AircraftFire

European-Union 3.2 Million Euro research project

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On behalf of:

AircraftFire Team

AircraftFire – Presentation Scope

- Introduction to European Union 'Framework programme'
- Introduction to 'AircraftFire' Team
- Outline experimental work within 'AircraftFire'
- Key issues for the future

AircraftFire

Fire risks assessment and increase of passenger survivability

Framework 7

- The European Union’s instrument for supporting research
- Budget of over 50 B Euros
- Participants required to provide a financial contribution
- Framework 7 concludes 2013, to be followed by new instrument ‘Horizon 2020’

AircraftFire

- Progress Beyond State-of-the Art
- Investigation covering all fire aspects from ignition through to safe evacuation of passengers

AircraftFire - Scope

<u>In-flight</u>

<u>Post-crash</u>

Impact
Pool fire
Burnthrough
Evacuation

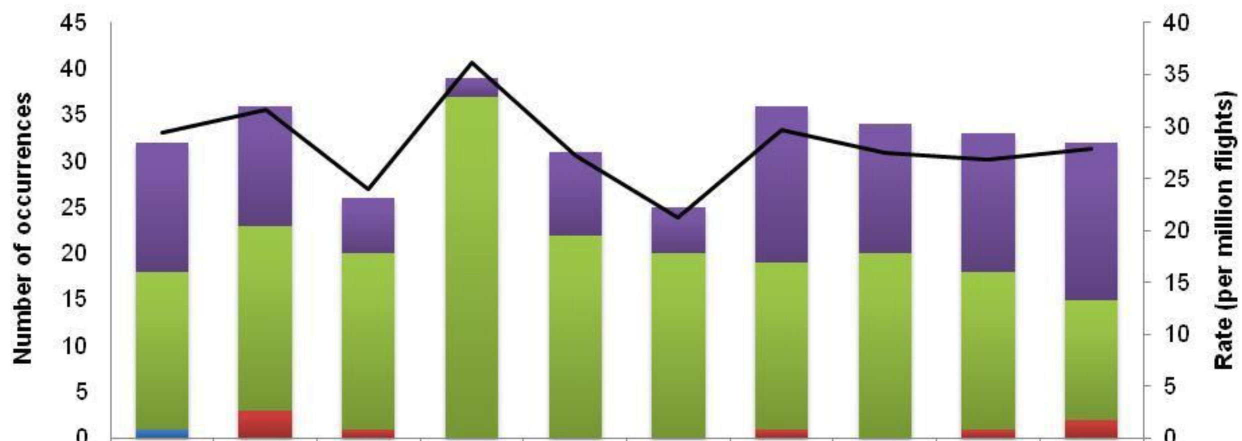
Purpose of AircraftFire

- To investigate fire safety issues of new-generation composite aircraft
- Not a regulatory-requirements based study and therefore able to explore longer-term issues
- To be holistic, bringing different scientific disciplines together
- General in nature, not aimed at a particular aircraft type

Work Package Structure

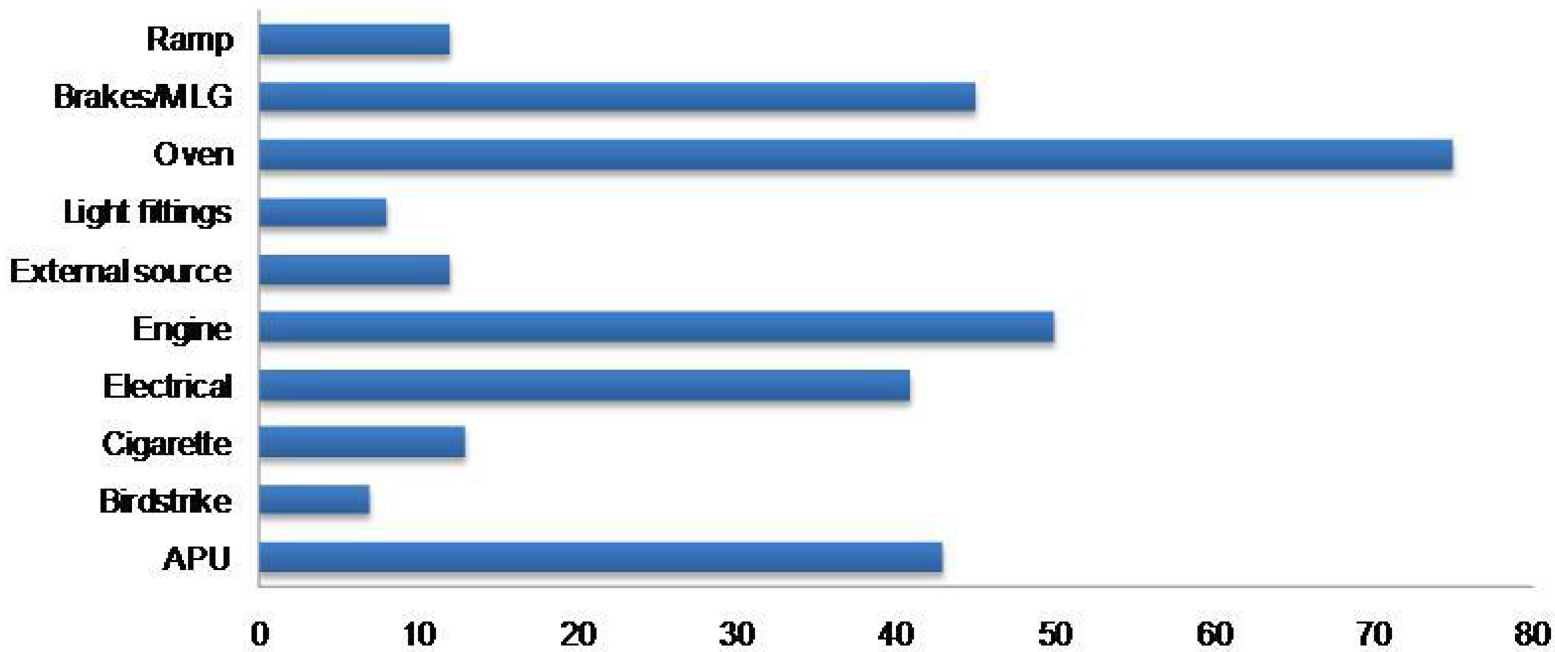
- WP1 Fire Threat Analysis
- WP2 Fire Prevention
- WP3 Modelling of Generic Fire Configurations
- WP4 Simulation Tools
- WP5 Synthesis of Results
- WP6 Project Management
- WP7 Exploitation and Dissemination

Fire Threat Analysis



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
D	14	13	6	2	9	5	17	14	15	17
C	17	20	19	37	22	20	18	20	17	13
B	0	3	1	0	0	0	1	0	1	2
A	1	0	0	0	0	0	0	0	0	0
Rate per million flights	29.42	31.69	24.01	36.17	27.27	21.28	29.74	27.46	26.89	27.82

Fire Threat Analysis

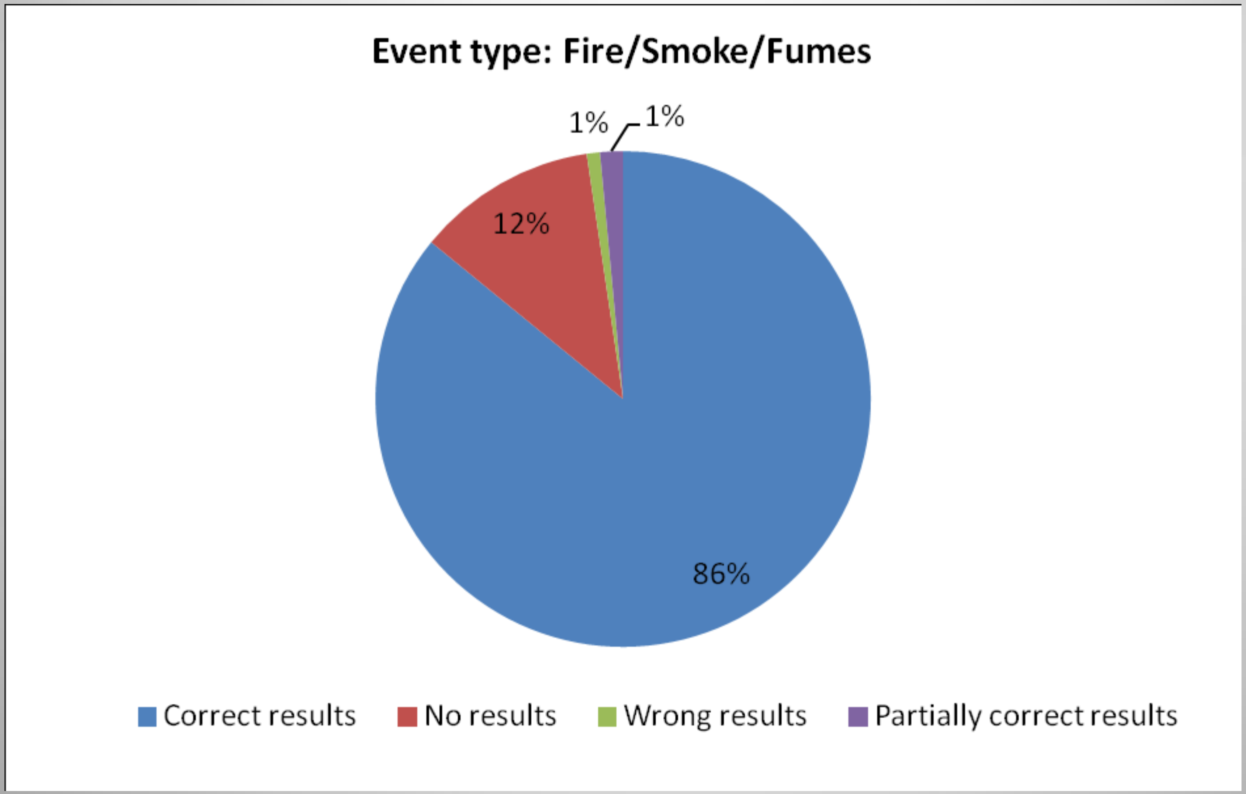


	APU	Birdstrike	Cigarette	Electrical	Engine	External source	Light fittings	Oven	Brakes/MLG	Ramp
Total	43	7	13	41	50	12	8	75	45	12

number of occurrences

Fire Threat Analysis

Text Analysis



Fire Threat Analysis
Data Mining

Fraunhofer	CAA	Comments
IFE occurrences often in XXXX	In agreement	N/A
APU occurrences often in XXXX	In agreement	Also XXXs show similar trend
Unusually many brake fires on XXXX	In agreement	Also XXXXs show similar trend
Unusually many seat fires on XXXX	In agreement	Same with IFE, because seat fires are normally IFE fires
In XXXX fumes often occur during landing	Not in agreement	CAA analysis shows that most fume events in XXXXs occur during descent

Accident timeline – In-flight fires

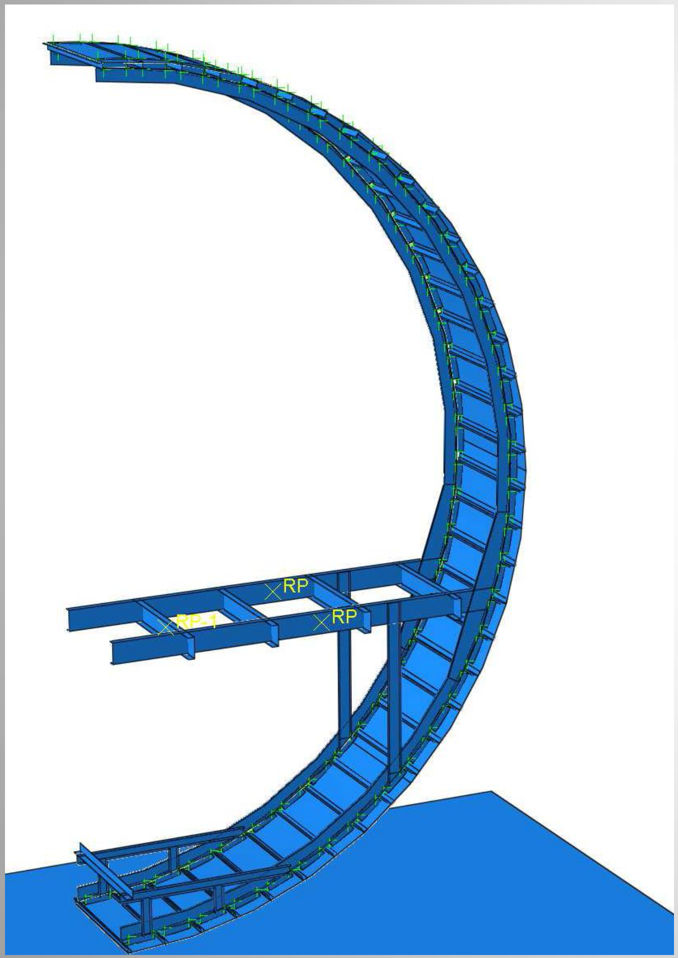
- Hidden area fires
  - Detection
  - Extinction
- Contribution of composites
  - Flammability
  - Toxicity

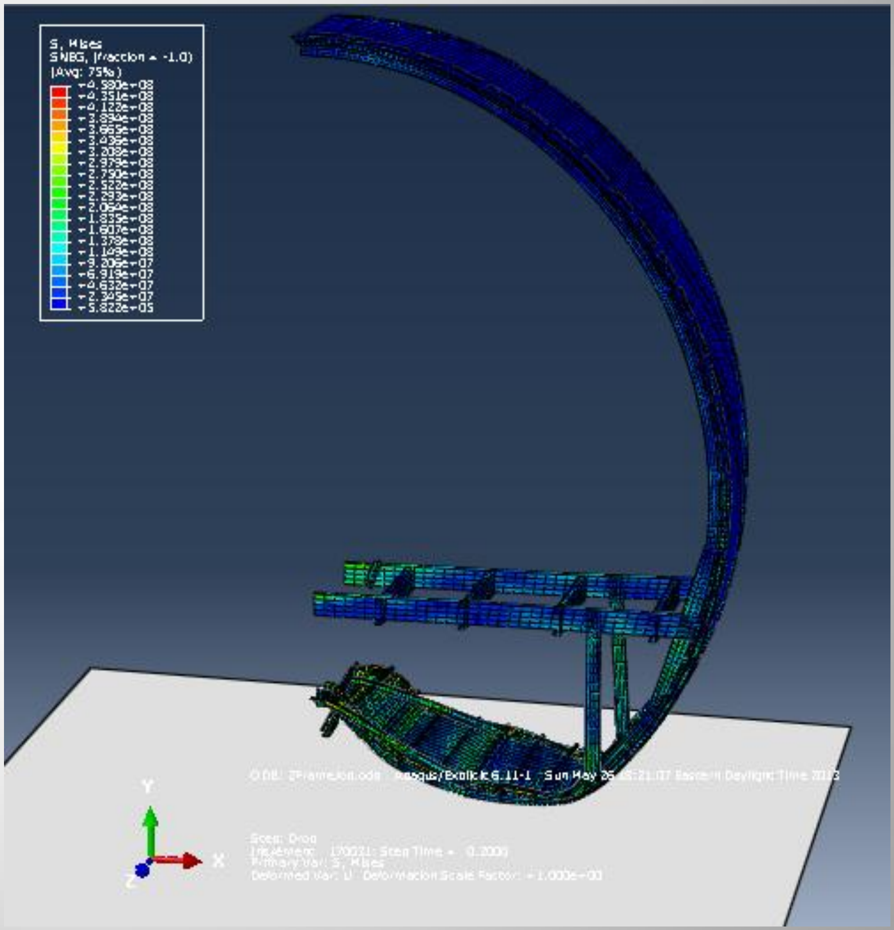
Accident timeline – Post crash fires
Impact model

- Create dynamic models to compare crash between metallic and composite aircraft
  - Therefore compare existing metallic body a/c with composite
  - Can compare the crash characteristics of an A320/B737 with simulated performance of a composite a/c
    - Validate model for A320
      - Two-frame test
      - Section test (certification)
      - Full fuselage
    - Repeated for A330 and composite aircraft

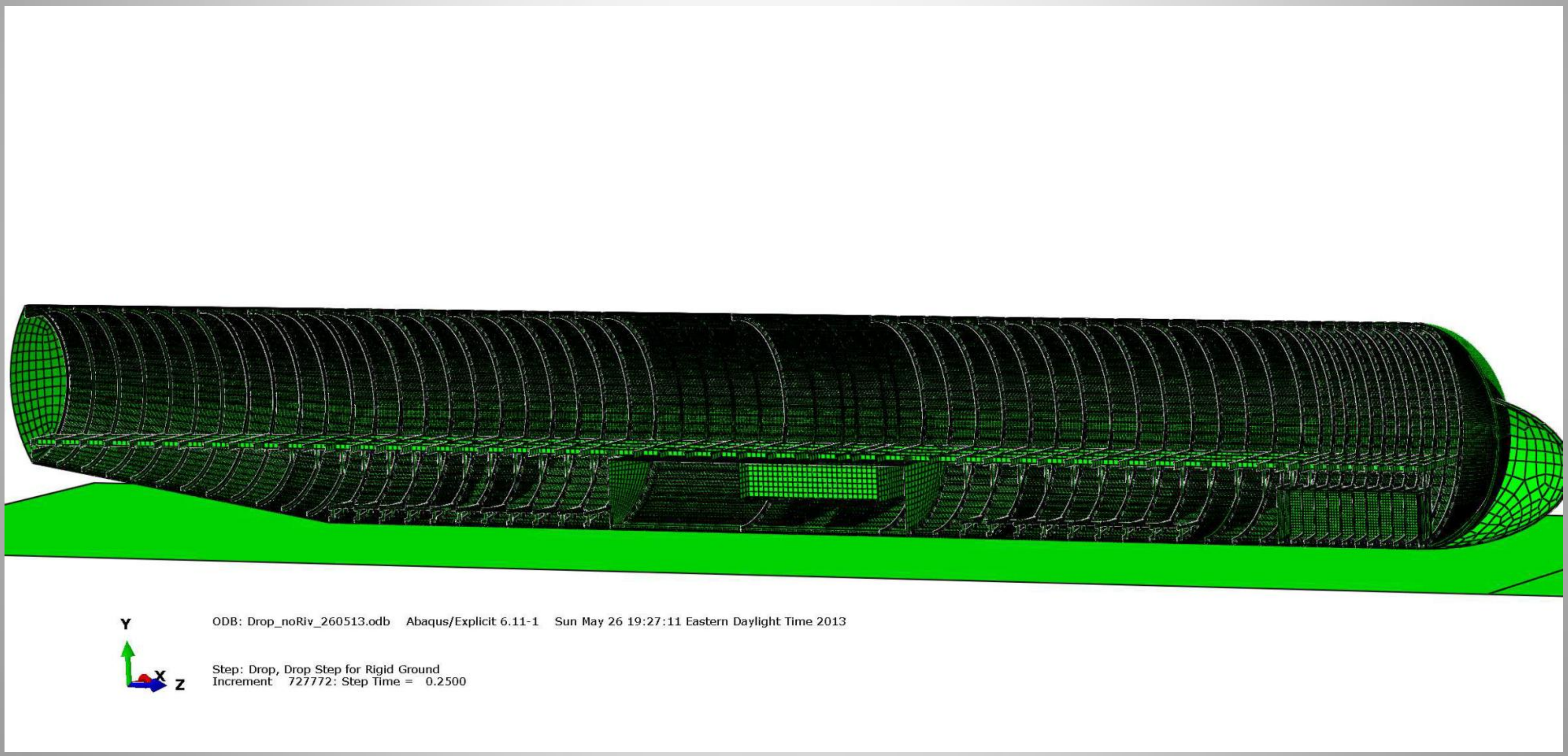
Accident timeline – Post crash fires

Impact model



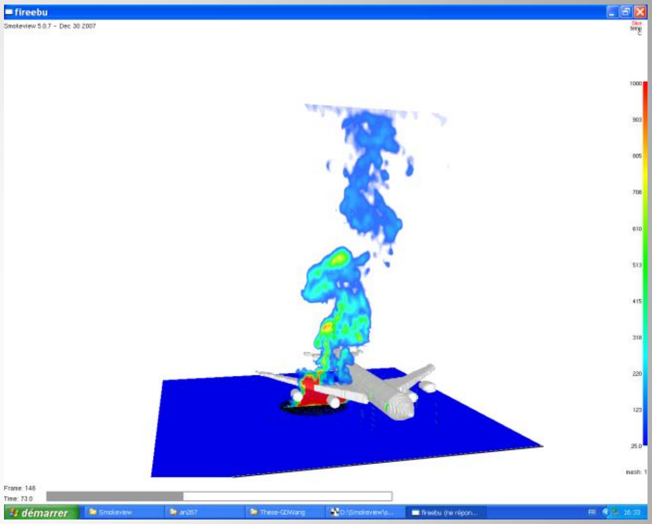


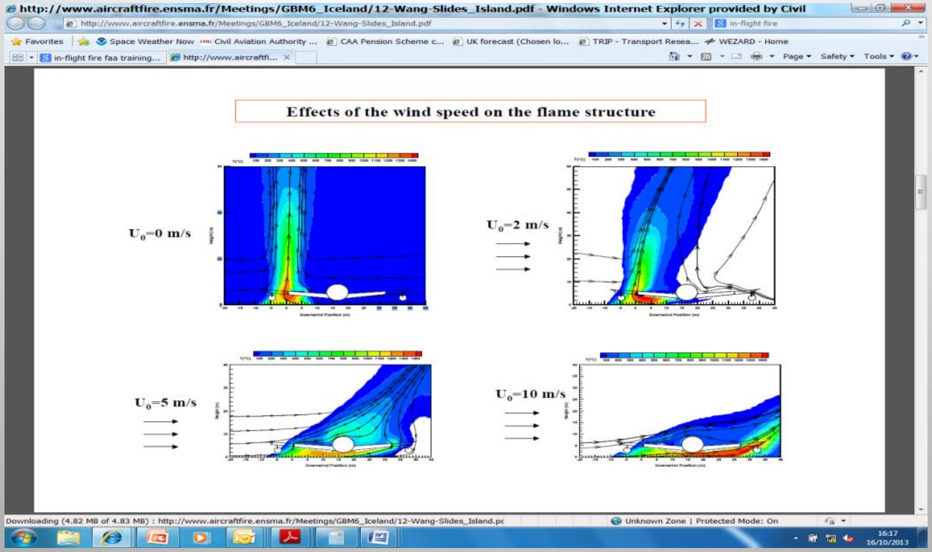
Accident timeline – Post crash fires
Impact model



Accident timeline – Post crash fires

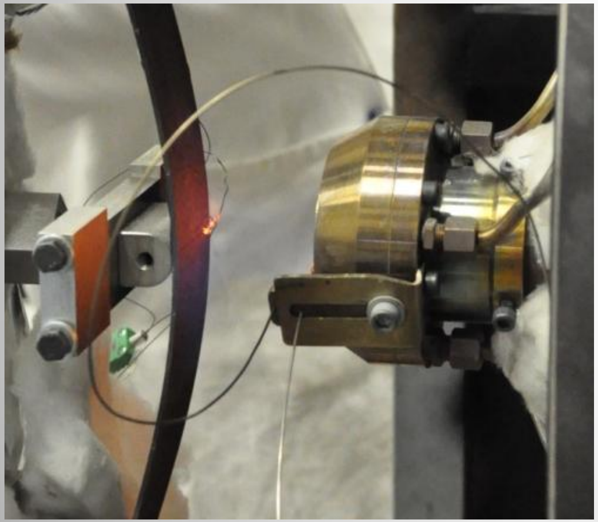
Pool fire simulation



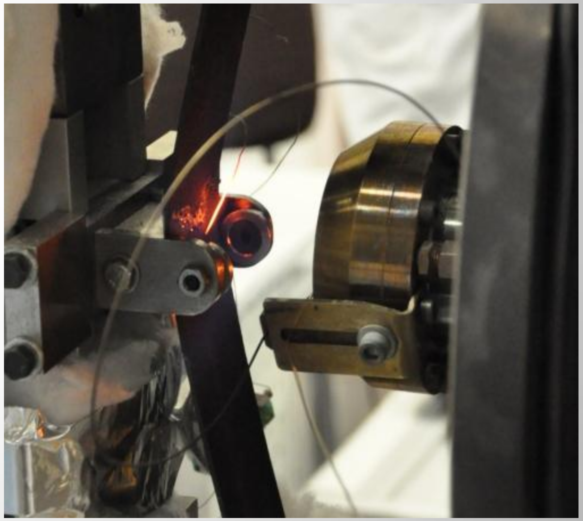


Accident timeline – Post crash fires

Burning composites under load



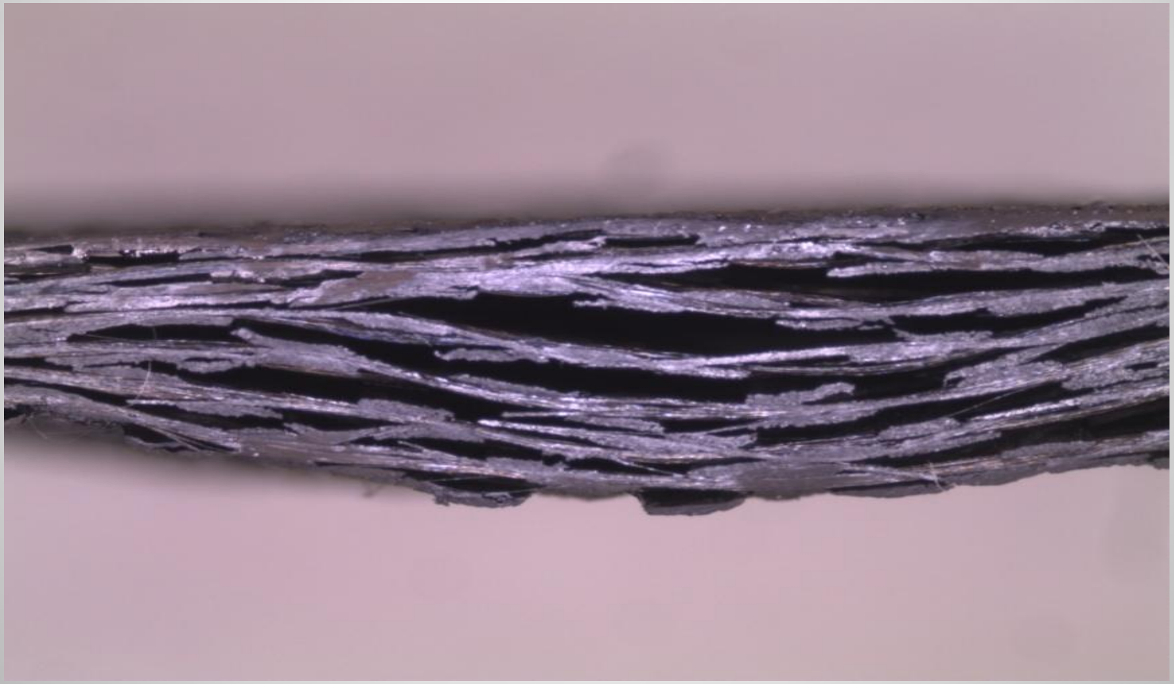
Constrained fibres
exposed to the flame:
Tension stress



Constrained fibres
exposed to the flame:
Compression stress

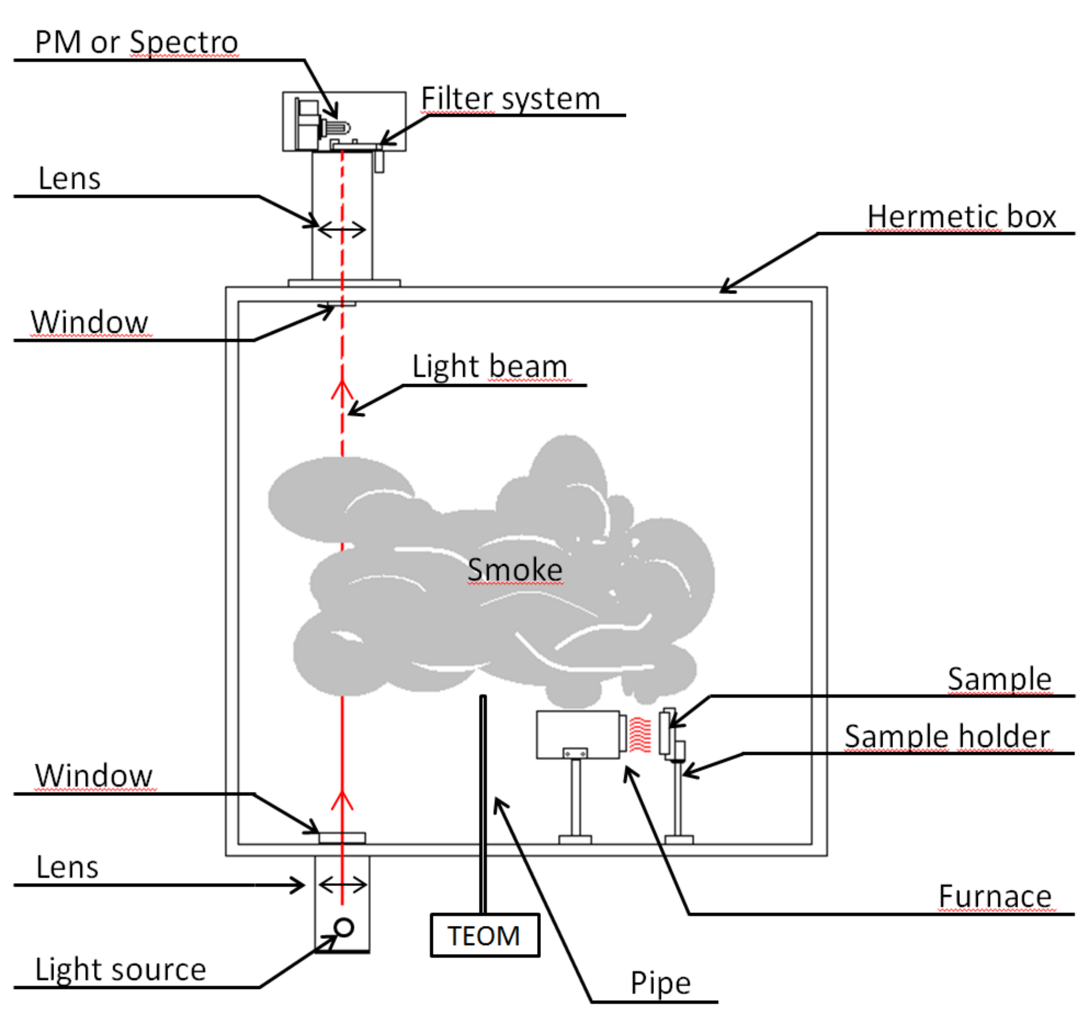
Accident timeline – Post crash fires

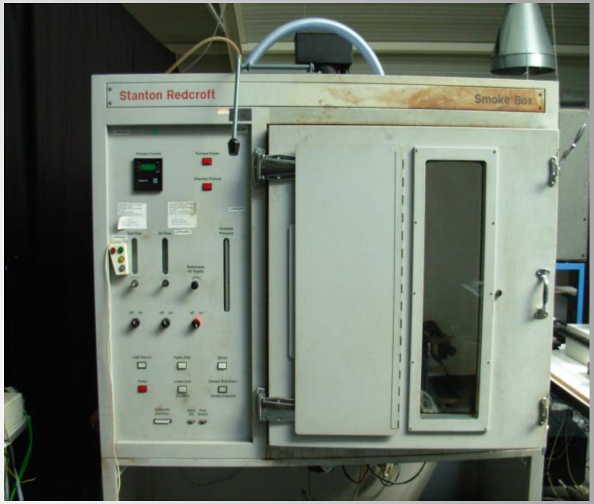
Burning composites under load



Accident timeline – Post crash fires

Smoke characterisation





ASTM E662-9 and ISO-5659-2 **standards**

Accident timeline – Post crash fires
Optical Effects of Smoke Simulation

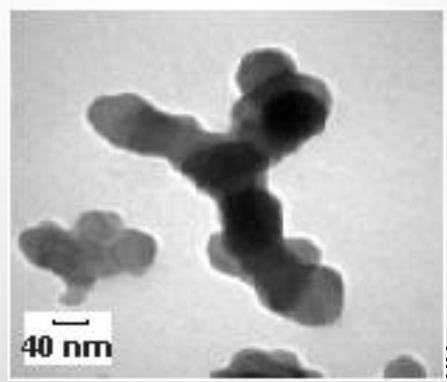
- **Quantum-Electrodynamics** approach to describe light-smoke interaction: Combination of Rayleigh and Mie Theory and geometry to describe smoke effects

Light attenuation

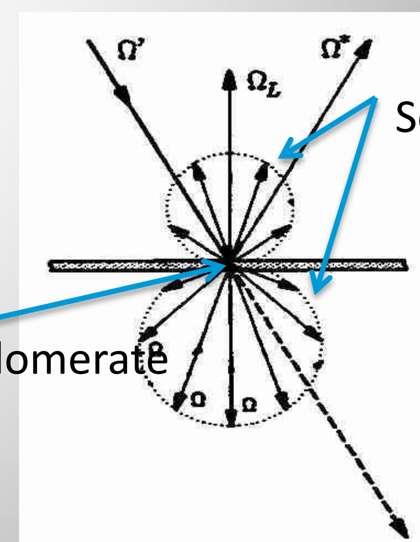
•Main influence by soot

•Light absorption

•Light scattering



gglomerate



Scattering

Accident timeline – Post crash fires

Heat transport characteristics in composites in composites and cabin materials

- Non-isotropic materials – conducting heat better in the direction of fibre
- Heat transfer characteristics substantially affected when subject to damage
- Thermal behaviour of non-homogeneous samples have limited predictability

Accident timeline – Post crash fires

Pyrolysis – a modelling challenge

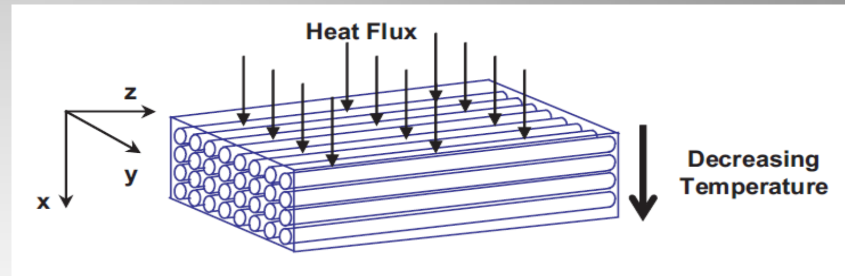
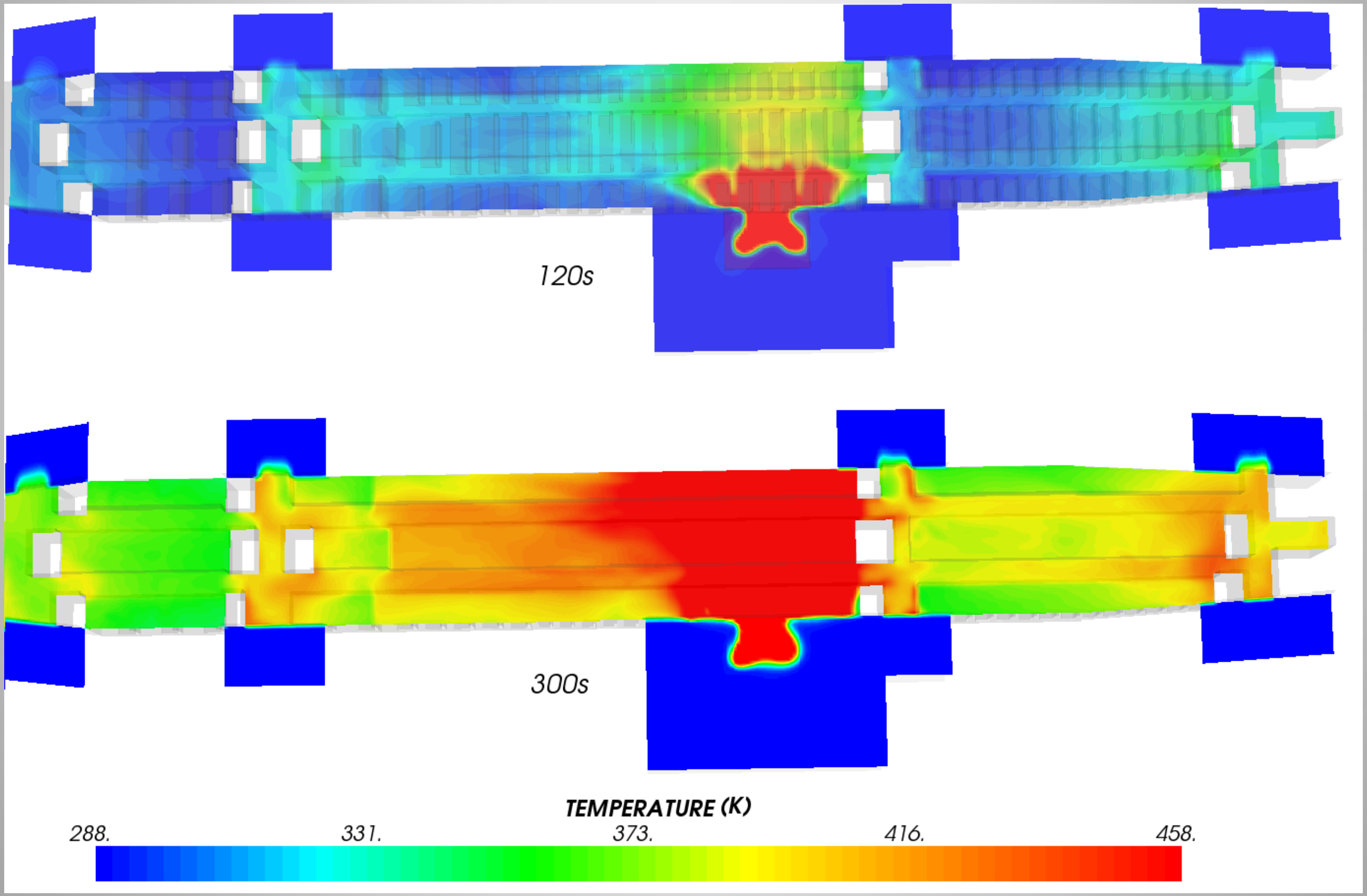


Table 5.1. Summary of the main processes when a composite is exposed to fire.

Anisotropic heat conduction through virgin material and char
Thermal expansion/contraction
Decomposition of polymer matrix and organic fibres
Pressure rise due to formation of combustion gases and vapourisation of moisture
Flow of gases from the reaction zone through the char zone
Flow of gases into the virgin composite
Thermally-induced strains.
Formation of delamination and matrix cracks
Reactions between char and fibre reinforcement
Ablation

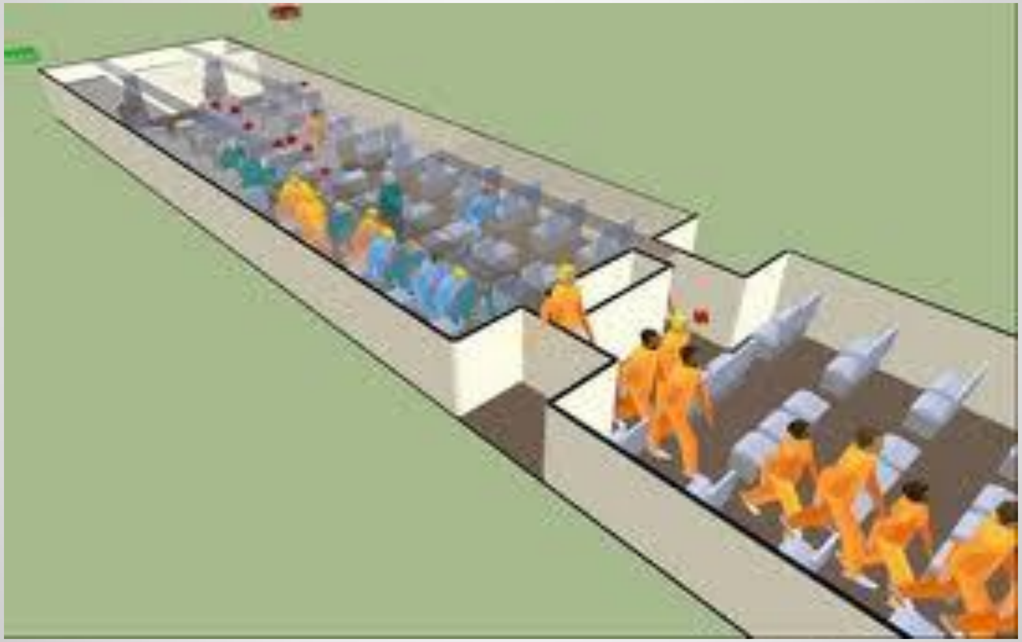
Accident timeline – Post crash fires

Cabin fire simulation



Accident timeline – Post crash fires

Evacuation simulation



Fire measurements in AircraftFire based on typical scenarios

- The effect of under ventilation and the depletion of oxygen
- Smouldering
- Fire spreading from a local initial fire
- Presence of unburned pyrolysis gases which may ignite if oxygen concentration is increased
- Burnthrough related phenomena
- Burning composites under load

Materials Selected for Characterisation

- 12 Different commercial materials representative of use in new-generation aircraft
- Anonymised, designated ACF 1-12

- Mixture of structural and cabin materials plus thermal-acoustic insulation

Material Characterisation

- Conductivity, Specific heat
- Ignition temperature (or the critical heat flux)
- Heat of combustion
- Heat of pyrolysis
- CO, CO_2 and smoke yields
- Smoke point height
- Kinetic parameters for reaction (i.e. activation energy and pre-exponential factor)
- Fuel concentration in the pyrolysis gas
- Char properties

Detailed information for Simulation

Ignition and flame spread data

There are four ignition criteria in the flame spread model. These are:

1. The material surface temperature reaches its ignition temperature;
2. The pyrolysis front advances from an adjacent burning cell face to the cell face in question;
3. The flame envelope is in contact with the material and the flame reaches a critical temperature for a critical period of time;
4. The surface is exposed to a critical heat flux for a critical period of time.

Data required

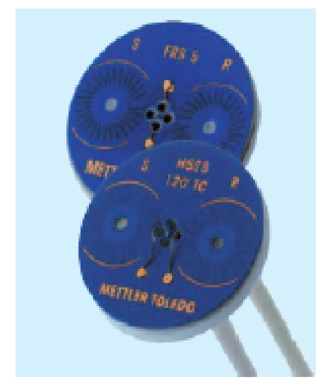
- flame spread rates (m/s) in three modes
  - upward flame spread rate (face-up and face-down) at a number of different angles of the surface to the vertical
  - downward flame spread rate and
  - lateral flame spread rate if lateral flame spread is observed in the tests
- Surface Ignition Temperature (K)
- Critical flame temperature (K) exposed to a surface that ignites the surface after a period of time and the delay before surface ignition (s)
- Critical Radiative Heat Flux (W/m^2) exposed to a surface that ignite the surface after a period of time and the delay before ignition (s)
- Heat release rates or fuel loss rates
- The model needs the heat release rates of a material (or fuel loss rates) of unit surface area, which can be collected from small-scale experiments, like cone calorimeter tests at various irradiance levels. Heat release rates at three external irradiance levels of 25 kW/m^2, 35 kW/m^2 and 50 kW/m^2 may be required.
- Heat of pyrolysis

Characterisation Techniques

- Thermogravimetric Analysis (TGA)
- TGA FTIR/MS
- Differential Scanning Calorimetry (modulated)
- Cone Calorimeter
- Universal Flammability apparatus
- Smoke Box

Differential Scanning Calorimetry (DSC)

This experiment determines as a function of temperature the difference in the amount of heat required to increa temperature of a sample and reference.



Measurement of:

- Glass transition temperature (T_g),
- Melting temperature (T_m),
- Heat of melting (ΔH_m),
- Heat of pyrolysis (ΔH_{pyr}),
- Specific heat (c_p).

Thermogravimetric analysis (TGA)

This experiment determines changes in sample weight in relation to changes in temperature.

Sample mass of about 10mg → Material is uniformly heated.

Tests performed in Nitrogen or Air.

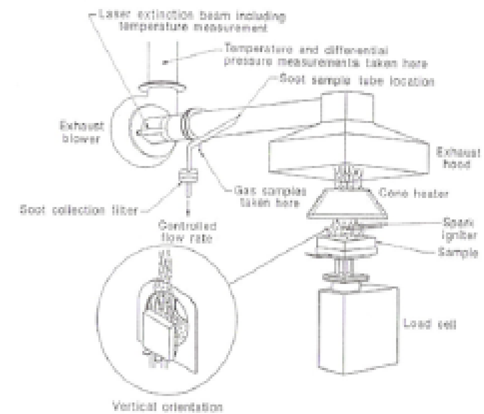
At three heating rates: 5, 10 and 20K/min.

Used to study thermal decompositions of polymers.

From these tests:

- Decomposition steps and temperatures
- Amount of residue
- Pre-exponential factor and Activation energy

Cone calorimeter

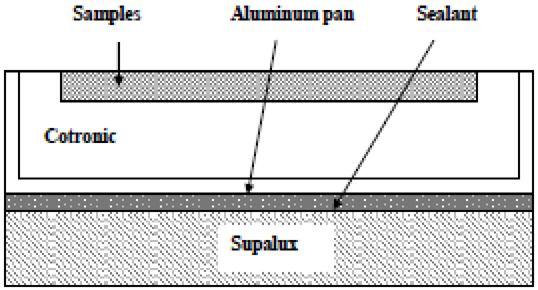


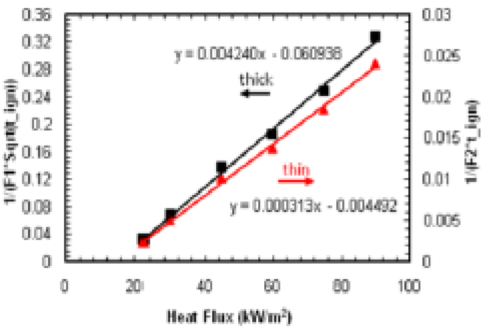
Principle: A 100 x 100 x 4 mm^3 sample is exposed to an external heat flux.

Ignition time, mass loss, CO&CO_2 production, O_2 depletion, light extinction are measured.

Determination of:

- CO, CO_2 and smoke production rates and yields,
- Heat release by oxygen consumption method,
- Material properties from ignition times (c_p, k, T_{ig}, α and).





Universal Flammability Apparatus

UFA has the same measurement principle as cone calorimeter but in a controlled atmosphere: A flow of air or a mixture of gases circulates upwards in the quartz tube

$$\phi = \frac{\text{Actual fuel / Air ratio}}{\text{Stoichiometric fuel / Air ratio}}$$

<u>3 methods to modify the equivalence ratio</u>:

$$\psi_0 = \frac{\Delta H_{C,eff}}{\Delta H_0}$$

$$\Phi = \frac{\dot{m}_{loss} \times \psi_0}{O}$$

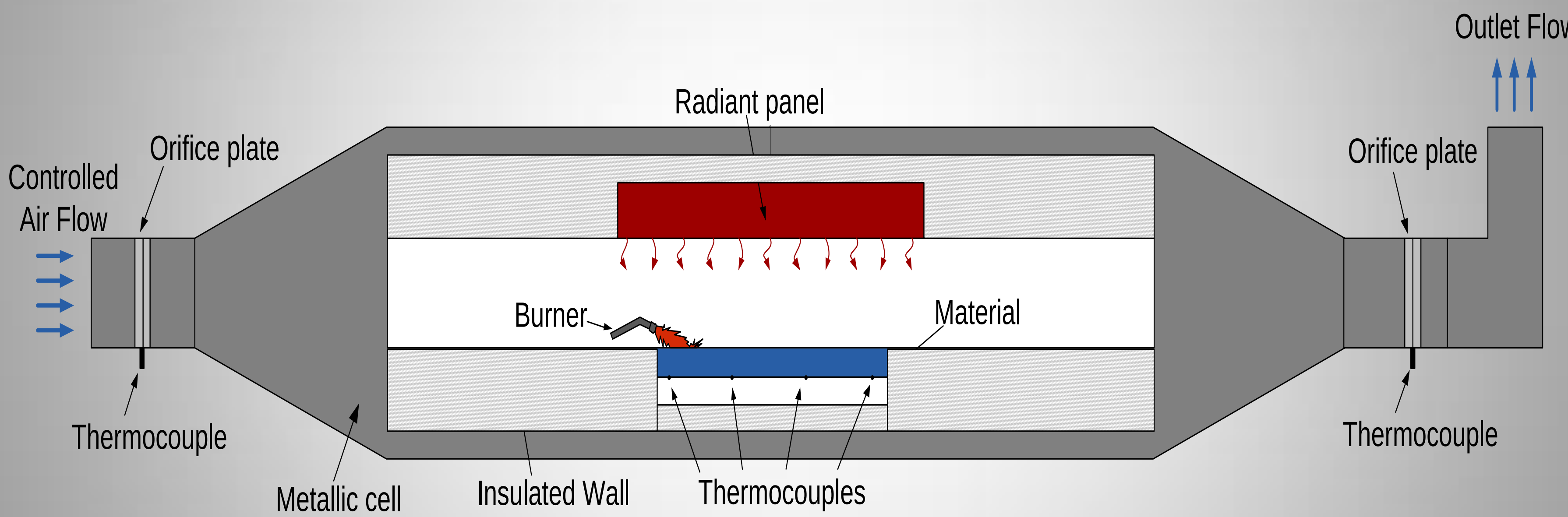
$\boldsymbol{O}$ **(mg/min)=** $\boldsymbol{P}$ **(lit/min) x [** $\boldsymbol{O_2}$ **] x 1330**

1) External Heat Flux

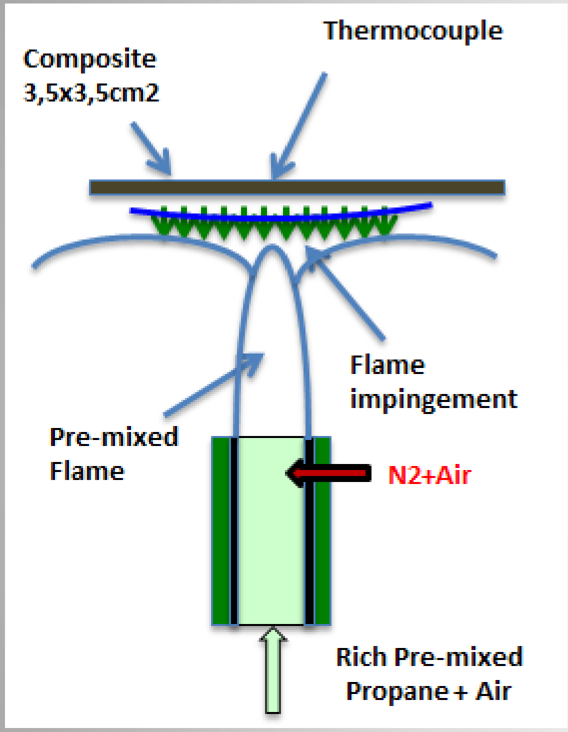
2) Variation of Air flow rate

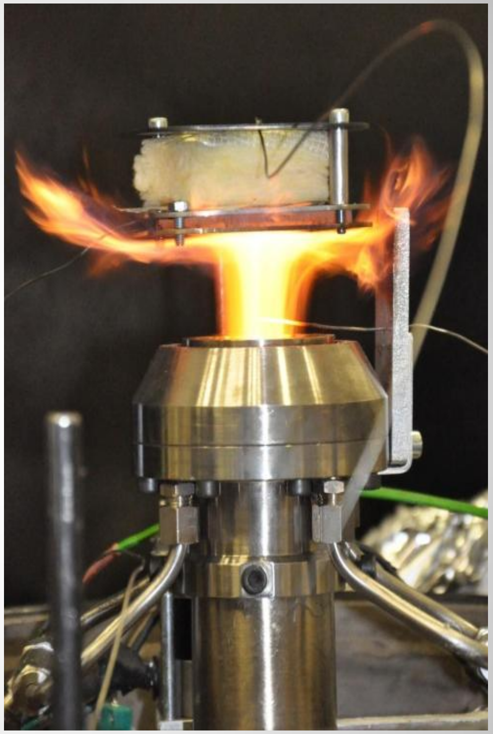
3) Variation of O_2 concentration

Custom Experimental Equipment



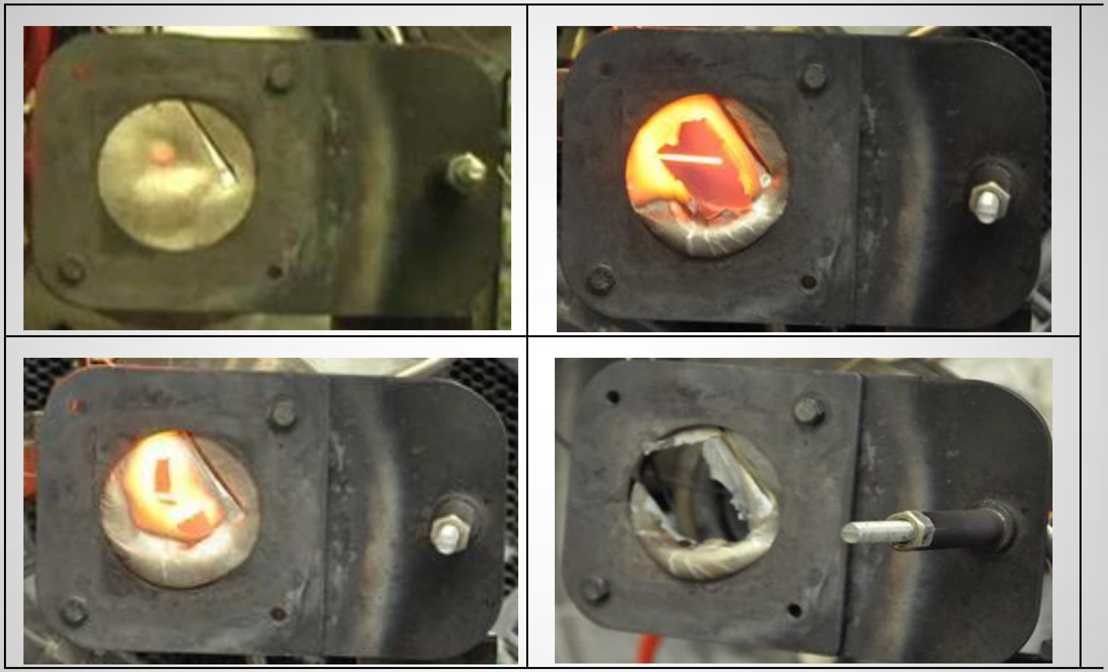
Lab-scale Burnthrough Test Facility



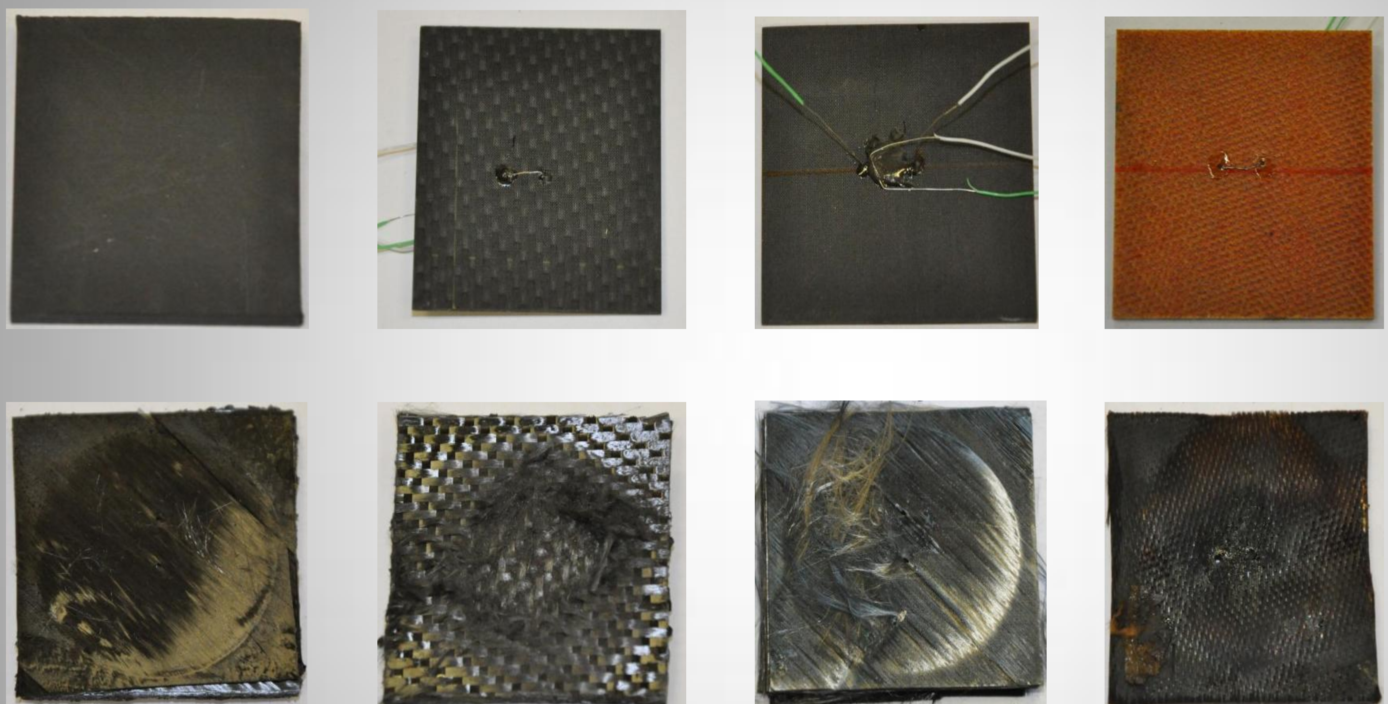


Inside burner dia 35mm
Burner-sample distance
1.7,3.5 and 5.2 cm

Aluminium Burnthrough



Composite Testing

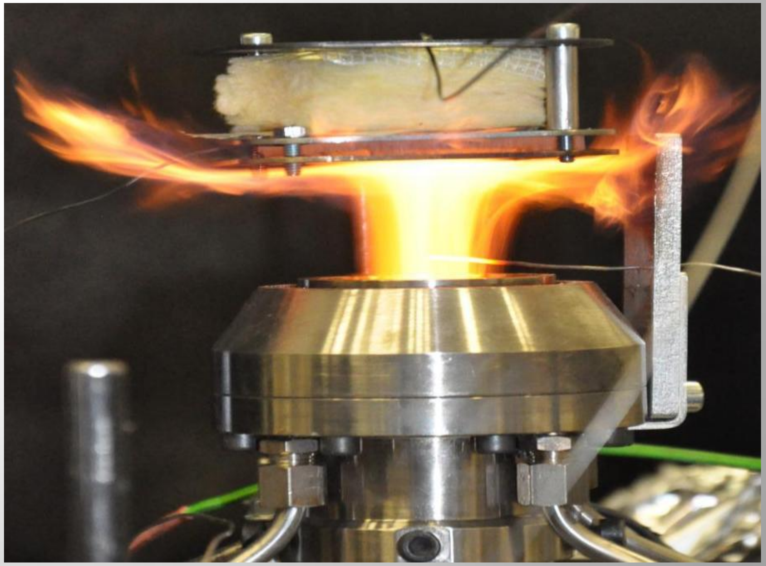


Before

After

Burnthrough: Standard test burner

Burnthrough: AircraftFire experimental burner



Fast and low cost tests for materials

Conclusion

- Extensive, detailed consideration of holistic fire considerations of new-generation aircraft
- Database of information to support future safety studies
- Workshop to present results in 2014