Fire & Cabin Safety Research Conference

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Numerical Simulation for Fire Suppression Agent Propagation in an Aircraft Cargo Compartment

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Stakes & Objectives

Stakes:

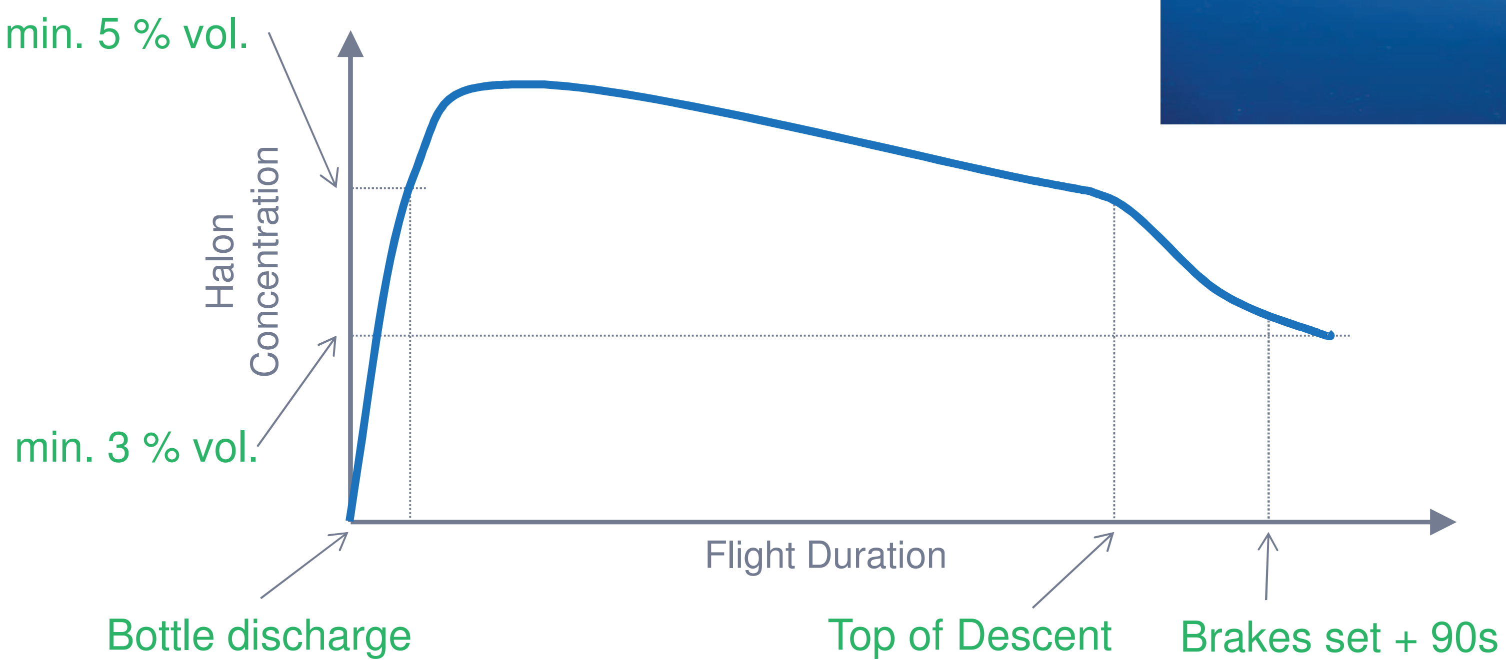
- Ensure appropriate design of the cargo compartment fire suppression system at early program stage
- Frontload discovery of potential design shortfall at fire suppression system level
- Limit environmental impact of fire extinguishing agent discharge based testing

Objectives:

- Set-up a fire suppression model built on flight testing experience & data
- Define a dedicated numerical simulation chain able to reproduce fire suppression agent propagation in an aircraft cargo compartment
- Validate simulation approach against existing physical testing

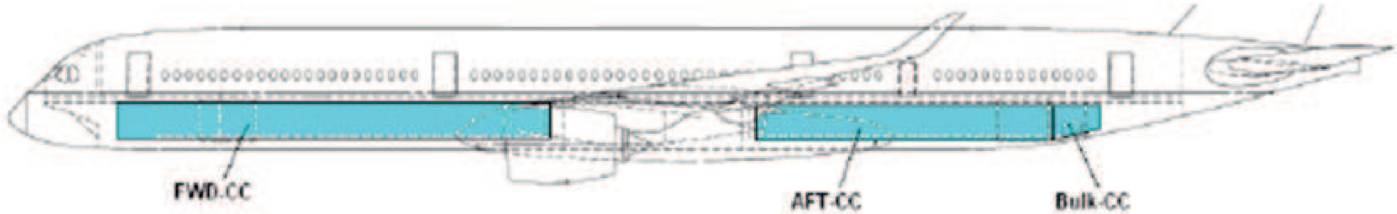
Background – General Cargo & Fire Extinguishing Description

- Certification context: CS25.851(b)(2), CS25.855(h)(3) & related AMC
- Compliance demonstrated through flight test

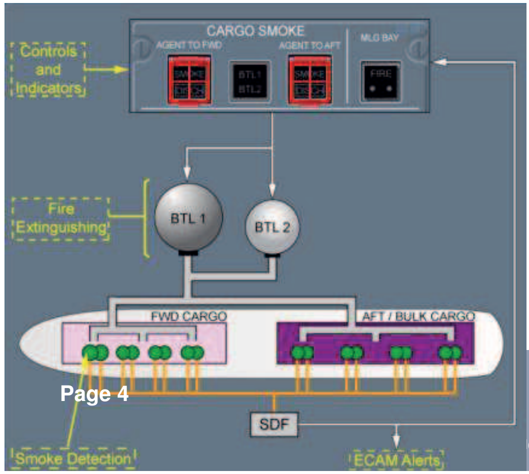


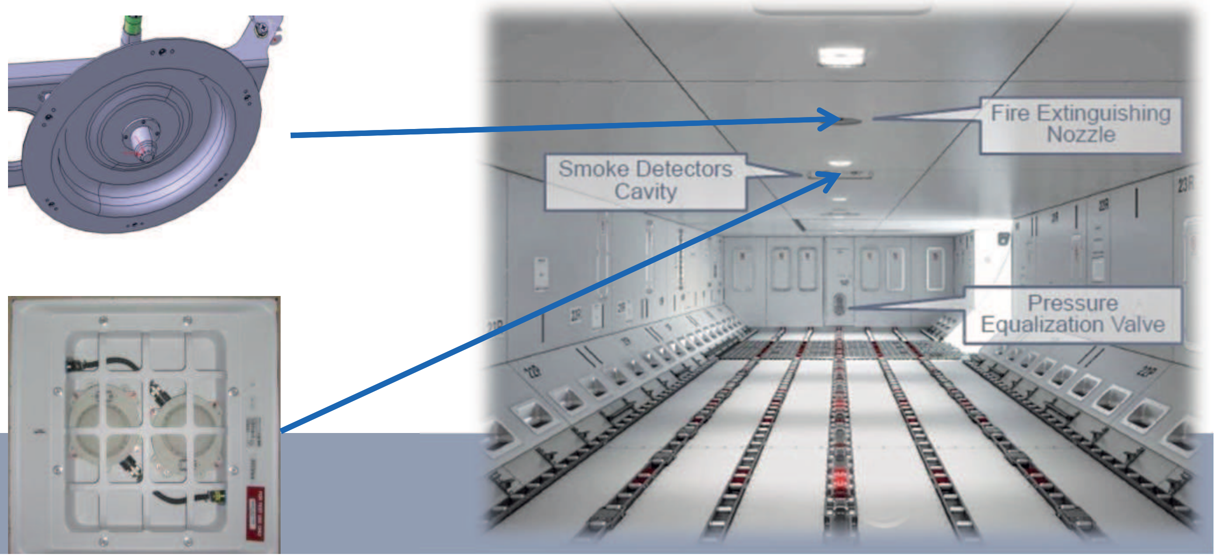
Background – General Cargo & Fire Extinguishing Description

- Airbus aircrafts are generally equipped with two separate cargo compartments located in the lower deck
  - AFT/BULK cargo compartment
  - FWD cargo compartment

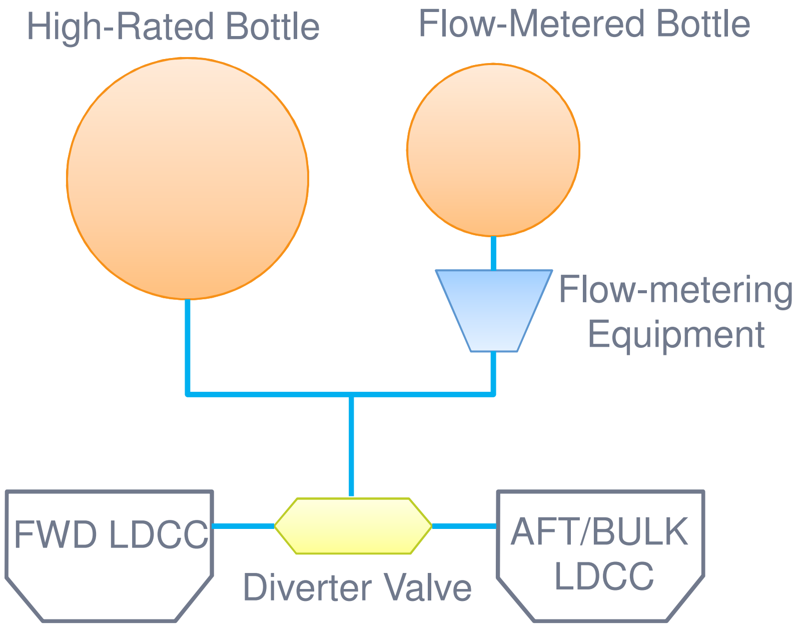


- Cargo holds are classified as Class C compartments & equipped with:
  - Fire Detection System (smoke detection)
  - Fire Extinguishing System

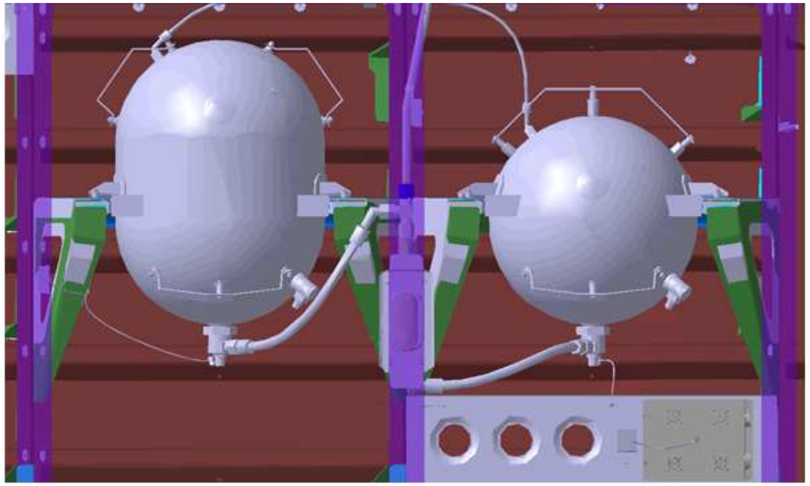




Background – General Cargo & Fire Suppression System Description



Suppression Agent:
Trifluorobromomethane (Halon 1301)



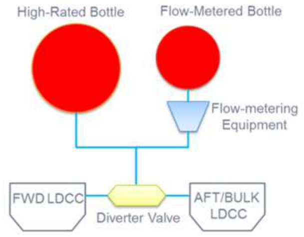
The High Rated Bottle will knock down a potential cargo fire in short time

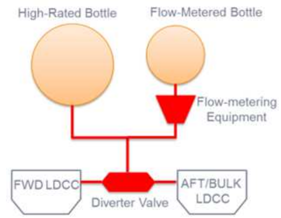
The Flow Metered Bottle will suppress a cargo fire until it can be completely extinguished by ground personnel following a safe landing

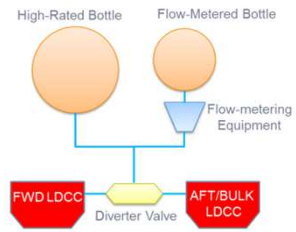
Modelling process principle

The agent discharge simulation process is divided into 3 steps

Inputs needed	**Simulation Steps**
Halon Bottles physical characteristics (Temperature, Pressure,…)	Step 1: **Fire Extinguishing Bottle discharge**
Fire extinguishing piping characteristics Mass flow calculated from Step 1 plus constant mass flow from Flow Metered Bottle	Step 2: **Fire Extinguishing Piping 1D Model**
Halon mass flow from Step 2 LDCC + nozzles 3D model	Step 3: **Cargo Compartment 3D CFD model**





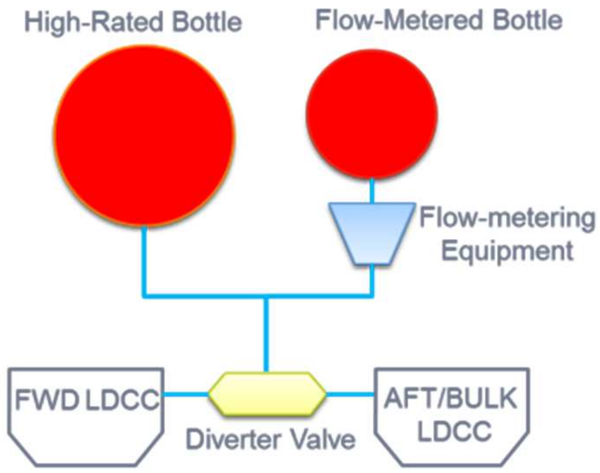


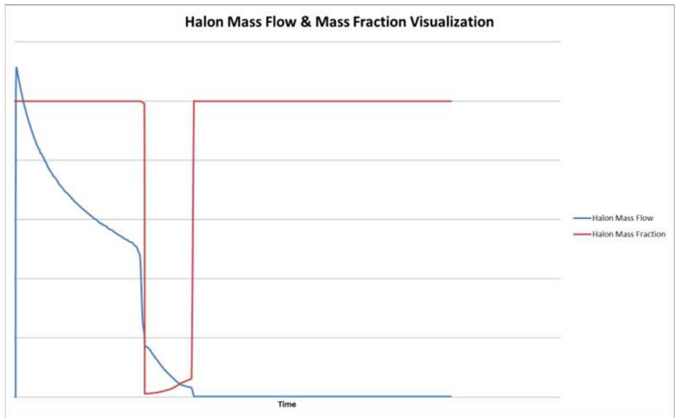
Step 1: Fire Extinguishing Bottle discharge

- Objective is to compute the halon mass flow & halon mass fraction out of the bottles over time

- A specific agent discharge code is used to get these information

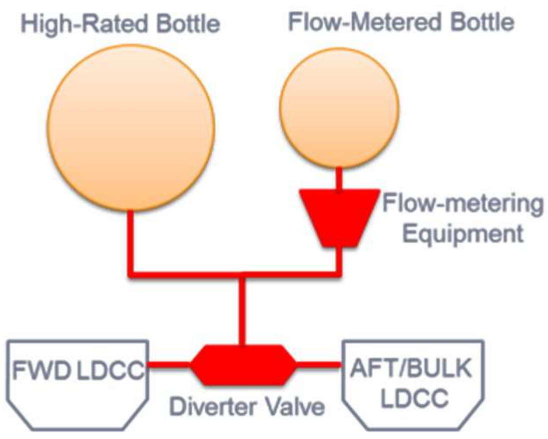
- To ensure behavioural correctness, additional information are required such as downstream piping pressure drop

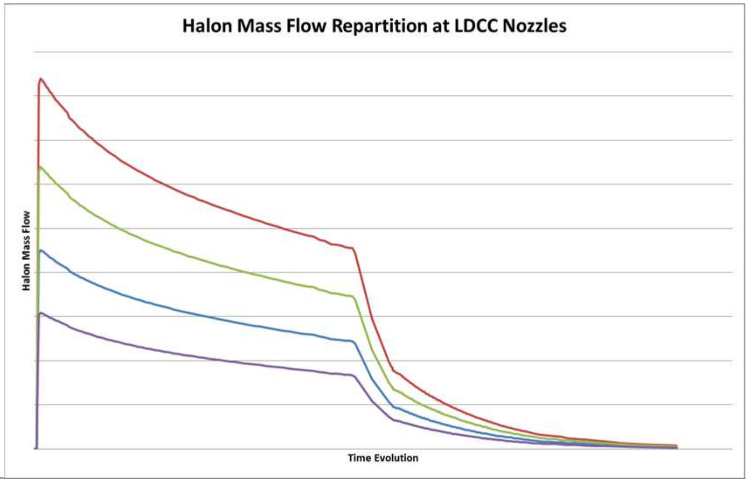




Step 2: Fire Extinguishing Piping 1D Model

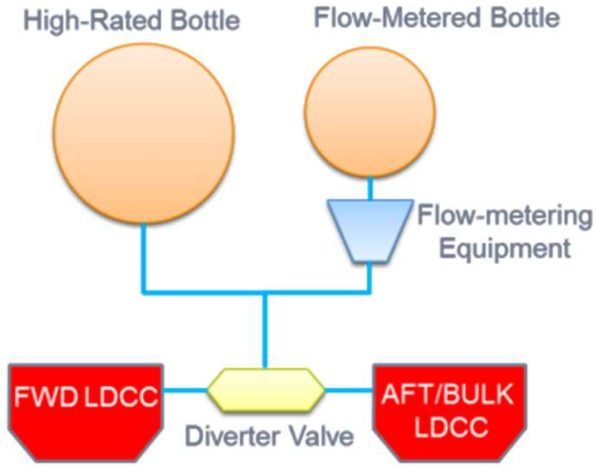
- Objective is to compute the correct halon mass flow repartition at each nozzle of FWD & AFT cargo compartment
- A dedicated 1D model of the aircraft fire extinguishing piping system is used
- All characteristics are extracted from equipment's specifications and actual aircraft 3D mock-up



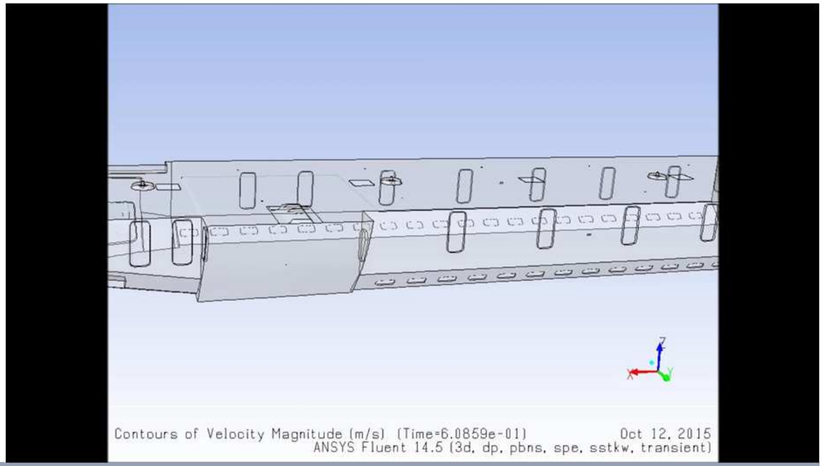


Step 3: Agent Discharge in Cargo Compartment 3D CFD model

- Objective is to simulate the fire suppression agent propagation in the actual aircraft cargo compartment
- A dedicated 3D model of the aircraft cargo compartment is extracted from the aircraft 3D mock-up
- The cargo compartment model is adapted for CFD purpose & meshed (Tet/Tri unstructured) with ~20-30M elements
- On a specific mission, for a dedicated set of points, the fire extinguishing agent concentration is monitored over time

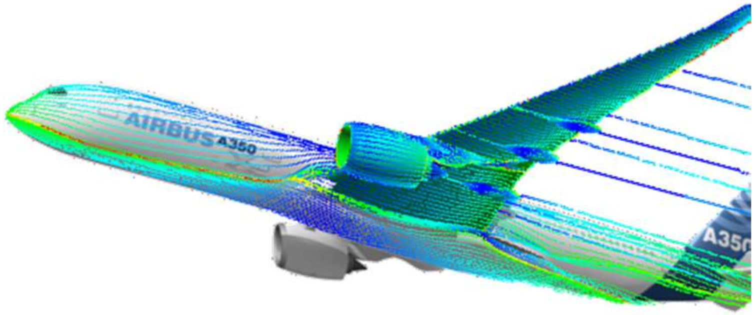


__*CFD post-processing video agent discharge (discharge + 10s*__) Halon Iso-surface mass fraction=0.1

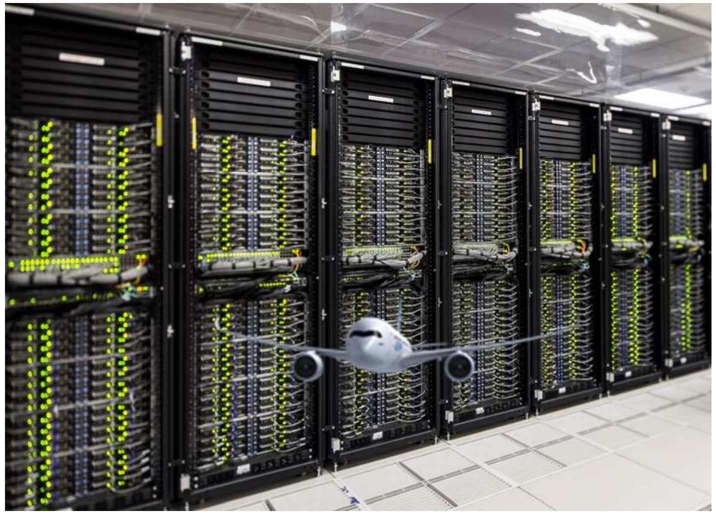


Hardware capabilities & numerical support

- The CFD simulations have been launched using High Performance Computing resources & run on ~500cpu in parallel per run

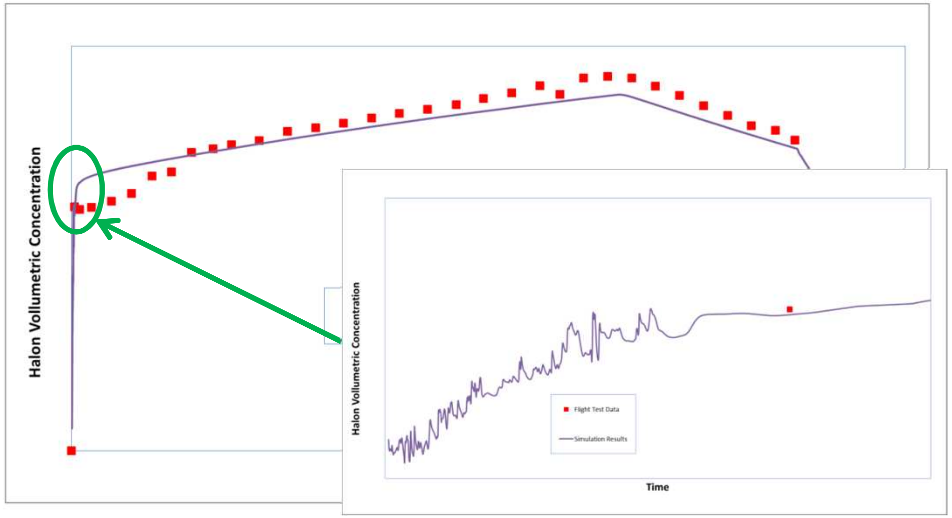


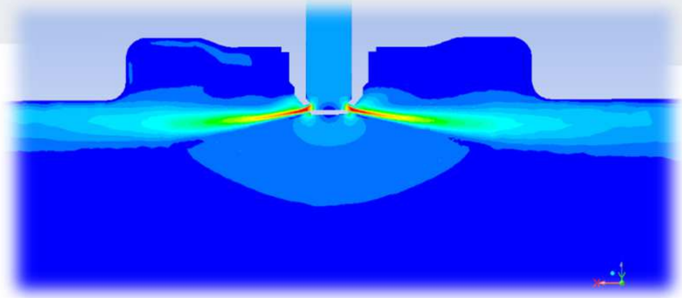
- The validation process has been focused on 4 particular test cases & simulation results have been compared to FT data

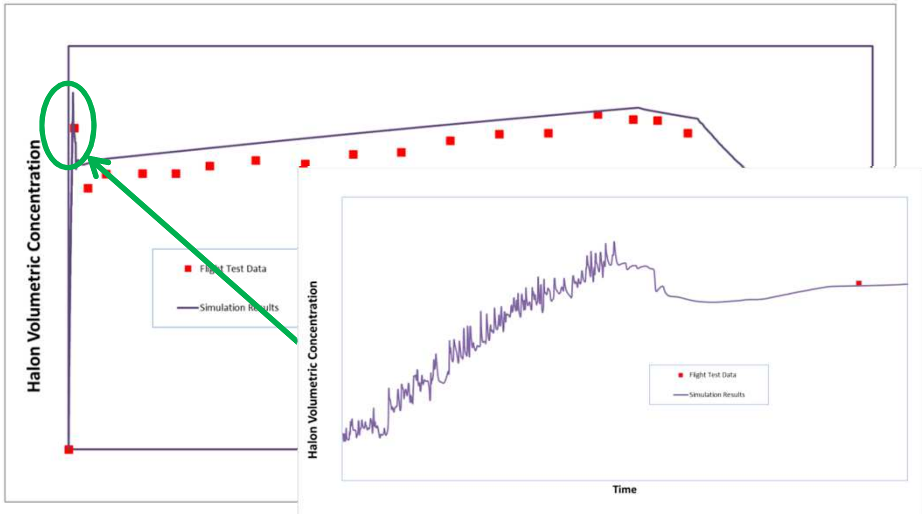


- Simulation time for one run (from bottle discharge in cruise to aircraft landing) is about 1 week

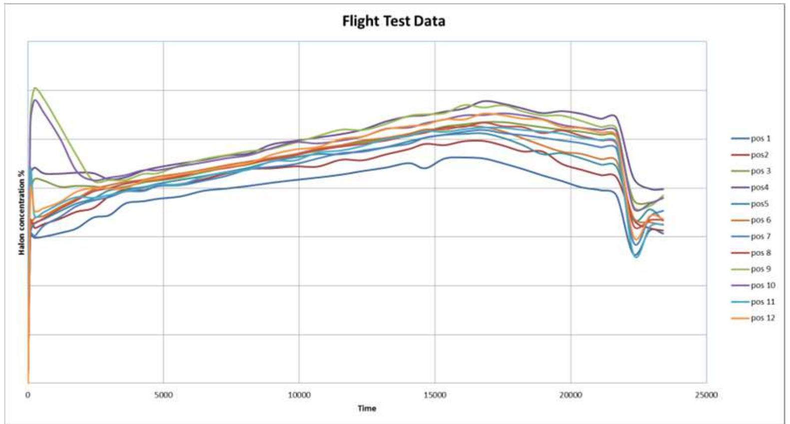
Validation of Simulation Method







- Simulation results have been compared to available flight tests data
- Positive correlation has been established enabling the validation of the approach



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Conclusion

- A modelling technique has been developed and validated against flight test data for prediction of fire extinguishing agent concentration in aircraft cargo compartments.
- This technique allows to perform early design de-risking and to guarantee compliance of the fire suppression system to the certification thresholds regarding extinguishing agent concentration.
- It can be used to verify system sizing thus avoiding aircraft weight penalty while keeping agent concentration to the safest level under any circumstances.
- EASA involved for regular feedback on global methodology definition & approach validation