Modeling of Hidden Fire Smoke Signature in Aircraft

A CASE STUDY OF OVERHEAD AREA

Ezgi Öztekin, PhD

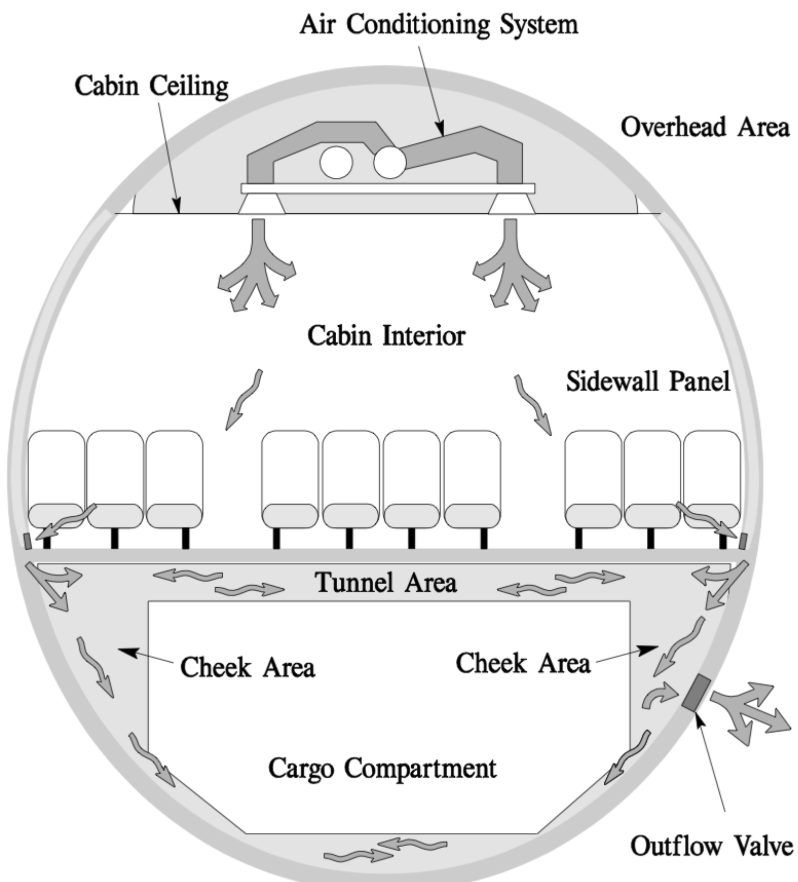
Technology and Management International (TAMI) LLC, Toms River, NJ

Fire Safety Branch (ANG-E21),
Aviation Research Division,
FAA William J. Hughes Technical Center, NJ

International Aircraft Systems Fire Protection Working Group Meeting,
22-23 May 2013, Köln, Germany

Introduction

- FAA Advisory Circular (AC) 120-80, In-Flight Fires, 2004.
- **Definition of hidden in-flight fires:** "*Fires that are "hidden" are not readily accessible, may be difficult to locate and are more challenging to extinguish.*"
  - *examples:* fires behind sidewall paneling or in overhead areas.
- **Potential causes:**
  - Wiring failures, electrical component failures, lightning strikes, hot temperature bleed air leaks, faulty circuit protection.
- **Indications:**
  - Abnormal operation or disassociated component failures, circuit breakers, hot spots, odor, visual sighting – smoke.
- **Locations of interest:**
  - Overhead area, cheek area, sidewall panel.

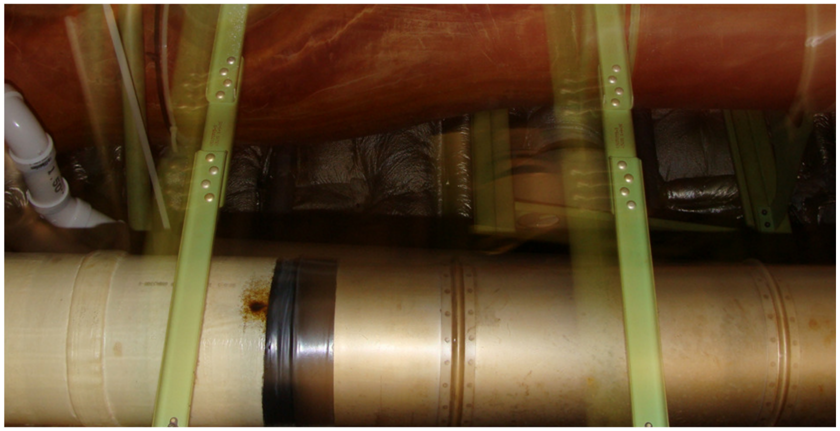


Objective

- Objective of the planned work is twofold
  a) to improve understanding of *hidden in-flight fires* with the help of analytical tools,
  b) to build analytical capabilities that will complement the existing experimental work for other fire scenarios.
- More specifically, the effect of
  - clutter,
  - ventilation/air circulation

  on the smoke movement due to a possible fire hazard in the overhead area of B747 SP aircraft will be studied using CFD (computational fluid dynamics).

Overhead area of **B747 SP** test article



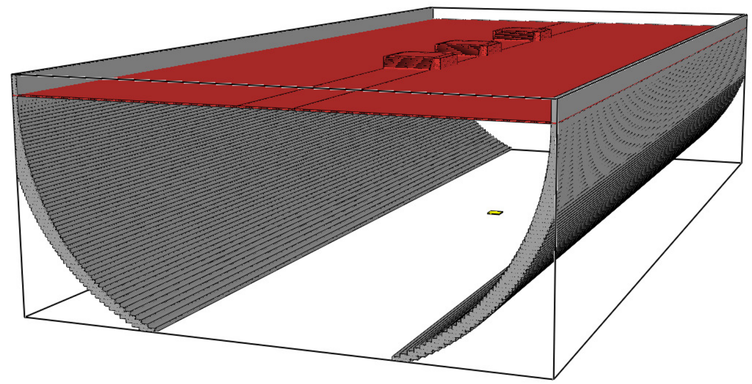
Methodology

Proposed steps of the technical approach:

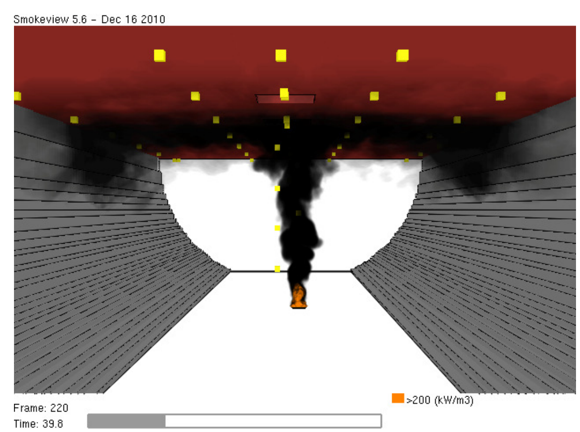
1. Use **CAD** (computer aided design) for the realistic representation of the dimensions and relative positions of the objects forming up the clutter in the overhead area,
   - such as air-conditioning ducts, wire bundles, other aircraft equipment and associated components.
2. Use **CFD** (computational fluid dynamics) for the solution of flow field as a result of aircraft system operations affecting the air movement,
   - such as ECS (environmental control systems) that determine the air-circulation, ventilation, etc.

   and the buoyancy-driven flow due to the specified fire hazard.

Example:
CAD model of B707 cargo compartment



Example:
CFD solution of smoke in B707 cargo compartment

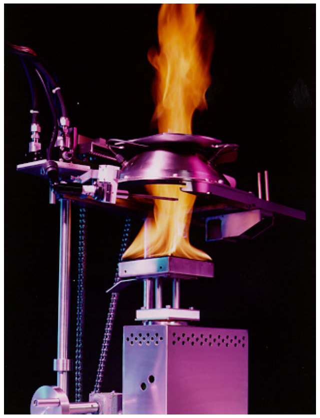


Methodology

3. Use laboratory/bench scale tests (such as TGA (Thermogravimetric Analysis), cone calorimetry, etc.)
   – for the characterization of the fire source to be employed in the full scale tests, and
   – for the determination of thermal and optical properties of selected materials within the cluttered area,
4. Determine type, number and location of instrumentation for full scale tests (such as thermocouples, anemometers, heat flux sensors, etc.),

TGA

Cone



Methodology

5. Conduct **full scale tests** in Boeing 747 test article at the FAA Technical Center when
   - ECS system is **on** but there is **no fire**,
   - ECS system is **off** but there is **fire**,
   - ECS system is **on** and there is **fire**.
6. Simulate all three scenarios using CFD models.
7. Compare simulation predictions with the test data for model validation.

B747 SP Test Article

Ongoing work

Next steps:

- Build CAD model of the overhead area of the 747SP test article.
  - Determine methodology and review available technology that will enable accurate measurements of internal dimensions.
- Set-up boundary and initial conditions for the CFD model.
  - Characterize the fire source,
  - Determine thermal and optical properties of chosen materials,
  - Specify accurate velocity field due to ECS.
- Plan for full-scale tests.
  - Identify appropriate instrumentation for the tests,
  - Specify their locations in the overhead area.

Ongoing work

Initial challenges:

- The exact dimensions of the obstructions in the overhead area are not known.
  - Measurements of each and every object is a major challenge.
- The operation of the ECS system, the amount of recirculation/ventilation, etc., is not clear.
  - Velocity measurements when there is no fire in the overhead area will be needed to quantify the air movement prior to fire.
- To avoid computational cost associated with the large overhead volume it is necessary to define a small section and work only in this part of the overhead area.
  - It is not clear how this decision should be made.