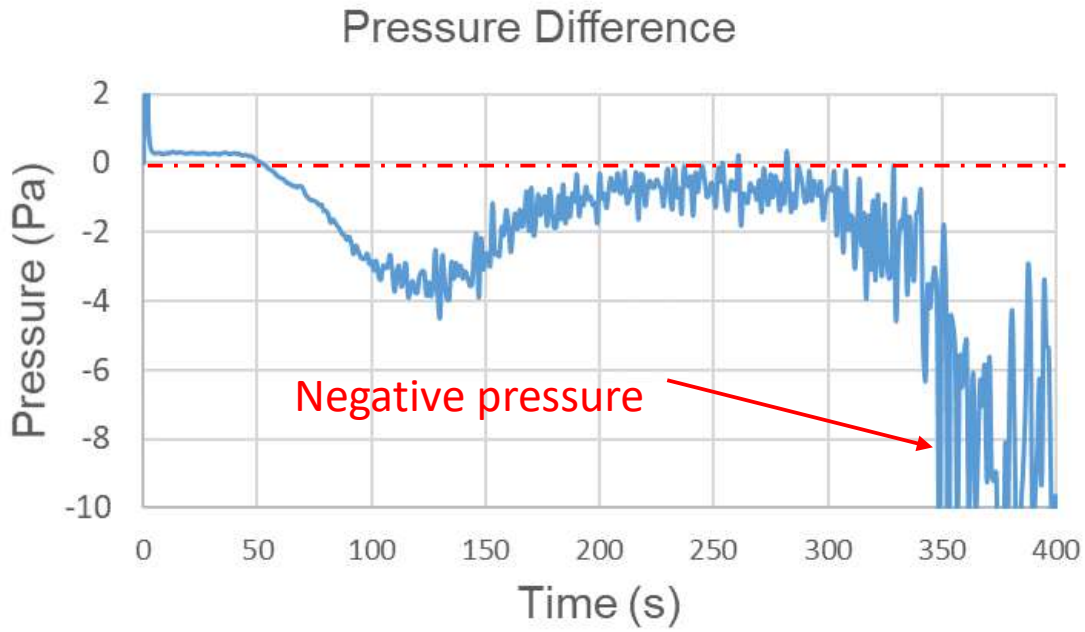
- Stored electrical energy.
- Non-uniform sampling.

Calculated peak HRR = 2 MW.

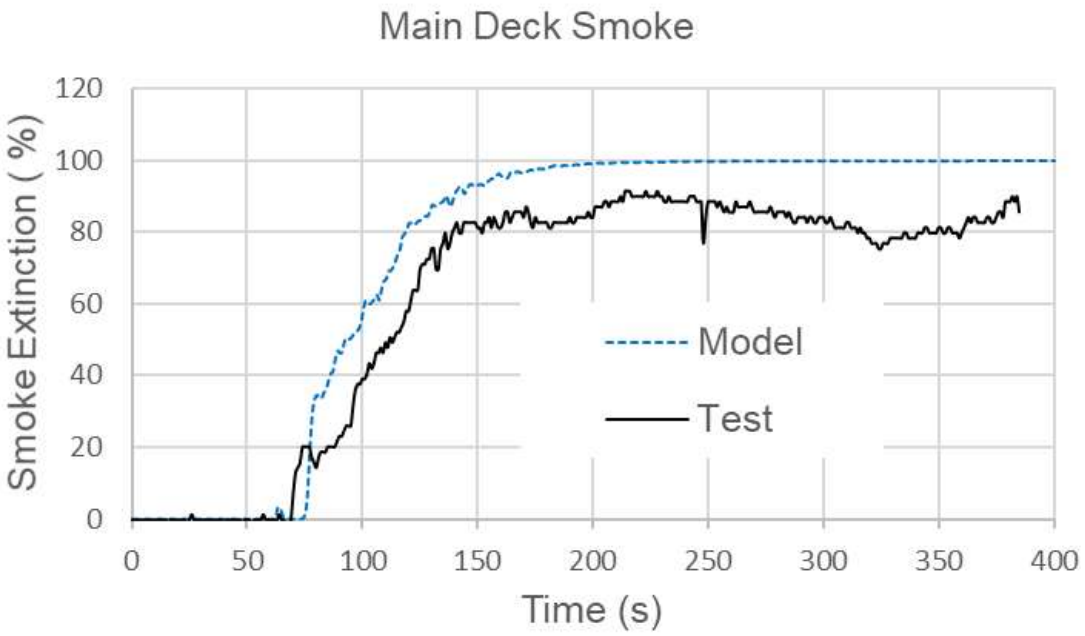
Model Results (T130226)

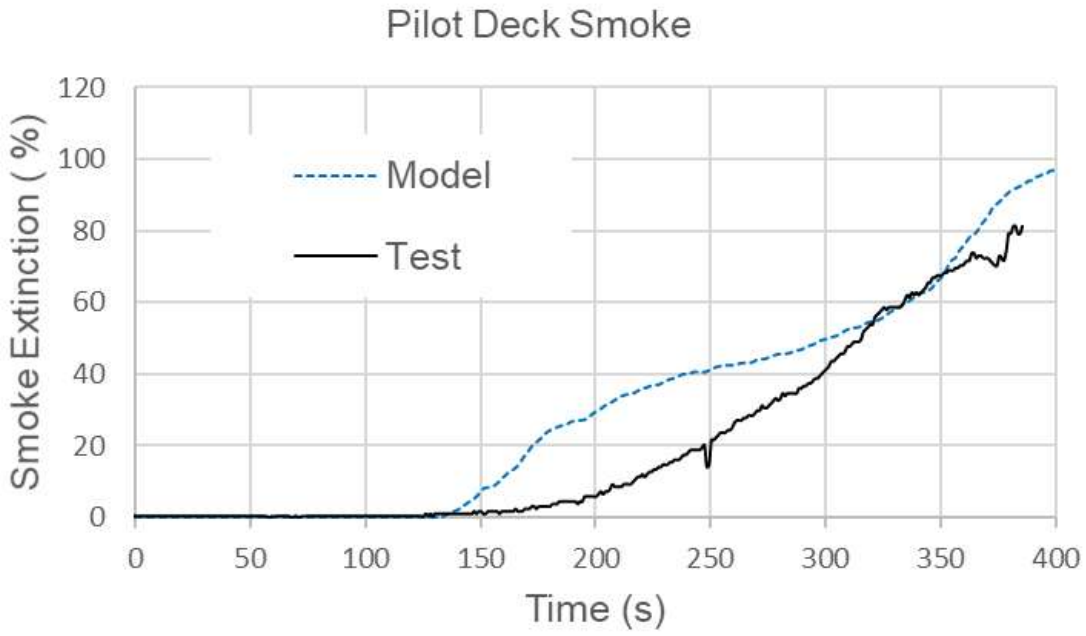
Modeled results with the updated flow condition and prescribed HRR.





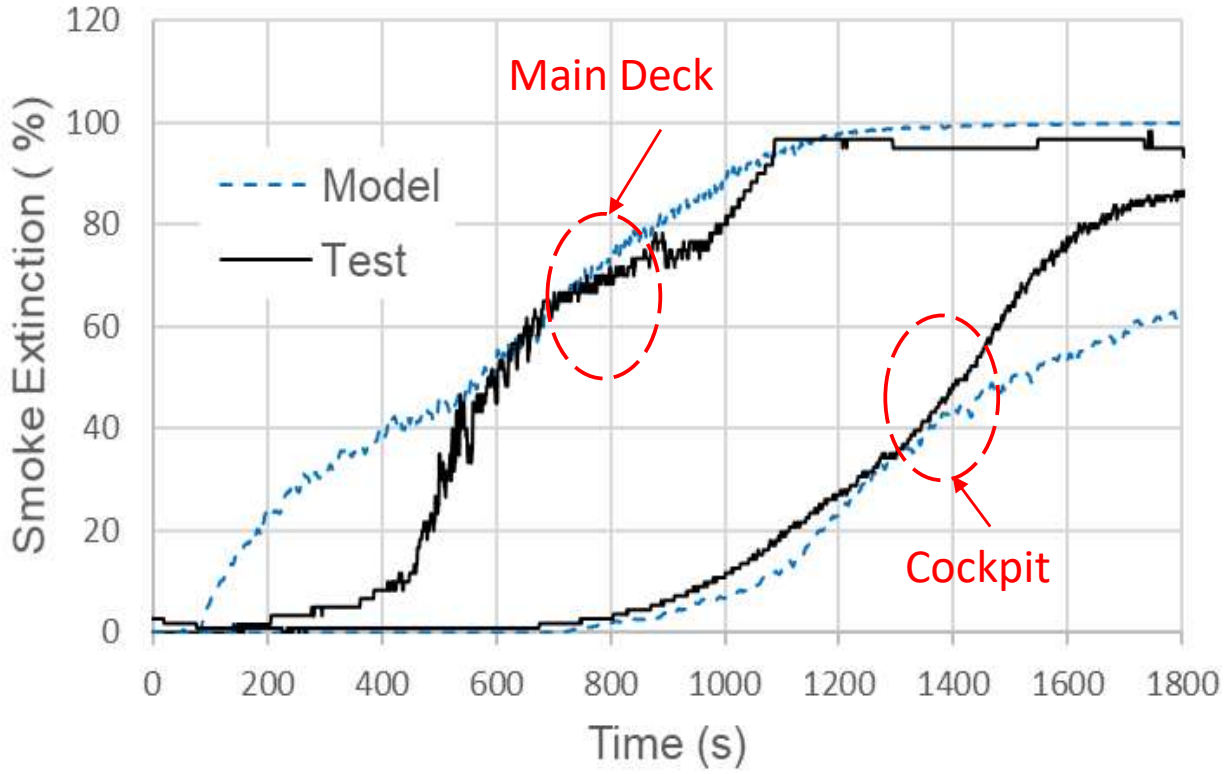
Model Results (T130226)





Modeled Results (T130409)

T130409, HRR_{max} = 200 kW, slower fire growth rate

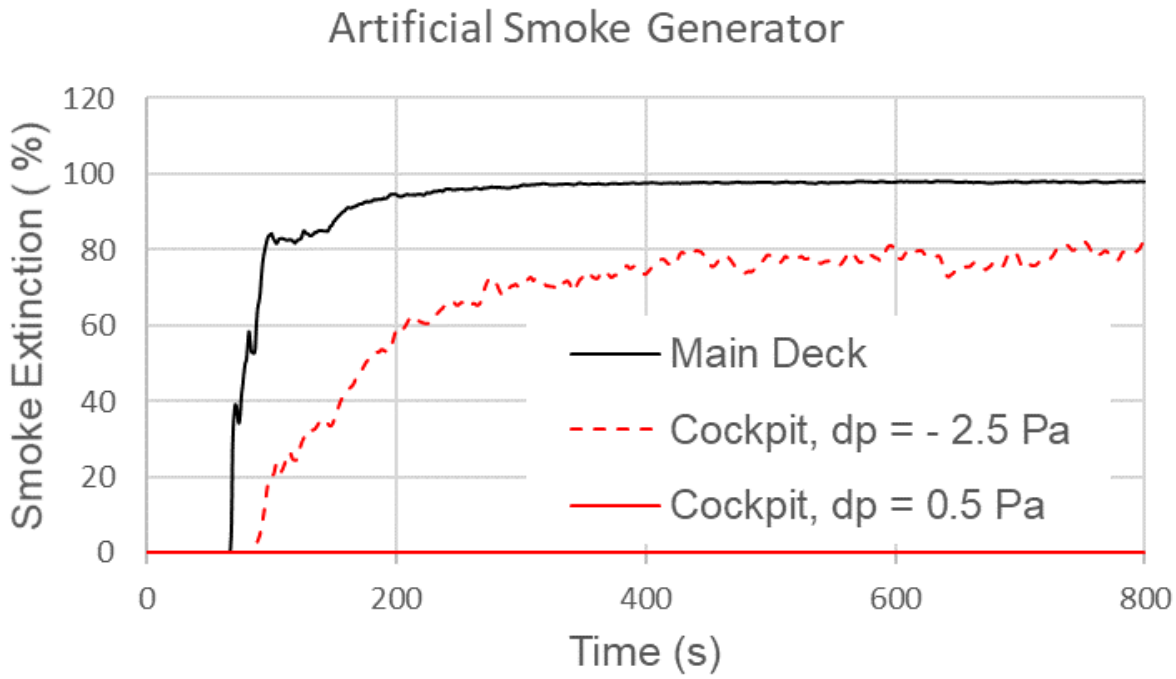


Artificial Smoke Generator

Smoke generator is widely used in industry (non-destructive).

Smoke generator does not provide enough heat to change the pressure field.

Flow rate can be easily adjusted in CFD to change the pressure field. (screening)



Summary and Future Works

A simplified CFD model is built to model the smoke transport in aircraft.

Model with prescribed HRR is able to predict the time delay and concentration of smoke penetration into cockpit region.

CFD model indicates that pure smoke injection won't result in smoke penetration.

Model also indicates that if the pressure field in aircraft can be tuned, the smoke generator can be used to verify the air-tightness of the aircraft design.

Battery HRR will be experimentally measured with room calorimeter.

Smoke transport will be experimentally validated with the full scale fire test with known HRR, and the differential pressure will be accurately measured.

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Q & A

Contact:
Haiqing Guo, PhD
Senior Fire Research Scientist
haiqing.ctr.guo@faa.gov
609-485-4415