



# *Full-Scale Aircraft Fire Tests*

August 22 & Sept 9, 2014

A comparison of Aluminium and Composite Burn-Through

Chief François Jacquet, OIAA ERS  
Ron Gould, NRC Aerospace (Retired)  
Simon Hind, NRC Aerospace



LTR-SMM-2015-0414

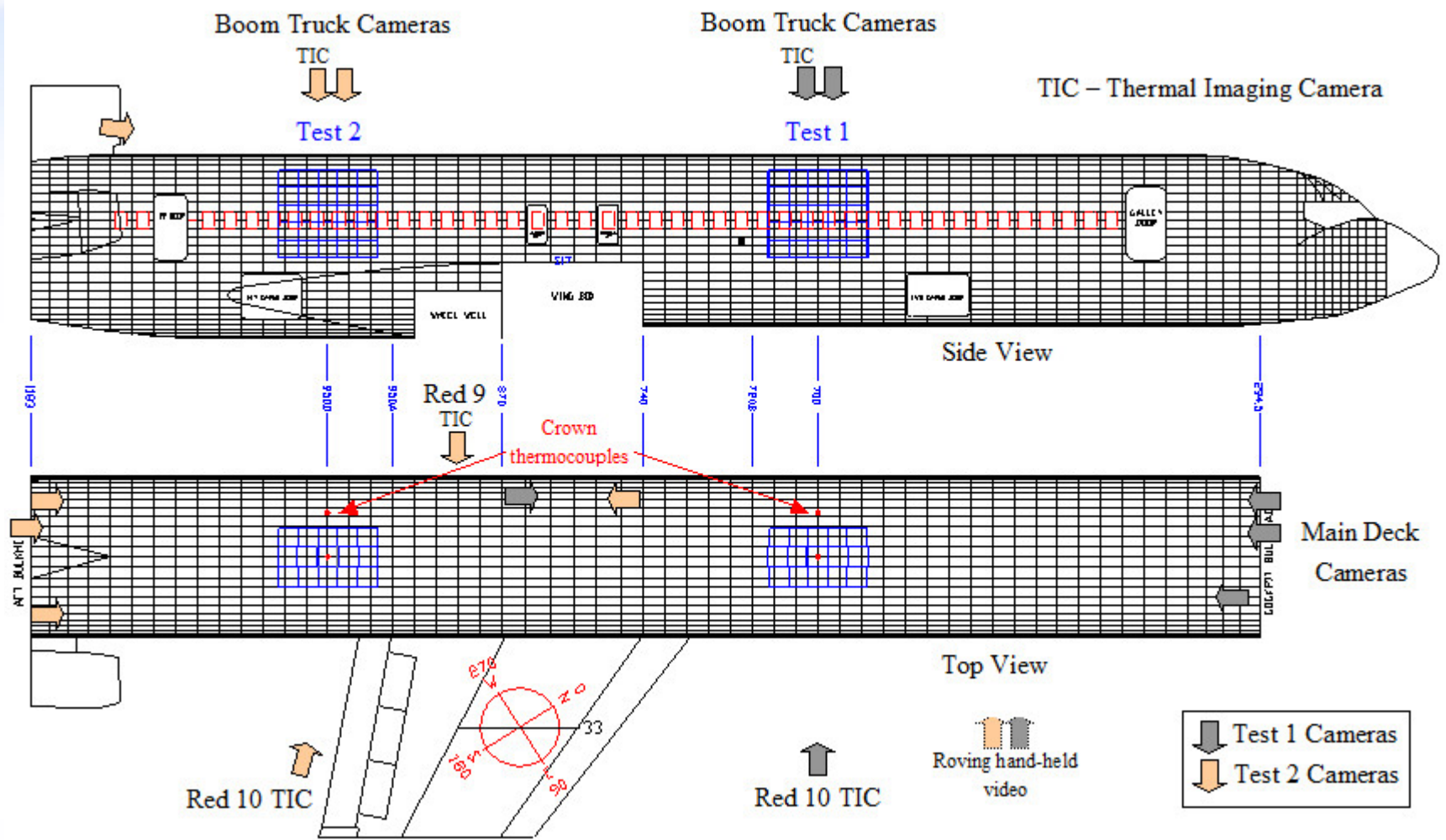


International Airport  
Authority



Administration de  
l'aéroport international  
Ottawa

# Test 1 & Test 2 Fire Locations & Camera Positions



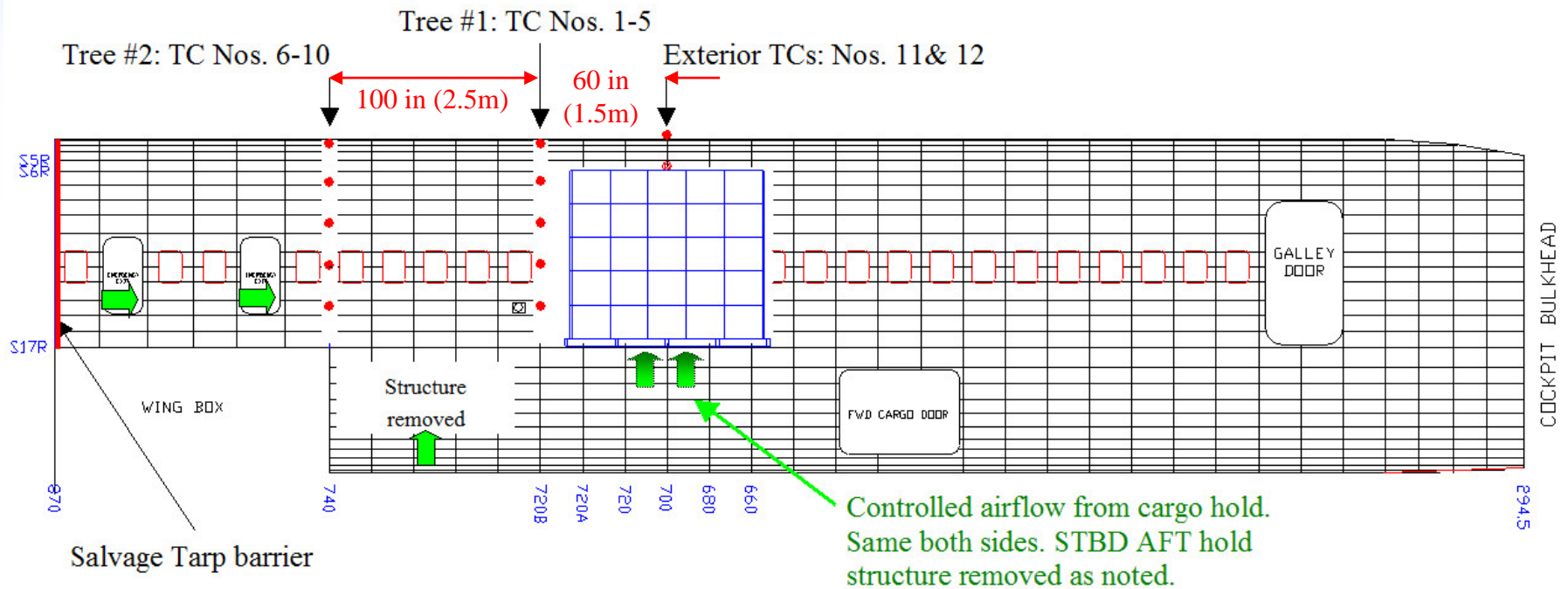
9 cameras for Test 1  
10 cameras for Test 2

International Airport  
Authority

Ottawa

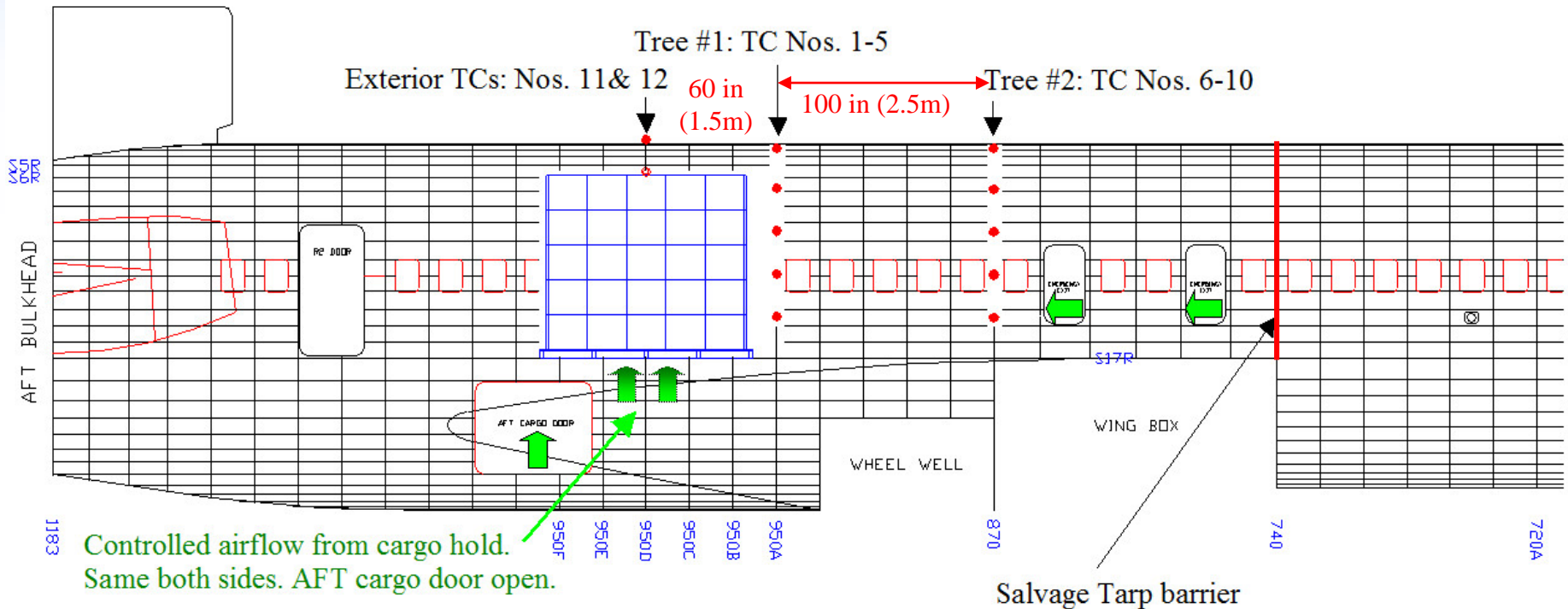
Administration de  
l'aéroport international

# Test 1 Fuel Package, TCs and Airflow



Main deck test area volume: 2,766 ft<sup>3</sup> (78.3 m<sup>3</sup>)

# Test 2 Fuel Package, TCs and Airflow



Main deck test area volume: 2,239 ft<sup>3</sup> (63.4 m<sup>3</sup>). 19% smaller than Test 1.

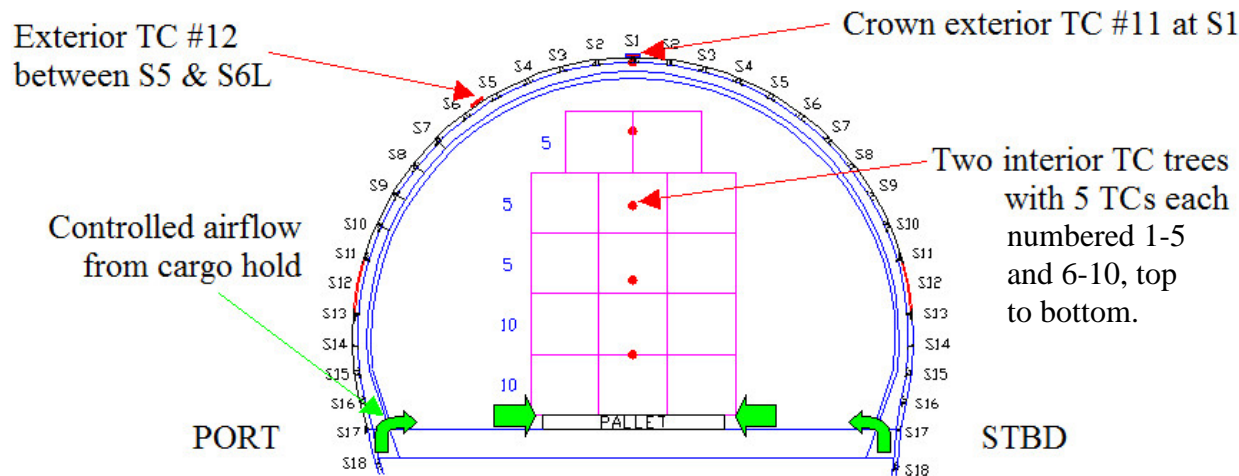
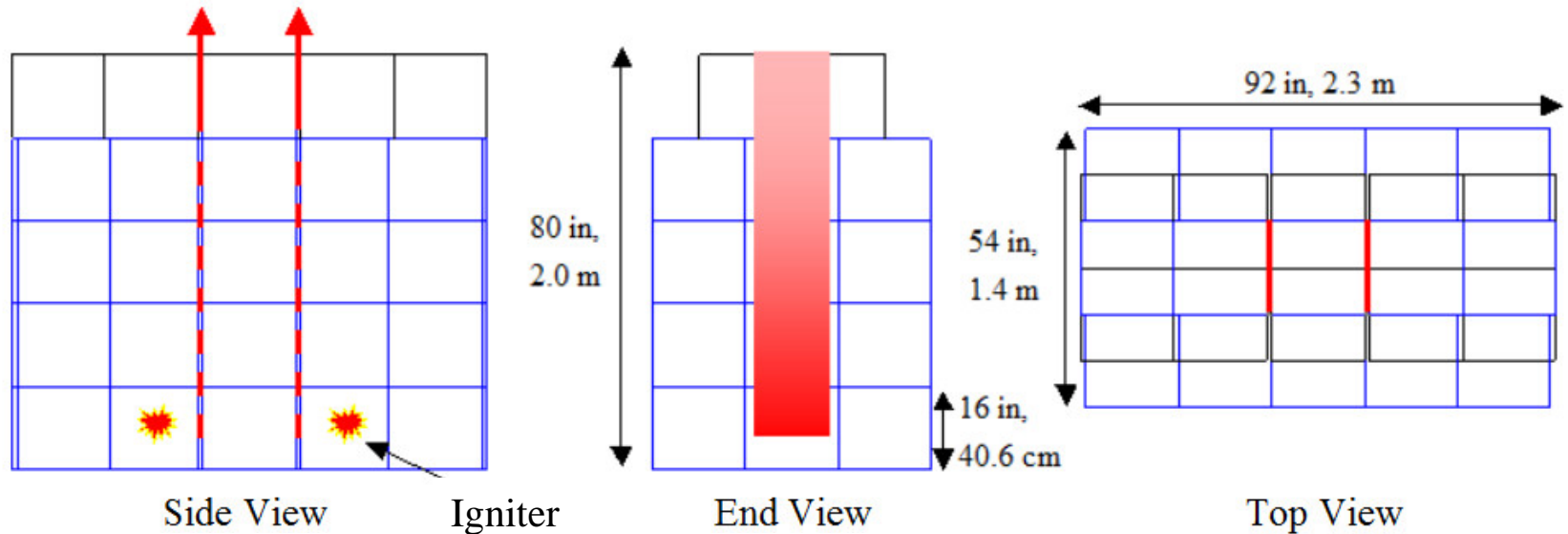
International Airport  
Authority



Administration de  
l'aéroport international



# Fuel Package



**Fuel: 500 lb (226.8 Kg) of shredded books.**

**Accelerant: 0.18 Imp Gal (0.8L) diesel fuel.**

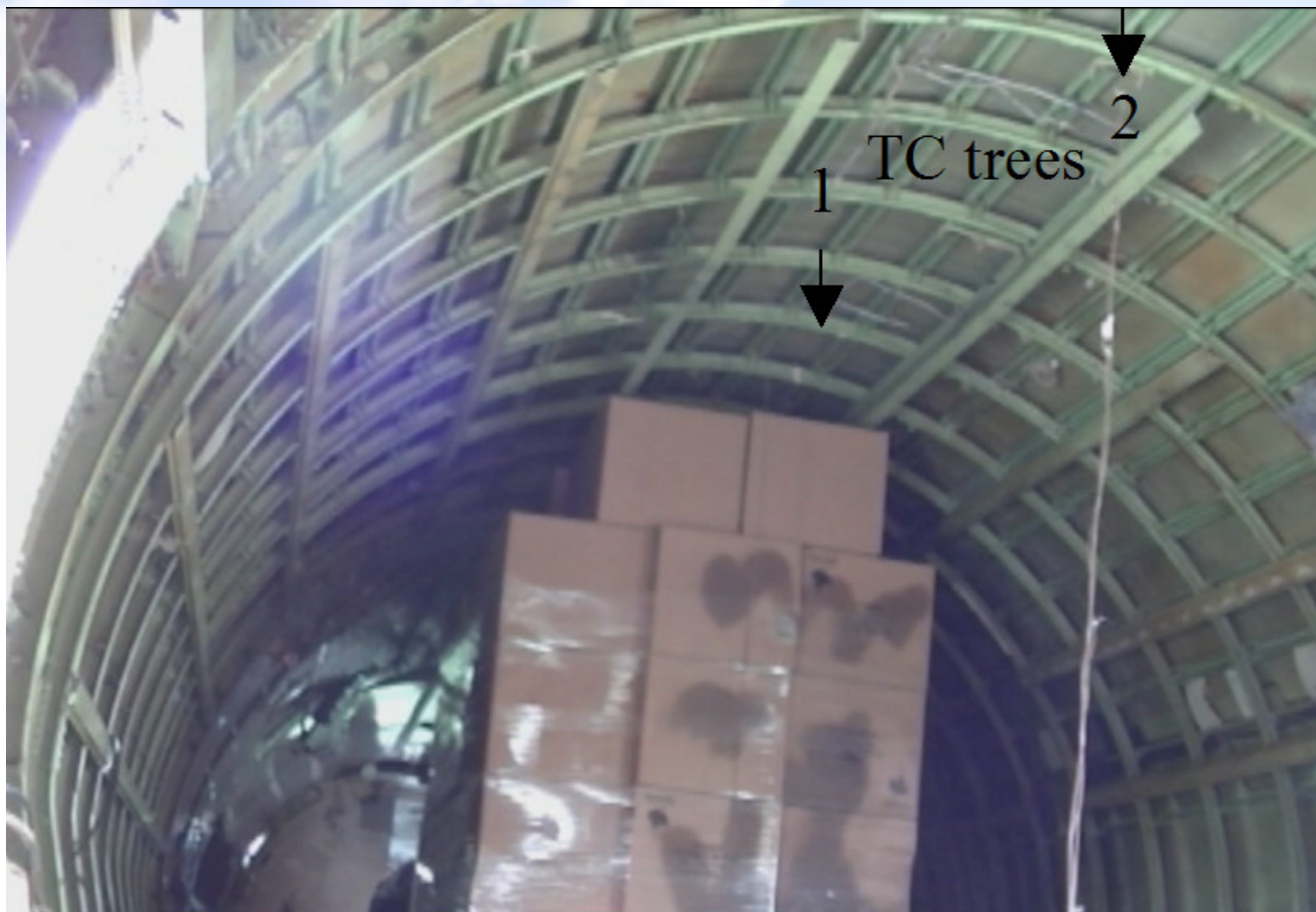
**Igniters: Overheated Lithium primary battery.**

International Airport  
Authority



Administration de  
l'aéroport international

# Test 1 Fuel Package, TC Trees



Looking FWD from PORT AFT over-wing exit

International Airport  
Authority

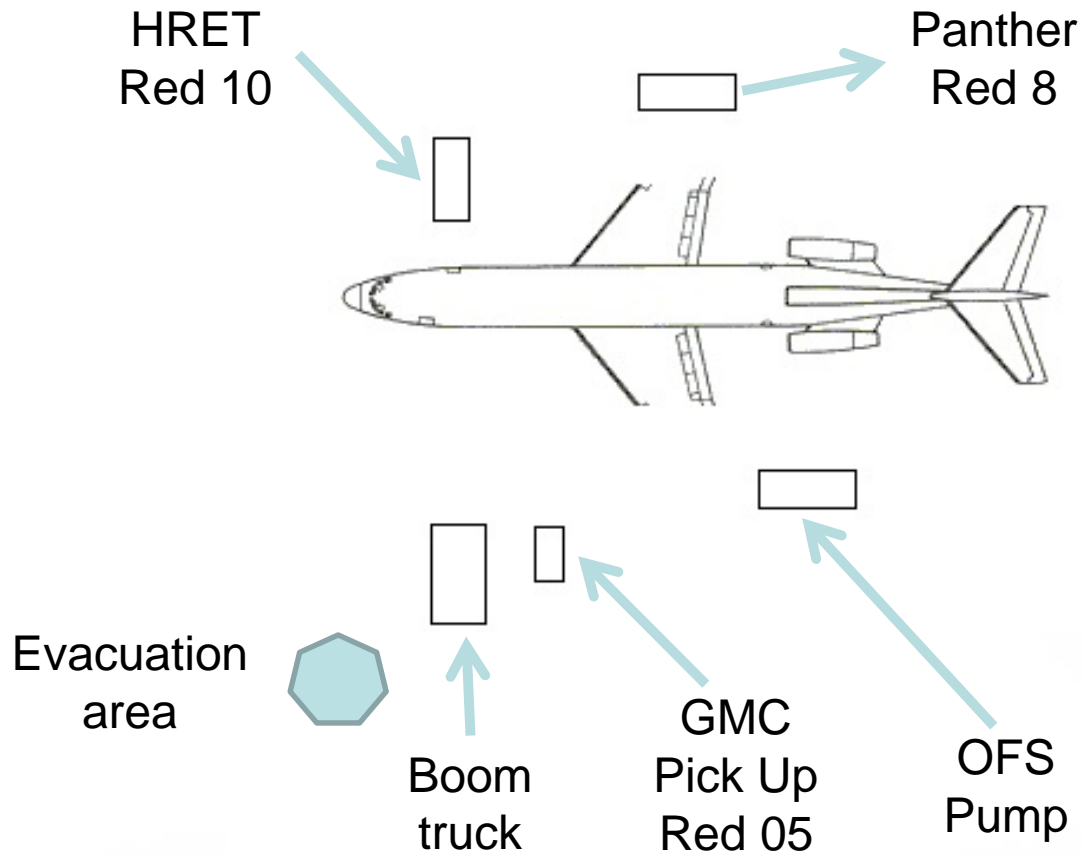
Ottawa

Administration de  
l'aéroport international



# Fire Operations

1. Incident Commander – Location: Red 05.
2. Safety Officer – OFS – Location: Mobile.
3. Radio Communication – Airport Fire 1 & 3.4.
4. HRET Red 10 – Pre-positioned right hand side B727-200.
5. HRET Deployed - Mid Attack. Location: Midway between R1 and over wing exit.
6. Both wings laddered.
7. OFS Pump – Location Left hand side.
8. Two airport firefighters on right wing with CAFS line charged.
9. Two OFS firefighters on left wing with 1.75 in line charged.
10. Spare ARFF vehicle in service.
11. Spare SCBA Units to be used.
12. Total personnel on site: 1 Chief Officer, 3 Captains, 9 Firefighters & 1 Safety Officer – Total 14 firefighters



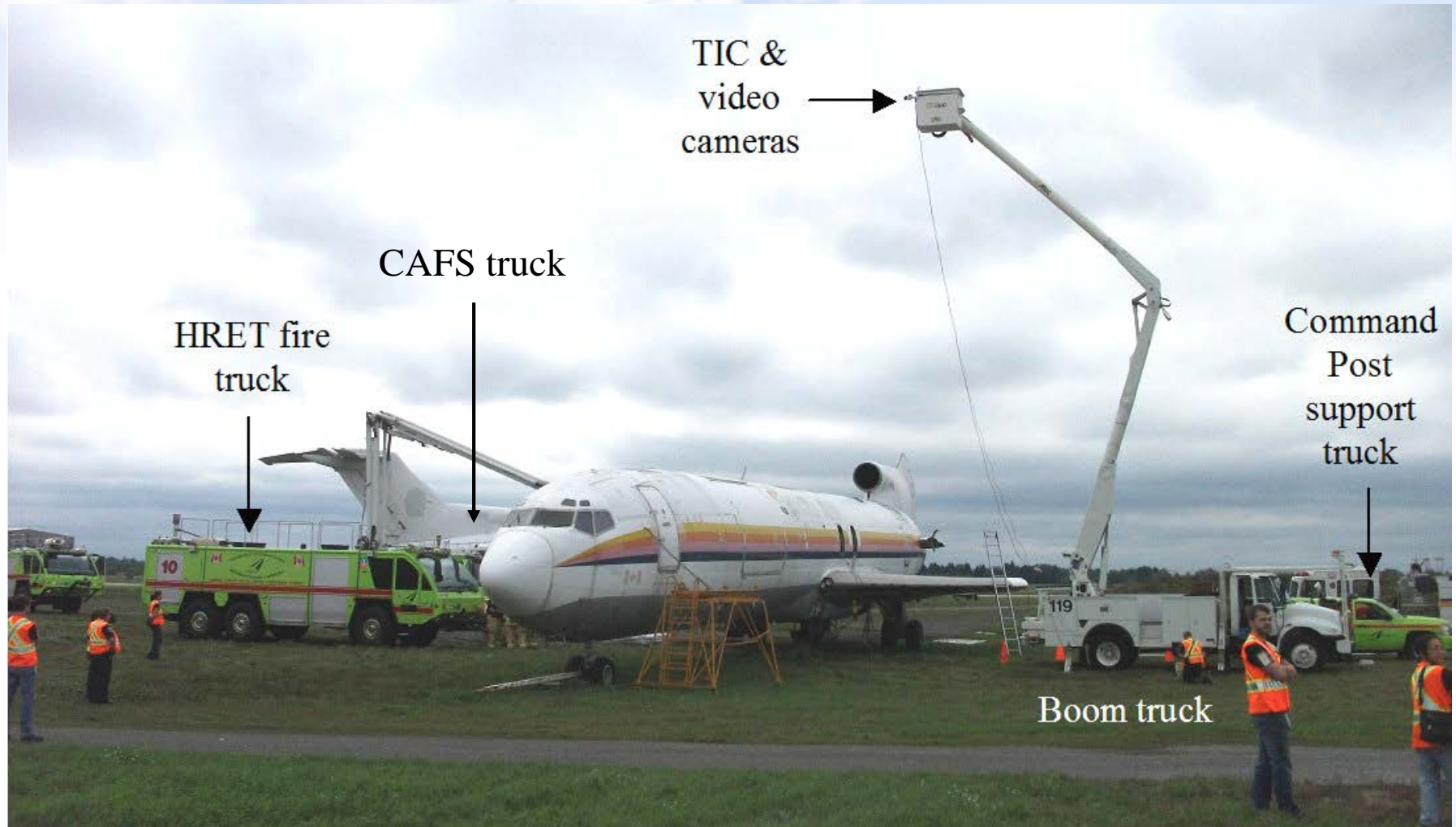
International Airport  
Authority



Administration de  
l'aéroport international



# Test 1 Equipment Layout

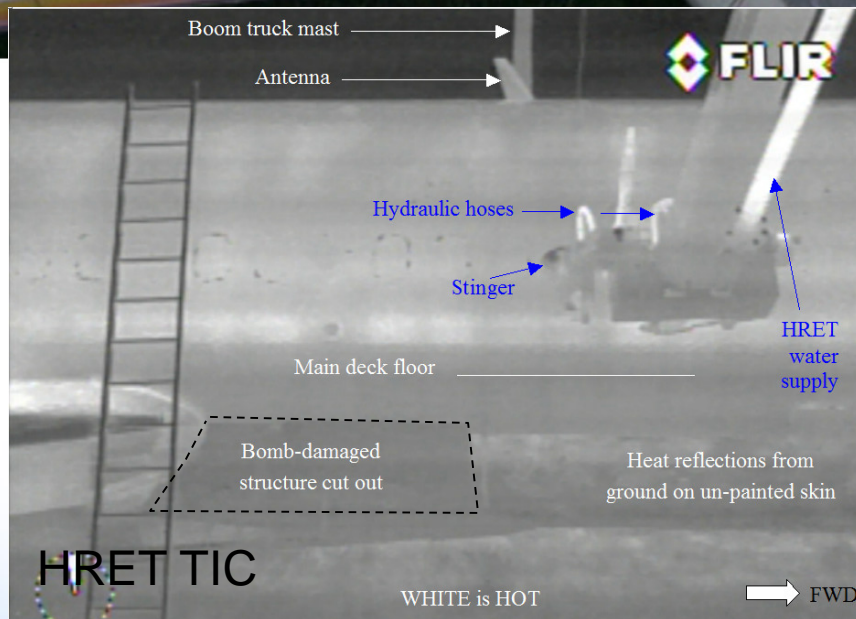
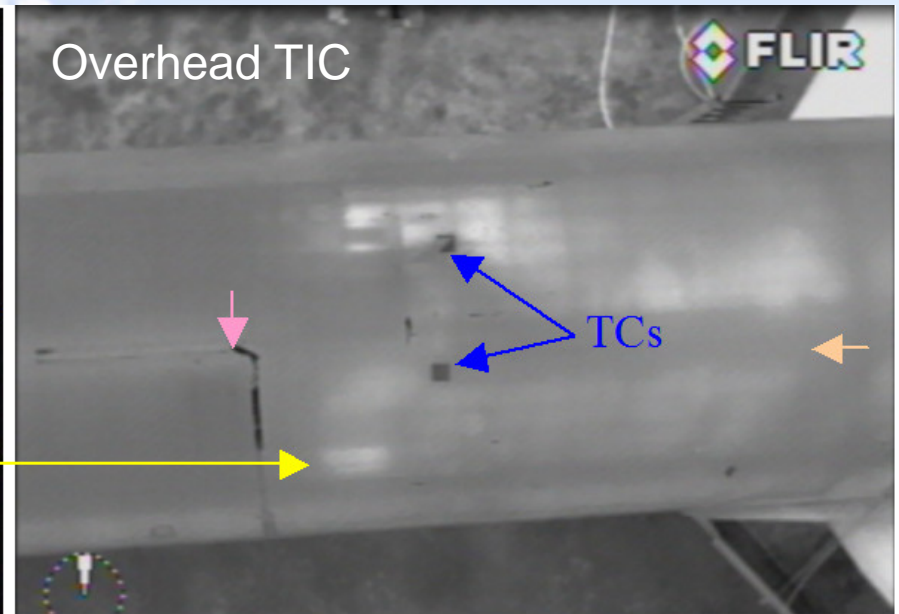


International Airport  
Authority



Administration de  
l'aéroport international

# Test 1 Overhead Video & TICs



Note solar heating of fuselage skin and differences in surface emissivity of paint (←→) and metal tape at cargo door (↓).

TCs covered with ceramic insulation blocks. Duct tape doesn't show.

International Airport  
Authority



Administration de  
l'aéroport international

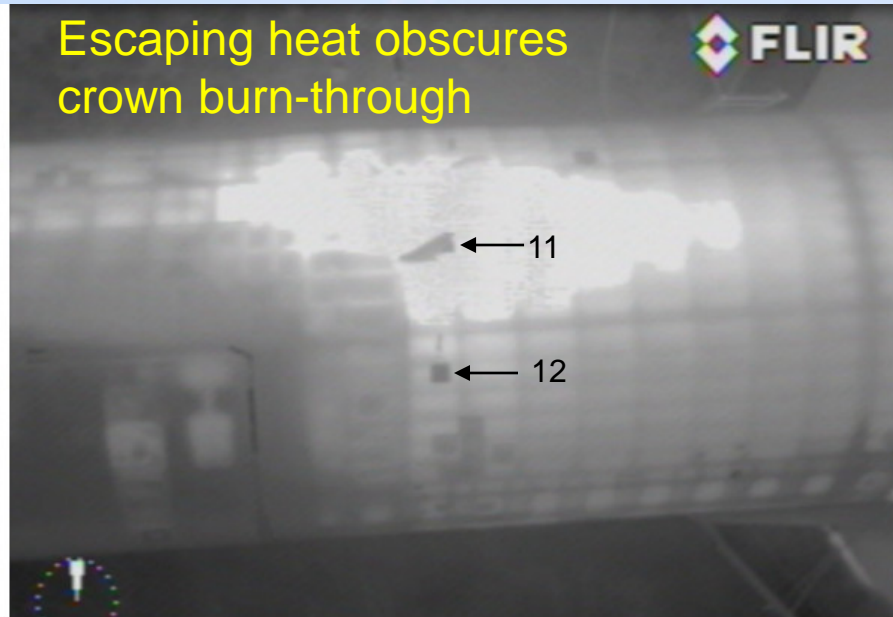


## Test 1 Overhead Video & TIC

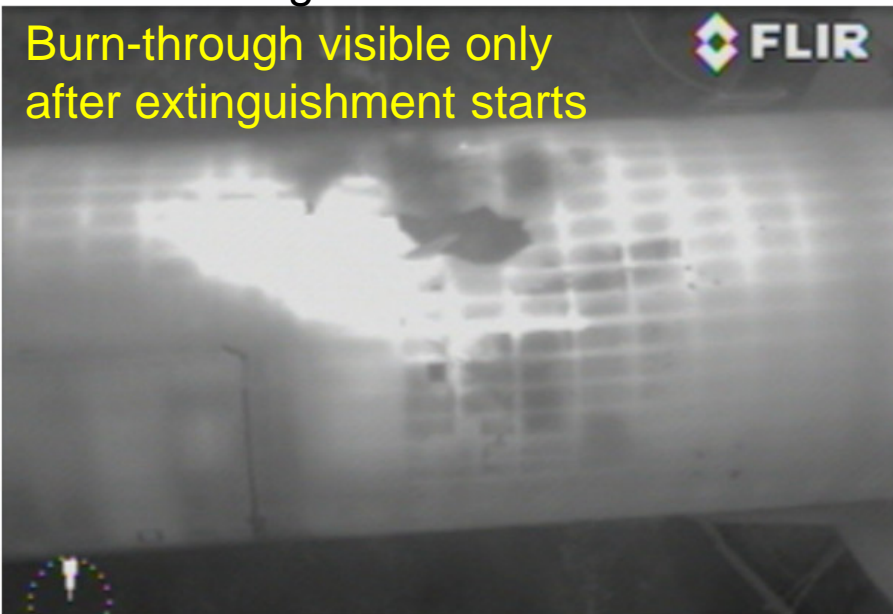


The first indication of fire (arrow) is in the region of solar heating.

If this was the first view upon arriving at the scene there could be some confusion as to the extent of internal heating.

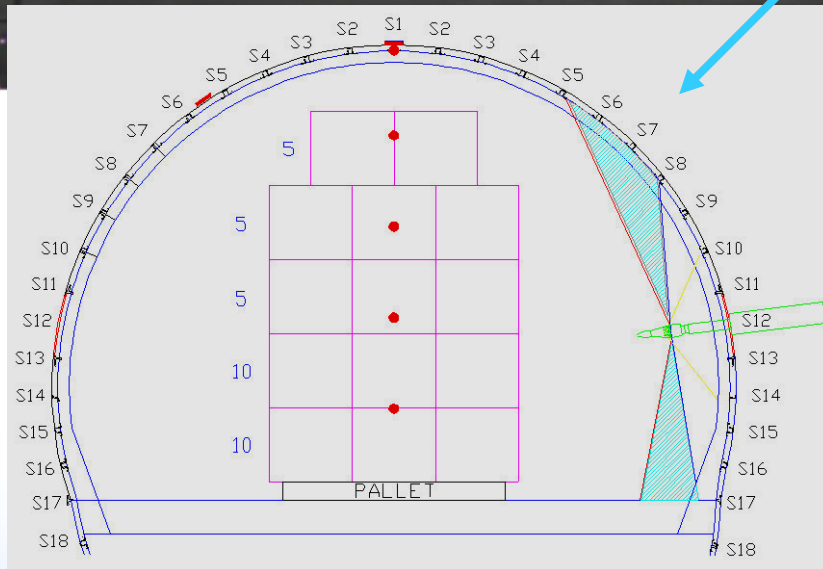
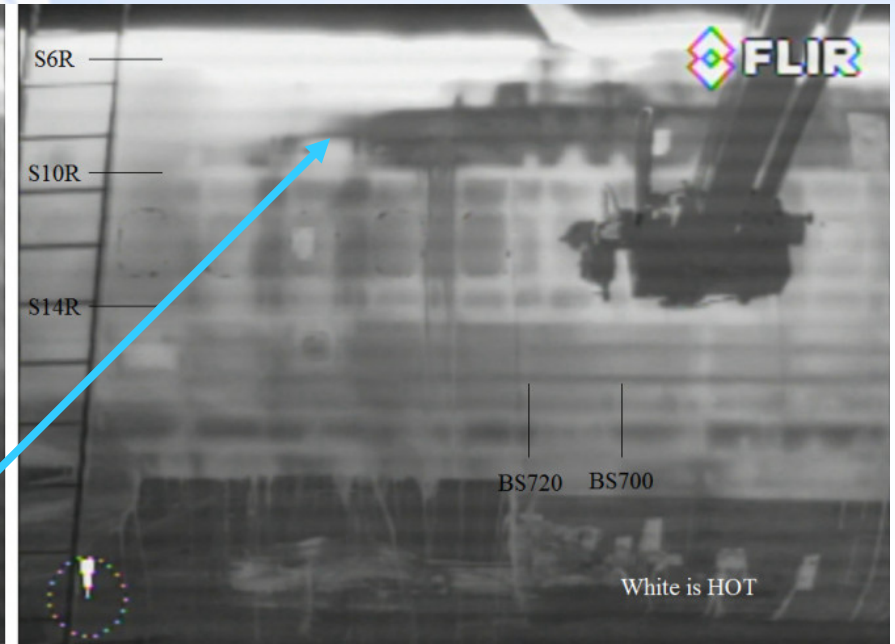


TC#11 falls into the aircraft when the crown burns through





# Test 1 HRET TIC



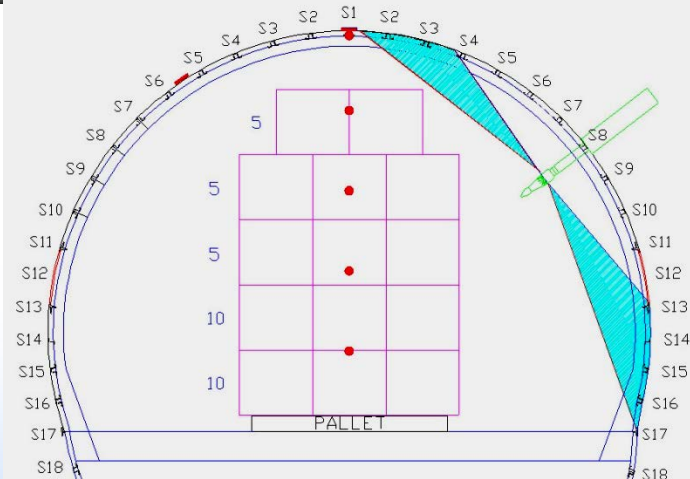
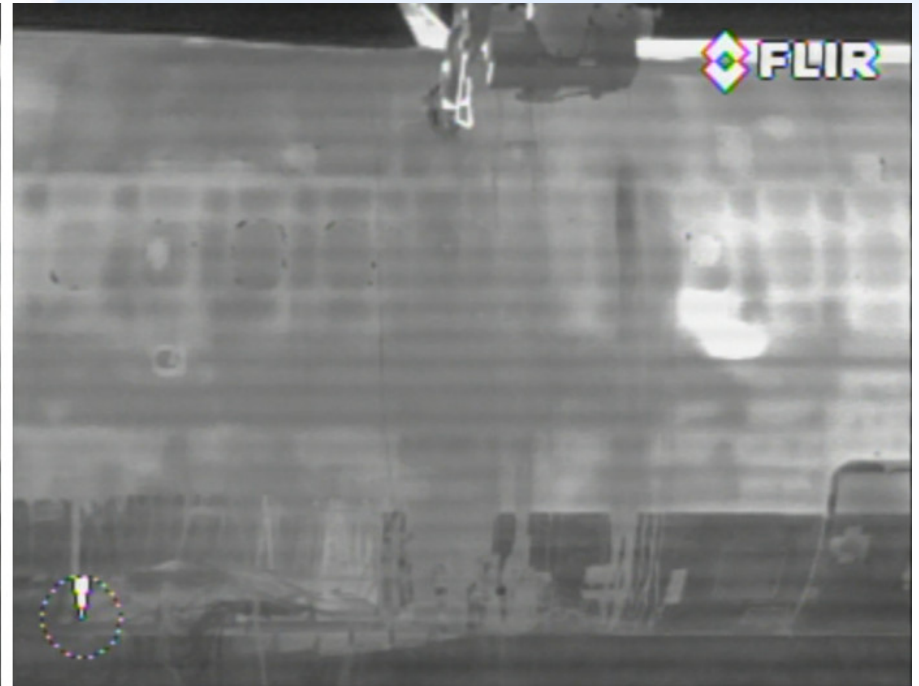
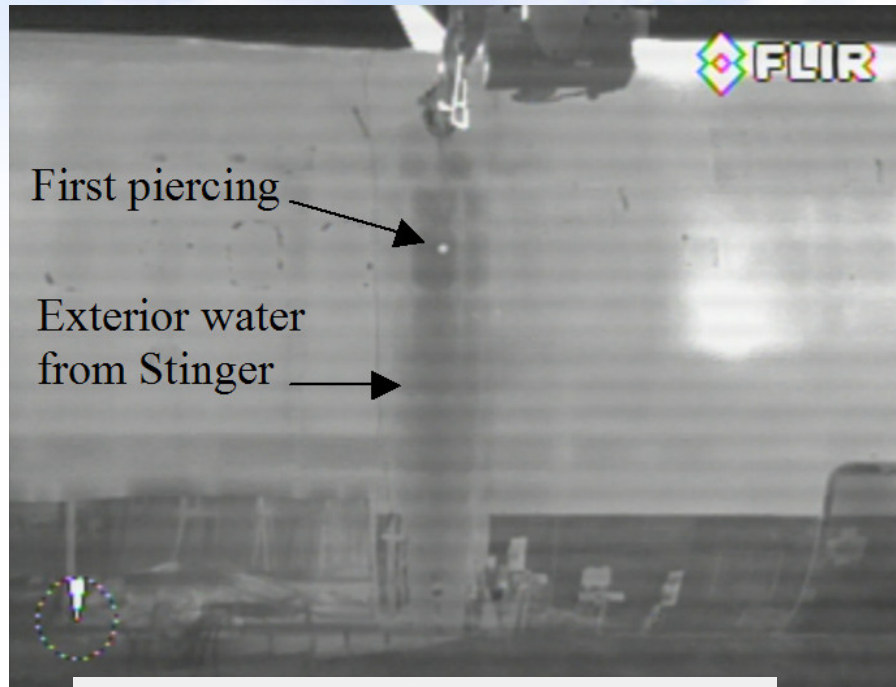
Stinger chisel tip fan-shaped water spray distribution pattern is confined by the fuselage curvature as shown by thermal images taken before and after first application.

International Airport  
Authority



Administration de  
l'aéroport international

# Test 1 HRET TIC



Stinger chisel tip water spray distribution pattern is improved by piercing higher on the fuselage as shown in thermal images taken before and after second application...but this is a cargo aircraft with no O/H bins.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international





Looking AFT



Looking FWD (Salvage Tarp lowered)



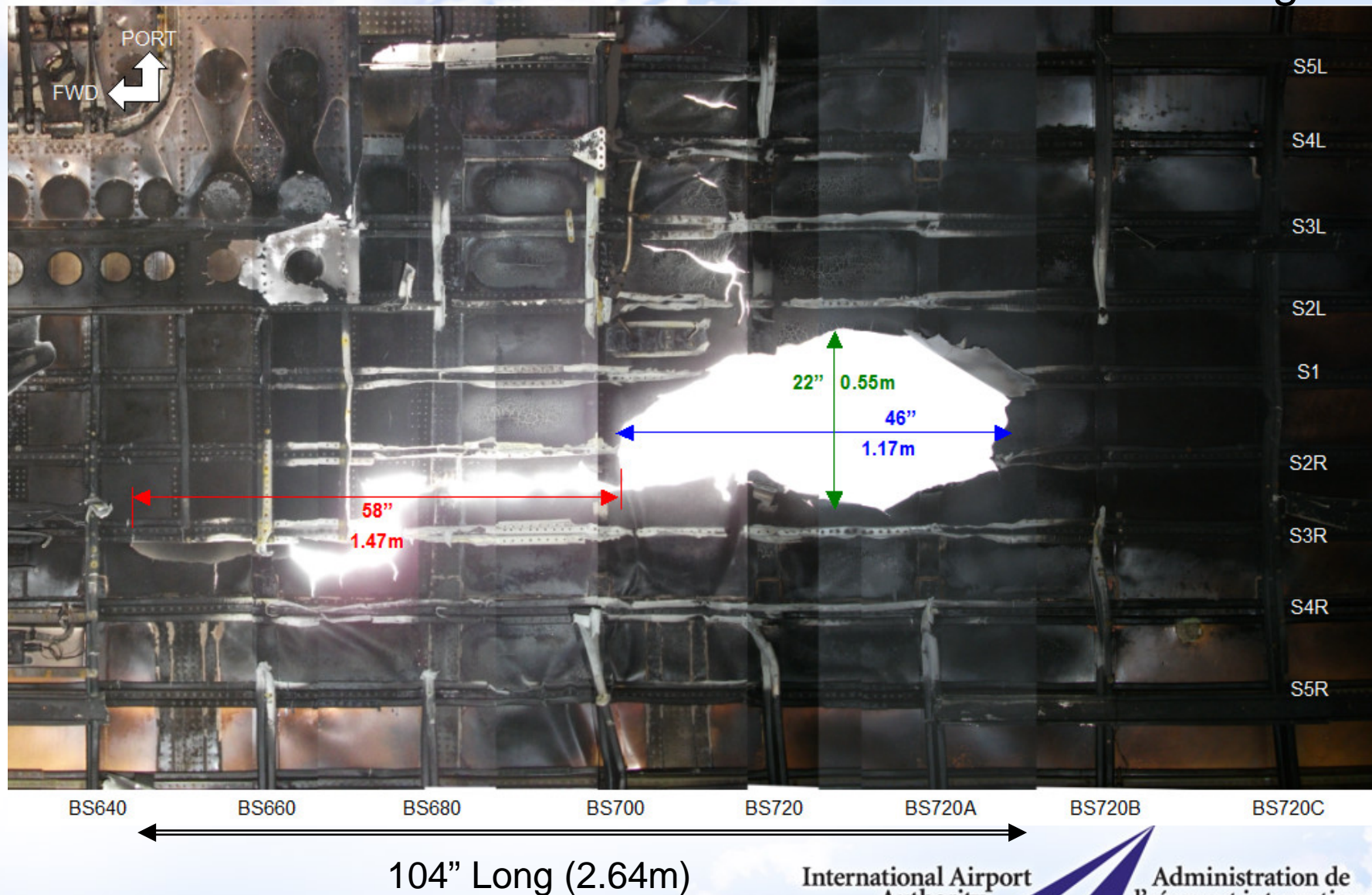
The CAFS foam persists even though 386 US Gal or 1,461 L of water was applied afterwards from the hand-line and second Stinger applications.

International Airport  
Authority



Administration de  
l'aéroport international

# Test 1 Crown Burn-through



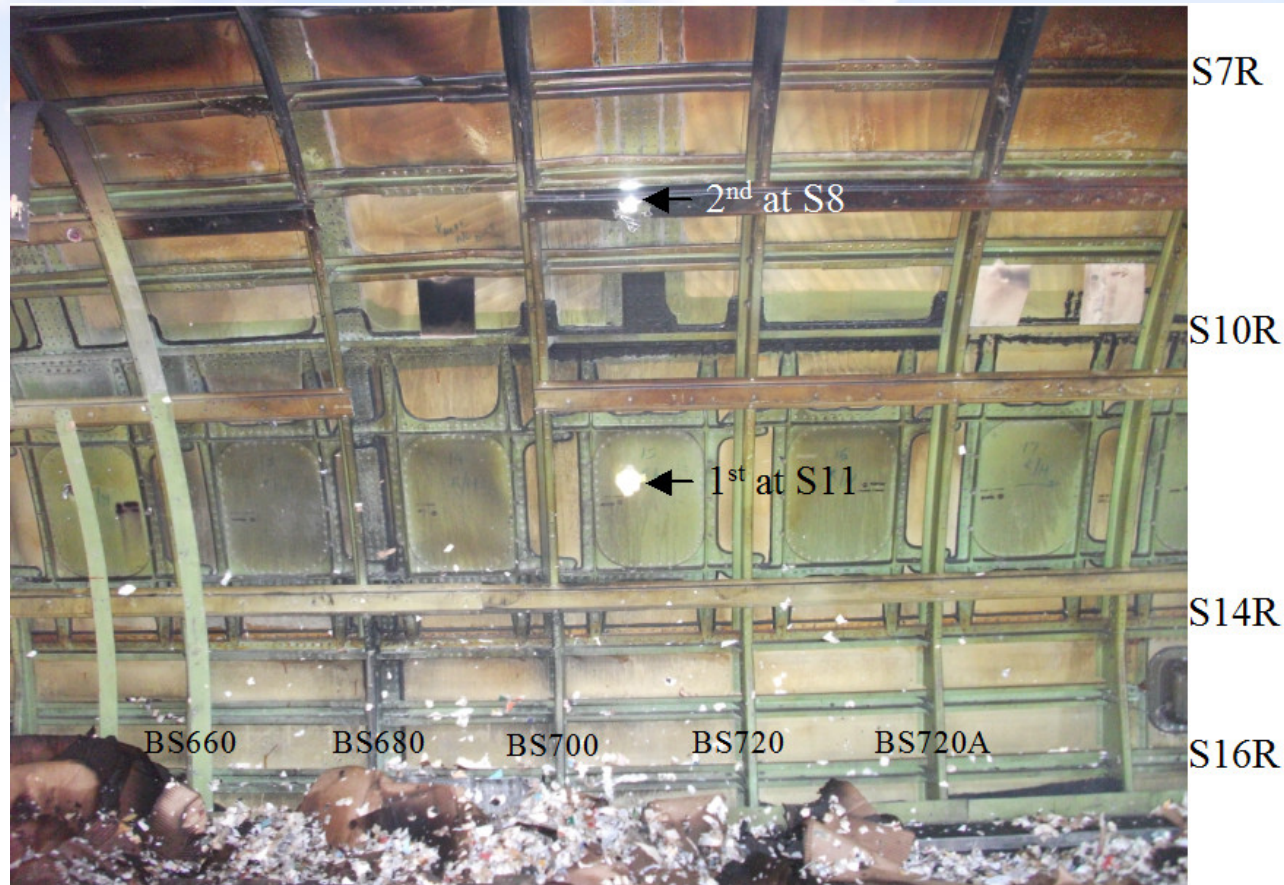
International Airport  
Authority



Administration de  
l'aéroport international



# Post Test 1



Little heat damage or sooting below S7 as evidenced by this typical view.

The two Stinger piercing locations are noted.

# Test 1 Timeline and Agent Applied

00:00 Audible pop of Li battery igniter.  
00:09 First smoke FWD side of fuel package.  
00:13 First smoke AFT side of fuel package.  
02:11 First visible flames at top of stack by FWD camera.  
02:27 First audible skin buckle and exterior paint seen to blacken.  
06:21 Flames first seen through crown skin.  
06:53 Stinger pierce through cabin side-window.  
06:57 Stinger - First flow of water (low pressure).  
07:00 Start Full pressure Stinger water flow.  
07:08 Last visible flames from overhead camera.  
07:54 End full pressure Stinger flow. **Duration:** 0:53. 210 US Gallons (795L)  
18.9 sec between Stinger end and hand-line CAFS #1 start.  
08:13 Start CAFS#1 from STBD over-wing exit doorway.  
09:45.26 End CAFS#1. **Duration:** 32 sec. 32 US Gal (121L)

73 seconds between CAFS#1 and CAFS#2.  
10:59 Start CAFS#2.  
12:08.12 End CAFS#2 **Duration:** 1:08. 68 US Gal (257L)  
97 seconds between CAFS#2 and OFS#1.  
13:45 Start OFS#1 water application from PORT over-wing exit doorway.  
14:27 End OFS#1 water. **Duration:** 37 sec. 92.5 US Gal (350L)  
34 seconds between OFS#1 and OFS#2.  
15:02 Start OFS#2 water.  
15:29 End OFS#2 water. **Duration:** 27 sec. 67.5 US Gal (255L)  
59 seconds between OFS#2 and Stinger#2.  
16:21 Stinger 2<sup>nd</sup> pierce through STR4R.  
16:27 Start Stinger#2 water flow.  
**17:24** End Stinger#2 water flow. **Duration:** 57 sec. 226 US Gal (855L)

Approx 700 US Gal (2,649L) of agent applied.

Burn-through: 6:21. 1<sup>st</sup> extinguishment: 6:57  
Stinger 1:50 + CAFS 1:40 + H/L 1:04 = 4:40

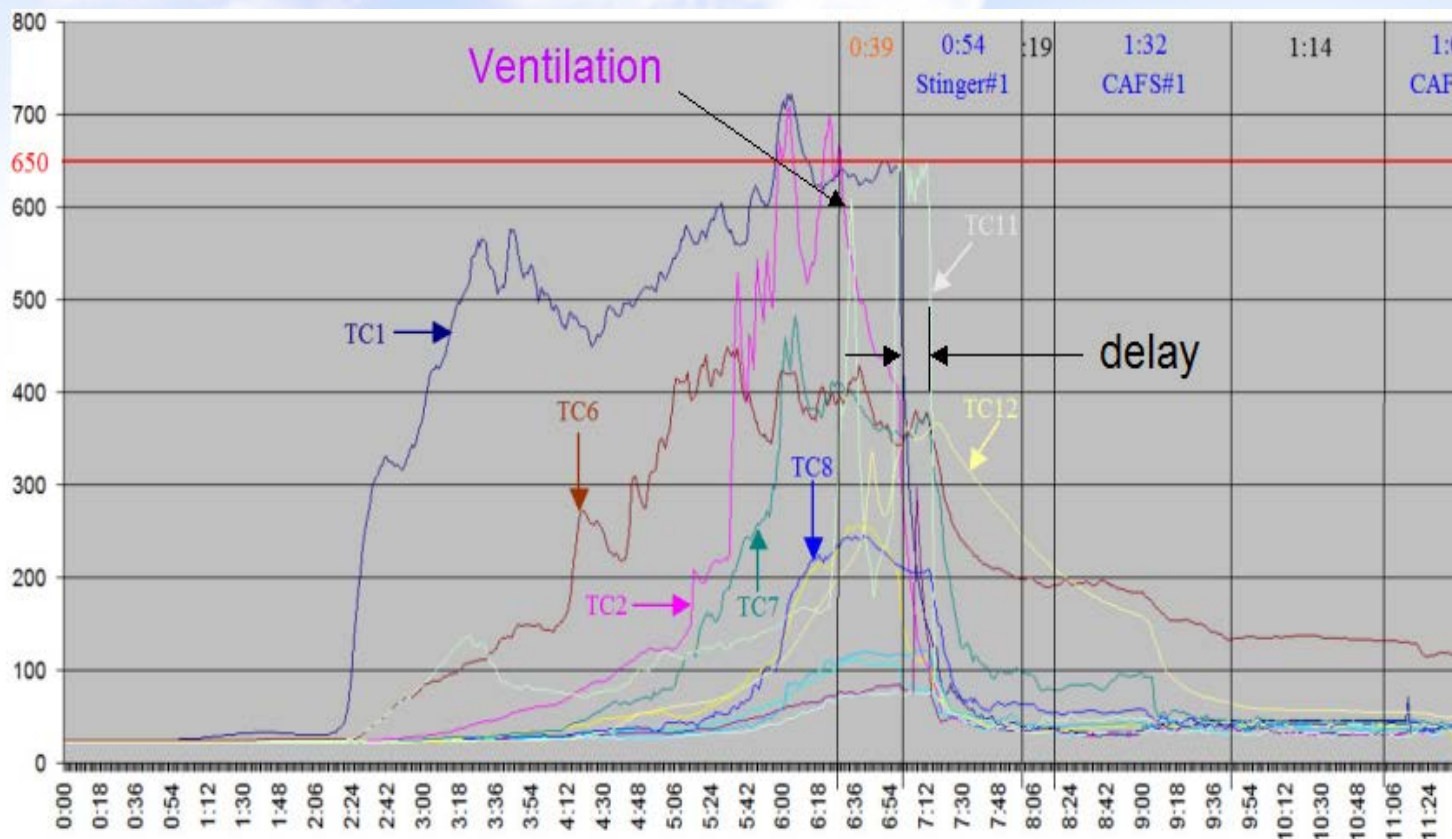
International Airport  
Authority



Administration de  
l'aéroport international



# Test 1 Temperature Profile & Initial Extinguishments



## Peak Temps

TC#1	1330°F (721°C)
TC#2	1308°F (709°C)
TC#3	488°F (353°C)
TC#4	226°F (108°C)
TC#5	177°F (80°C)
TC#6	831°F (444°C)
TC#7	900°F (482°C)
TC#8	473°F (245°C)
TC#9	248°F (120°C)
TC#10	169°F (76°C)
TC#11	1198°F (648°C)
TC#12	687°F (364°C)

Stinger water cooling effect delayed by distance from TC trees.

Red line is melting temperature of aluminium.

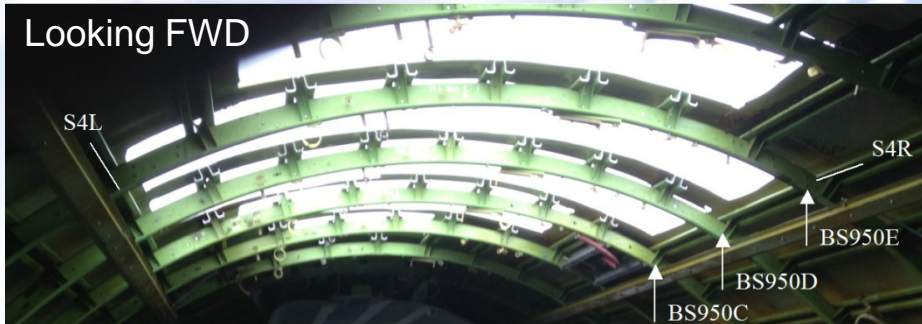
International Airport  
Authority

Ottawa

Administration de  
l'aéroport international

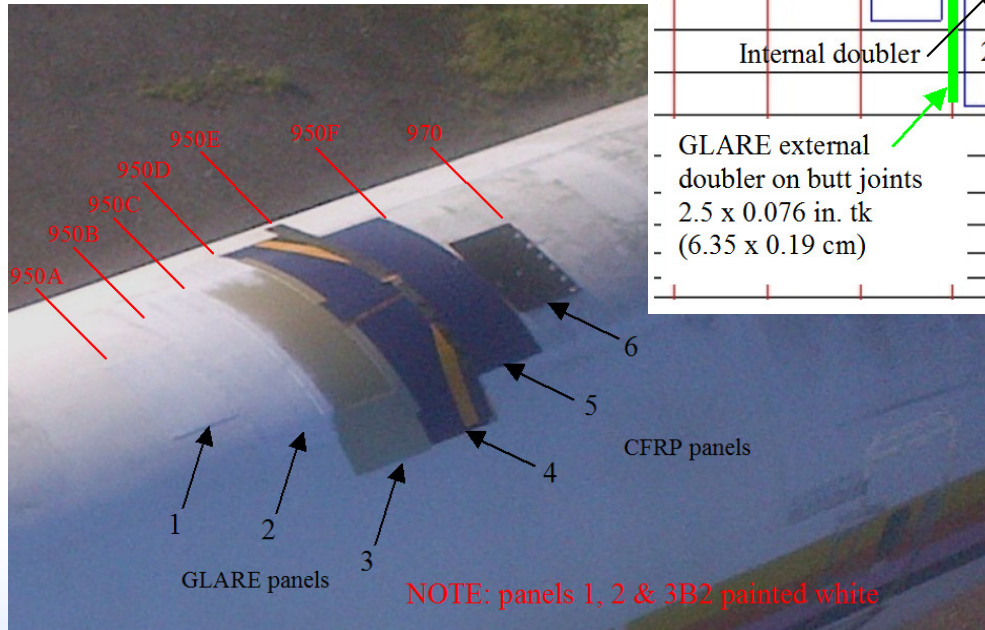
# Test 2 Crown Skin Replacement

Looking FWD

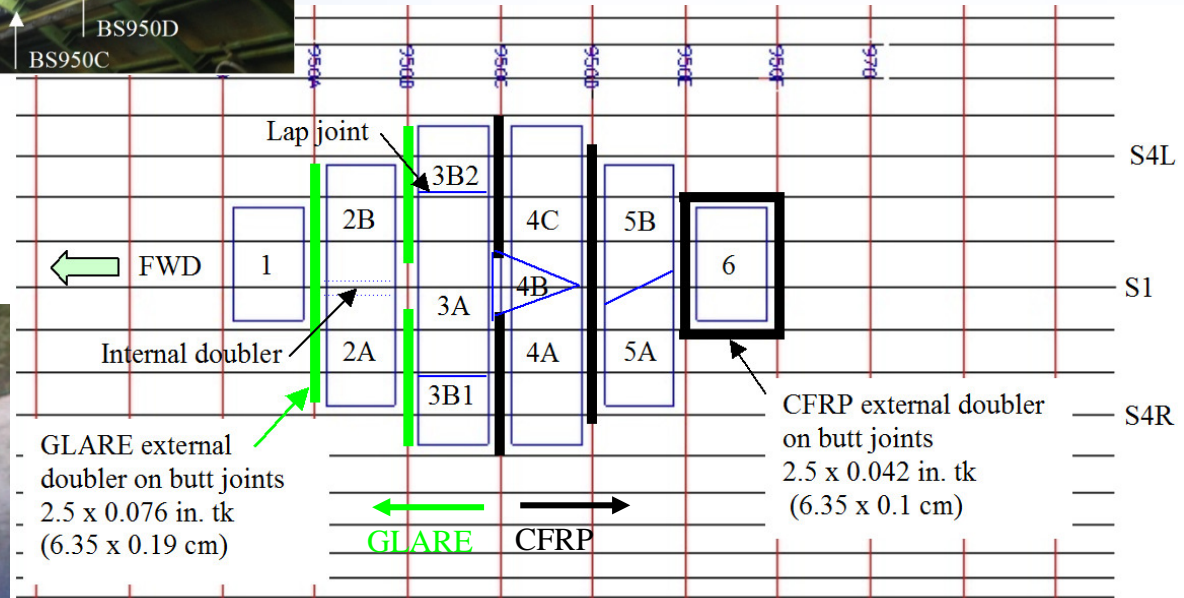


GLARE – Glass Laminate  
Aluminium Reinforced Epoxy.

CFRP – Carbon Fibre  
Reinforced Plastic



GLARE & CFRP panels  
mechanically fastened to  
aluminium frames.



Some external surfaces were  
painted and some left unpainted.

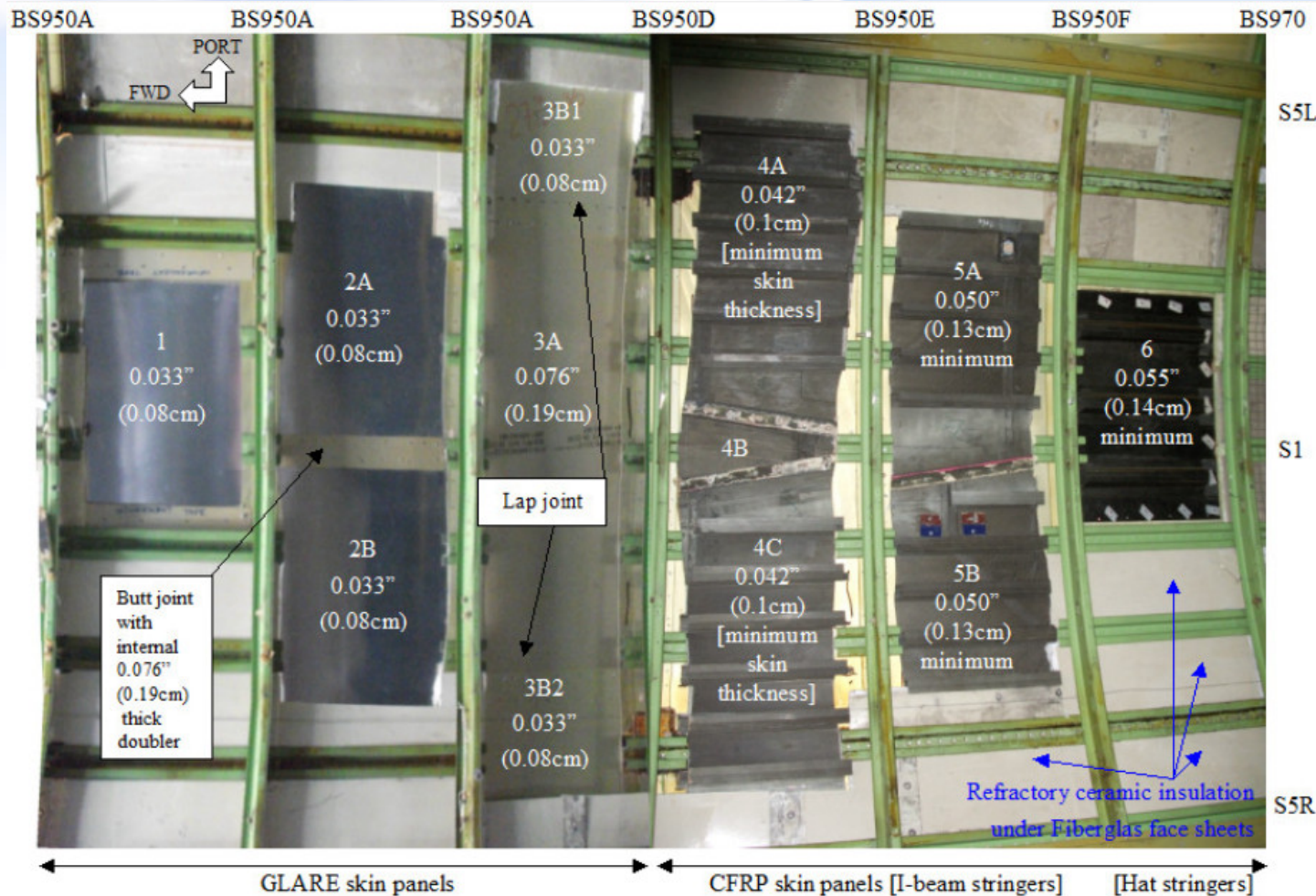
International Airport  
Authority



Administration de  
l'aéroport international



# Test 2 Crown Skin Replacement



Area with composite skins: ~26ft<sup>2</sup> (2.4m<sup>2</sup>).

Composites skins ranged between 0.033 and 0.076" tk (0.08-0.19 cm).

GLARE 40% thinner than Al skin (except 3A). CFRP equal to or 15% thinner than original Al skin which tapered from 0.050-0.060" (0.127-0.152 cm)

Refractory ceramic insulation used to protect the perimeter aluminium from burn-through.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international



# Fire Operations

1. Incident Commander – Upwind at Aircraft Tail.
2. Safety Officer – OFS – Location: Mobile.
3. Radio Communication – Airport Fire 1 & 3.4.
4. HRET Panther – Pre-positioned upwind on right side of B727-200.
5. HRET Deployed – Mid-Attack. Location: midway between over wing exit and tail.
6. Upwind side, wing laddered.
7. OFS Pump – Located on upwind side.
8. Two ERS firefighters upwind on wing with 1.75 in. line charged – TFT FLIP TIP Nozzle.
9. One firefighter upwind on platform / wing with Pyrolance.
10. Spare ARFF vehicle in service.
11. Spare SCBA Units to be used.
12. Four drain holes created to avoid weight & balance problems.
13. Total personnel on site: 1 Chief Officer, 4 Captains, 14 Firefighters, 1 hazmat officer & 1 Safety Officer – Total 21

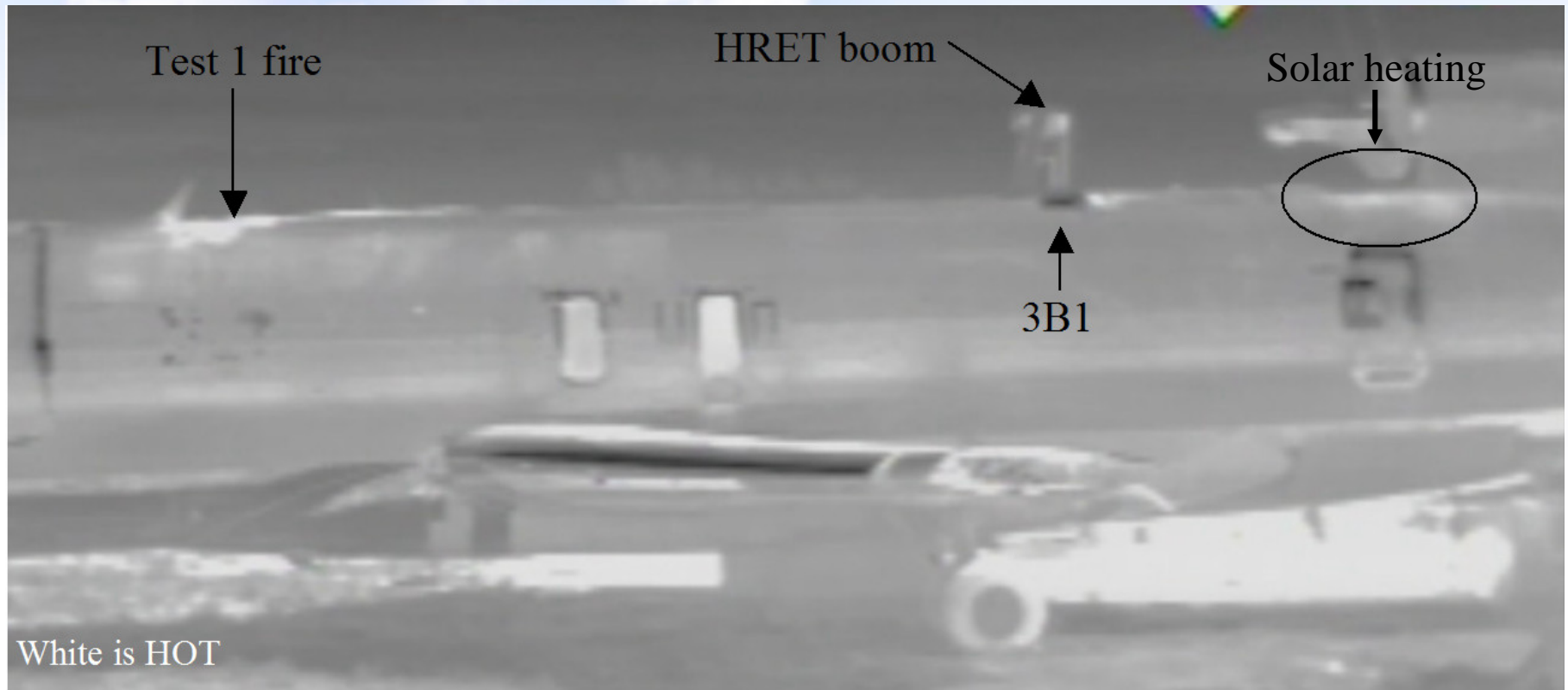


## Test 2 Command Post



Internal and overhead camera views provided to incident commander.

## Test 2 PORT Side TIC



NRC built GLARE panel 3B1 in primer shows black throughout test. Commercial Panel 3A also in primer does respond to heating as do the painted panels. NRC has IR stealth primer?

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international



## Test 2 PORT Side TIC



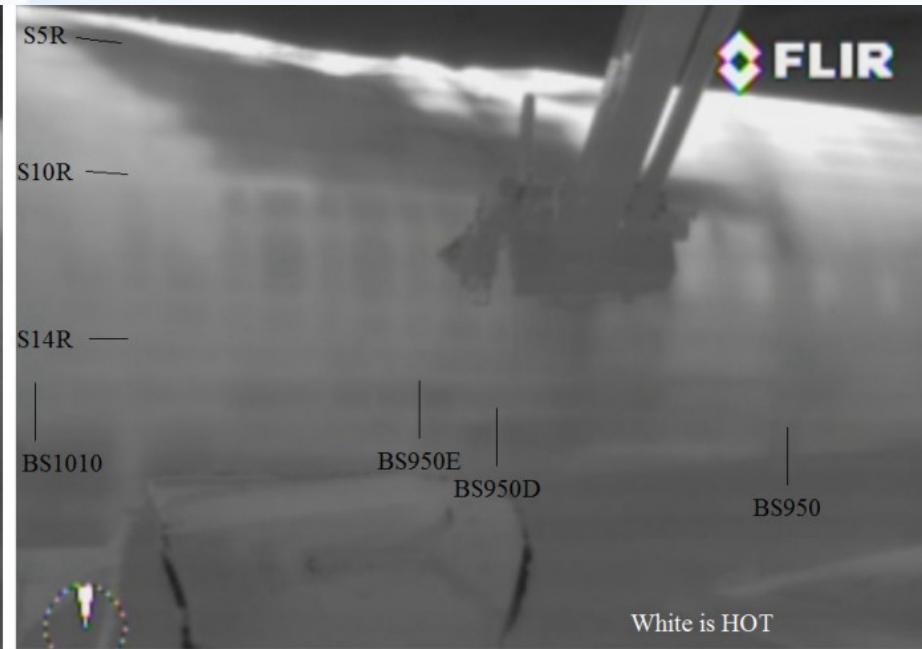
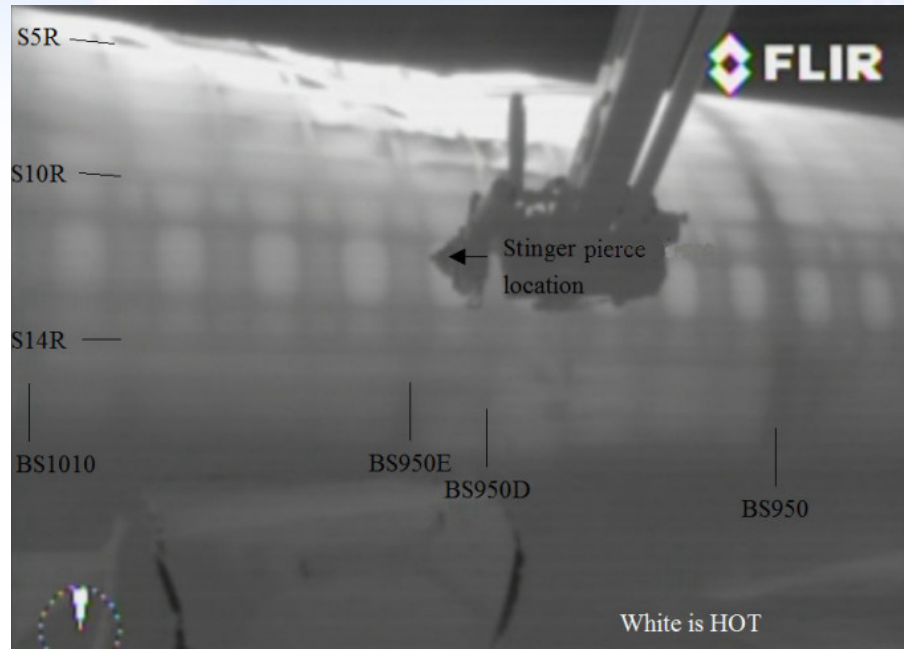
First indication of fire heating crown. Note that 3B1 is still black.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international

## Test 2 Red 10 STBD TIC



As in Test 1, the Stinger chisel tip water spray distribution pattern is confined by the fuselage curvature as shown by thermal images taken before and after the first application.

## Test 2 PORT Side TIC

Things looked like this during [Stinger application 7:49 to 8:55](#)



No evidence of Stinger application on PORT side. Heat haze obscures 3B1.

[Salvage tarp failed at 7:45](#) as evidenced by heat escaping Test 1 crown burn-through.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international



## Test 2 PORT Side TIC

Things looked like this during [PyroLance application 9:13 to 9:54](#)



PyroLance application cools PORT fuselage skin for entire duration of application. PyroLance stream was between TC trees and caused immediate cooling.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international

## Test 2 PORT Side TIC

Things looked like this at start of [Hand line application](#) 12:45 to 15:45



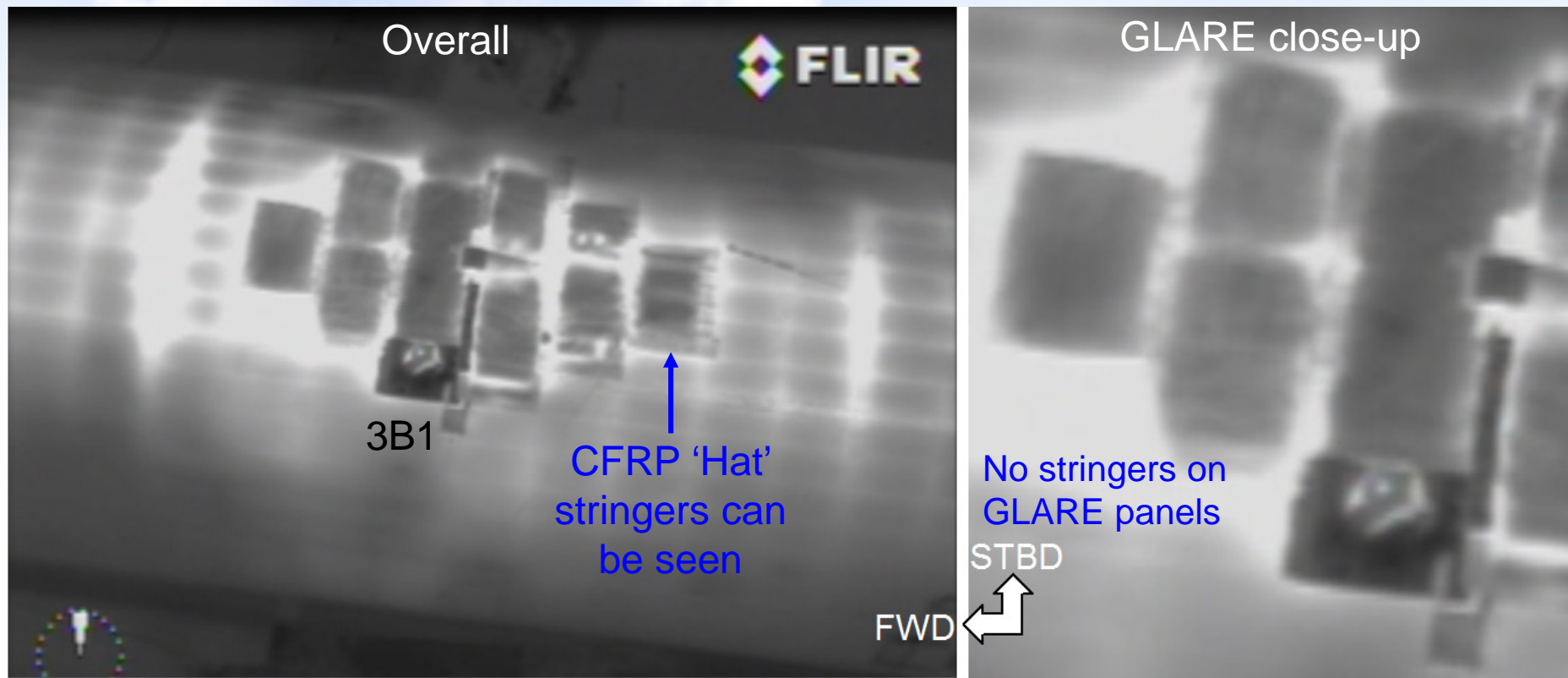
Hand-line application cools PORT fuselage. Note that GLARE panel 3B1 is still black.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international

## Test 2 Overhead TIC



Fire damaged GLARE & CFRP panels do not transmit heat well.

Panel 3B1 has been partially burned through.

International Airport  
Authority

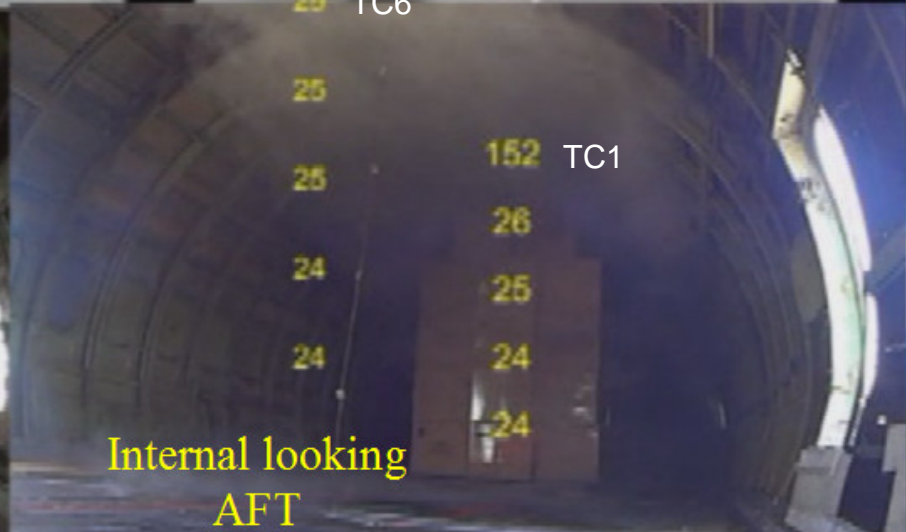
Ottawa

Administration de  
l'aéroport international





## Test 2 Composite video. Initial views.

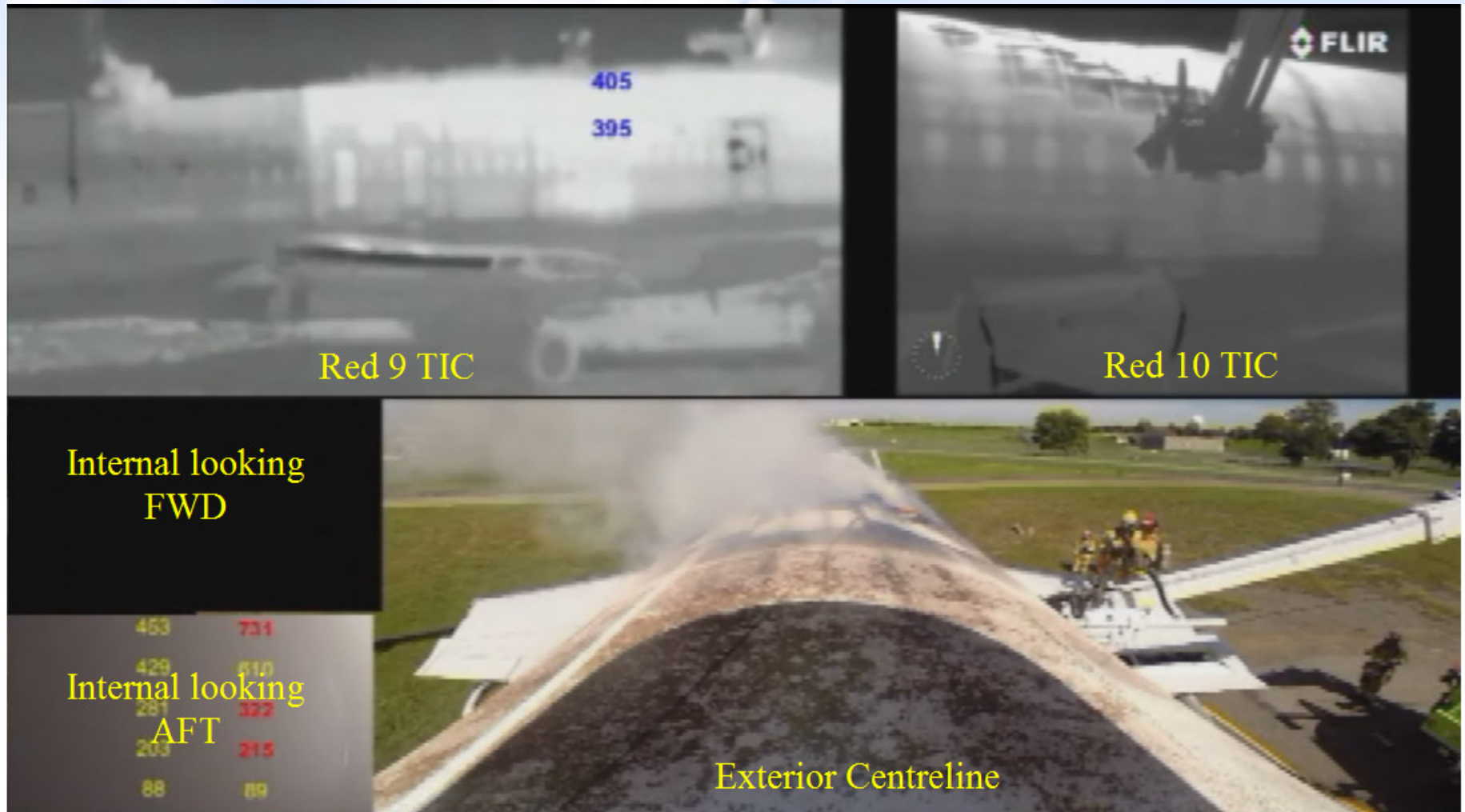


International Airport  
Authority

Ottawa

Administration de  
l'aéroport international

## Test 2 Composite video. Final views.



Maximum temperatures in RED

# Test 2 Timeline and Agent Applied

00:00 First smoke FWD side of fuel package.  
00:15 First visible flames at top of fuel package by FWD camera.  
07:40 Stinger pierce through cabin side-window.  
07:45 Failure of Salvage Tarp.  
07:49 Stinger - First flow of water (low pressure).  
07:52 Start Full pressure Stinger water flow.  
08:55 End full pressure Stinger flow. **Duration:** 1:06. 261 US Gallons (988 L)  
18 seconds between Stinger end and PyroLance start.  
09:13 PyroLance start.  
09:18 PyroLance pierces skin and first flow of water.  
09:54 PyroLance slips and flow to interior ends.

No burn-through 1<sup>st</sup> extinguishment: 7:49  
Stinger 1:06 + PyroLance 0:36 + H/L 2:08 +  
Overhaul 2:57 = 6:49

10:19 End PyroLance. **Duration:** 0:41 over 1:06. 6.8 US Gal (25.7 L)  
1:45 between end of PyroLance and hand-line start.  
12:04 Start hand-line from over-wing position.  
15:45 End over-wing hand-line **Duration:** 2:08 in four applications over 3:41. 320 US Gal (1211 L)  
1:58 between end of hand-line and start of overhaul.  
17:43 Overhaul from rear air-stair starts. 8 applications.  
**27:00** End overhaul. **Duration:** Total of 2:57 over 9:27. 295 US Gal (1117 L)

Approx 800 US Gal (3,345L) of agent applied.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international



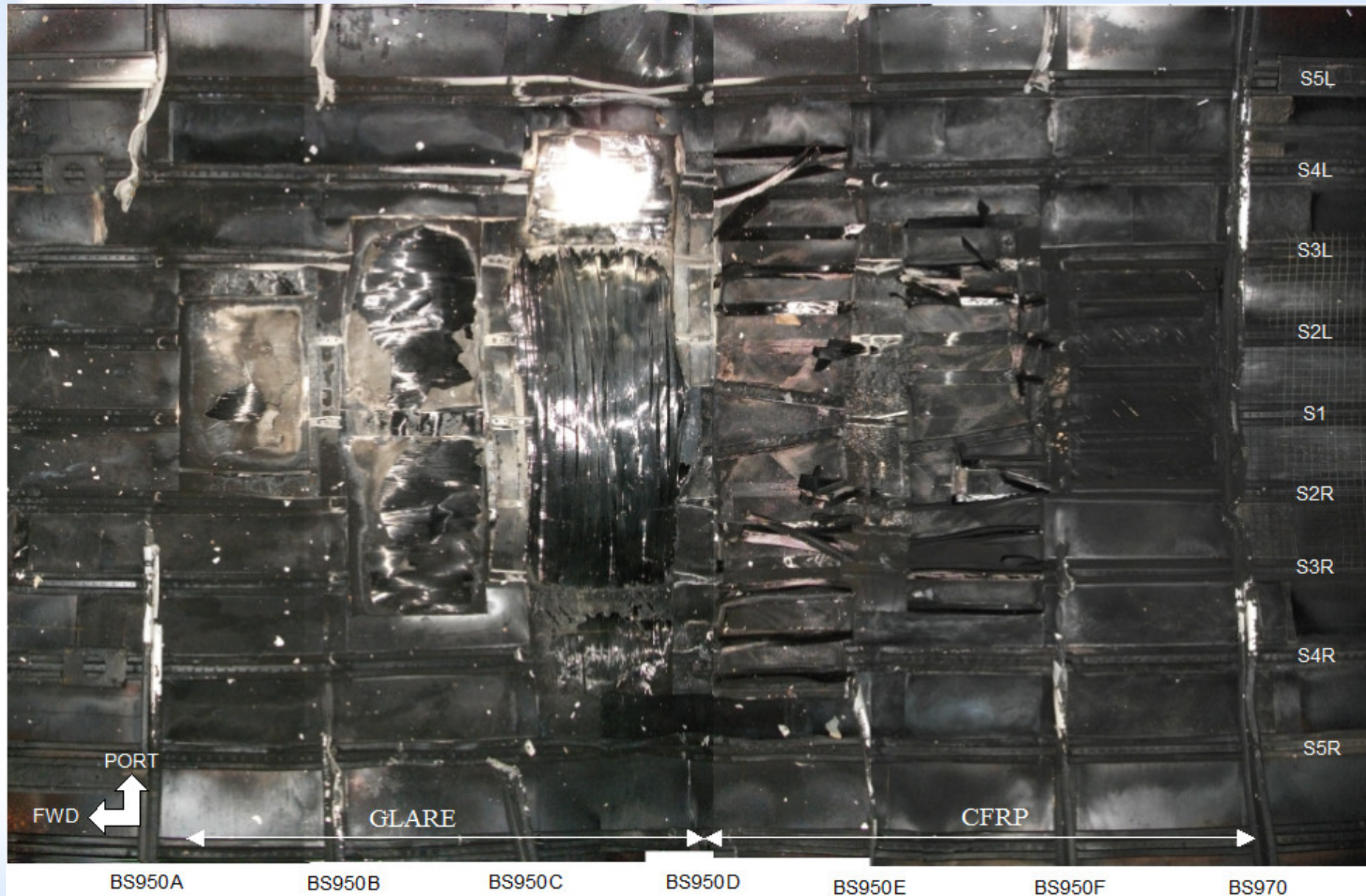
## Test 2 Damage to Composites, Exterior



Note refractory insulation protected skin between stringers from heat damage.



## Test 2 Damage to Composites, Interior, Overall





# Post Test 2 GLARE



International Airport  
Authority

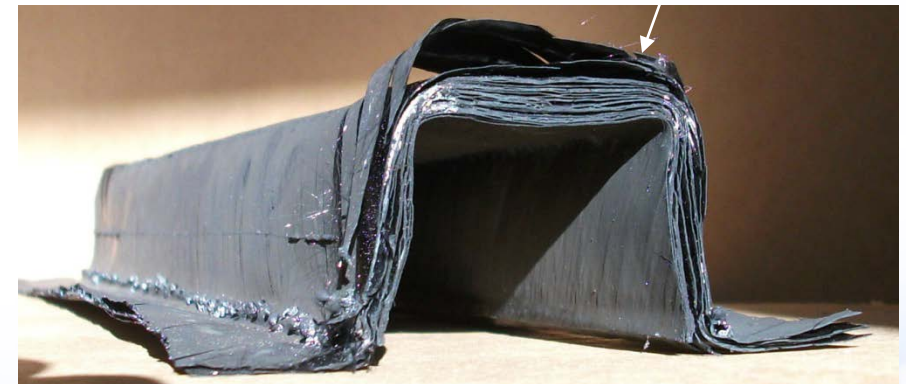
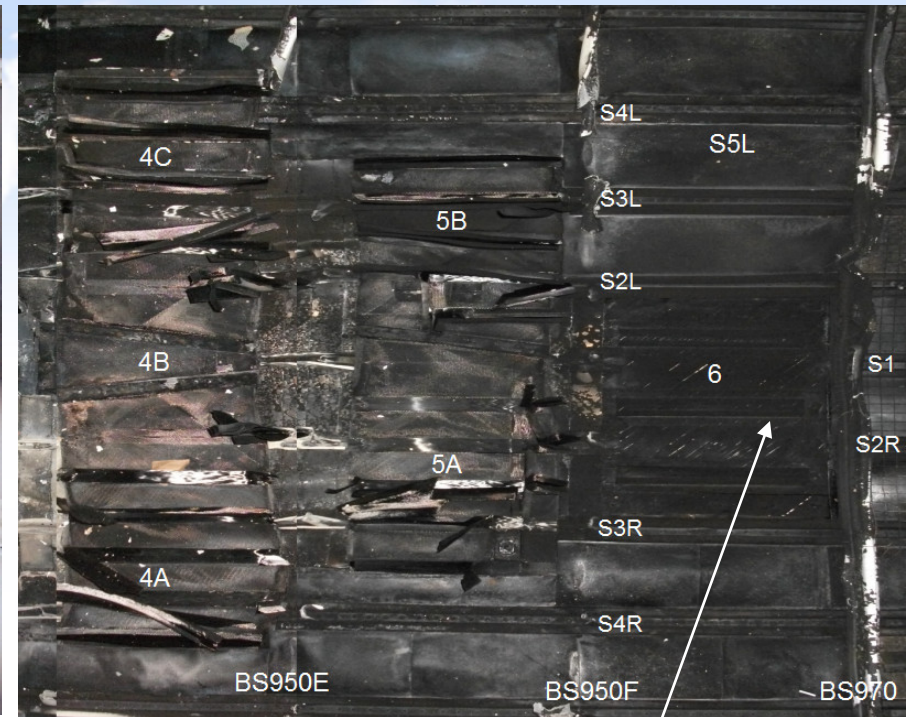
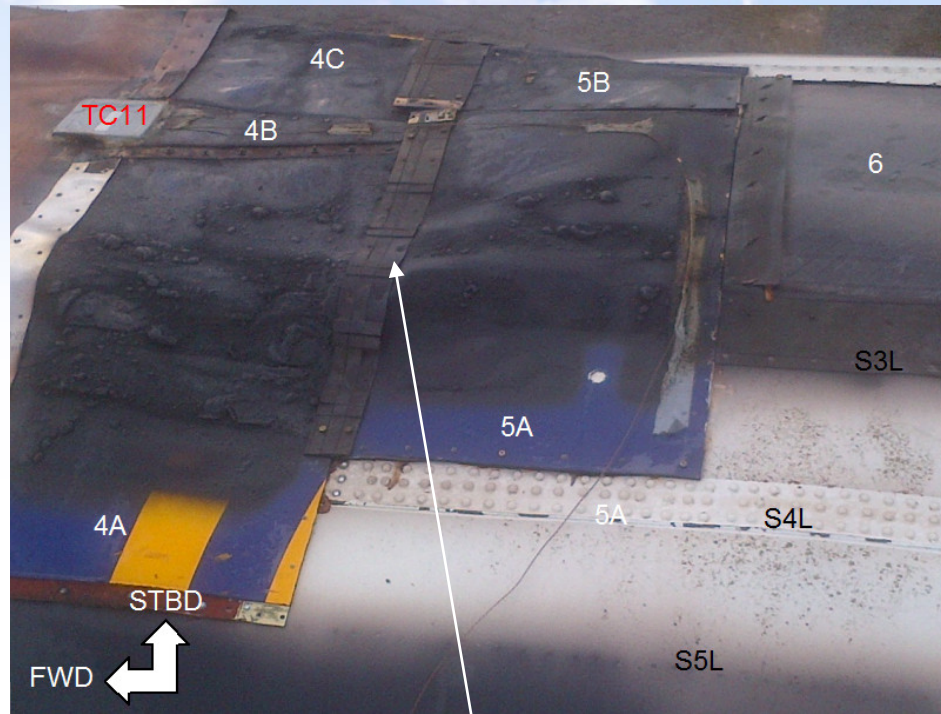
Ottawa

Administration de  
l'aéroport international





## Post Test 2 CFRP



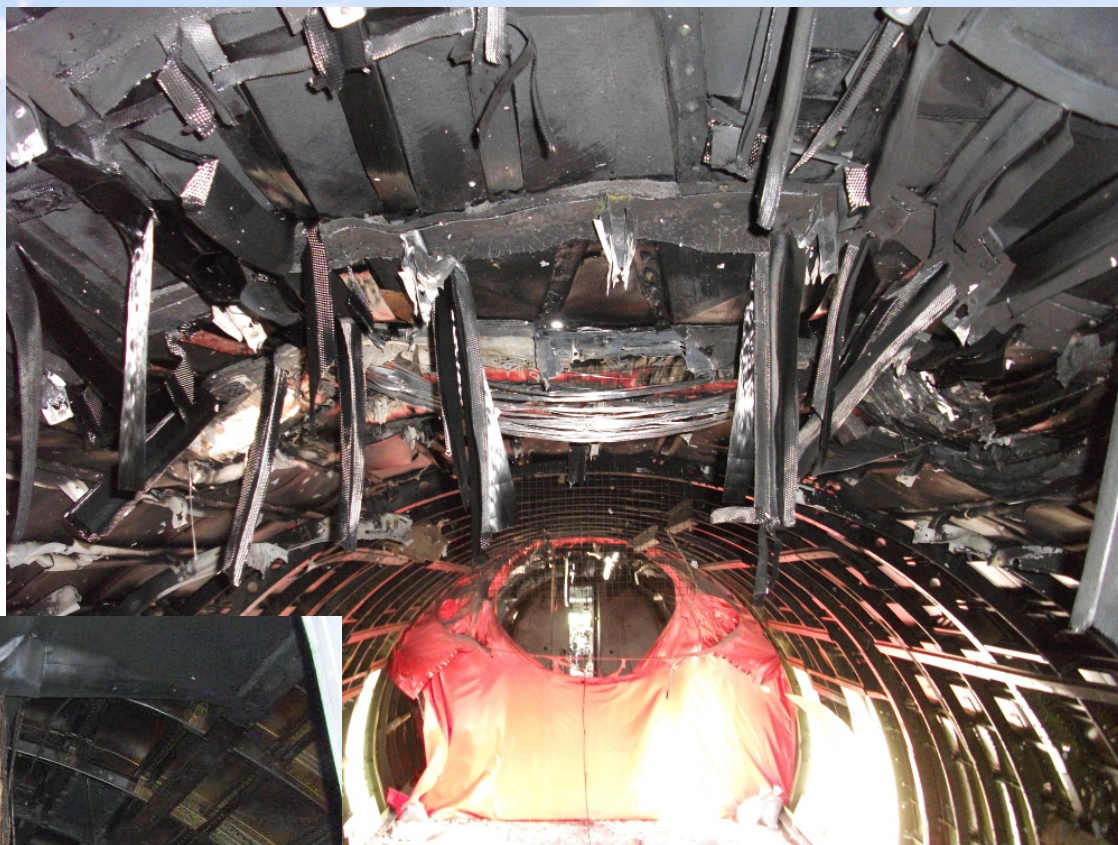
International Airport  
Authority



Administration de  
l'aéroport international



Add a forest of hanging CFRP plies to the existing entanglement hazard of displaced wiring bundles.

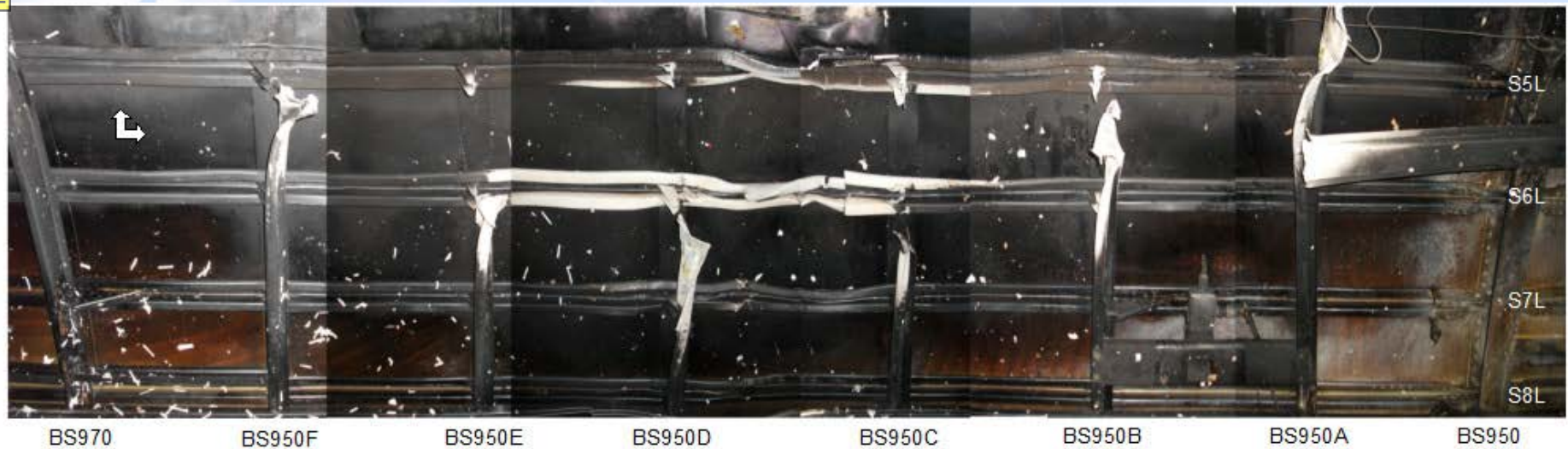


International Airport  
Authority

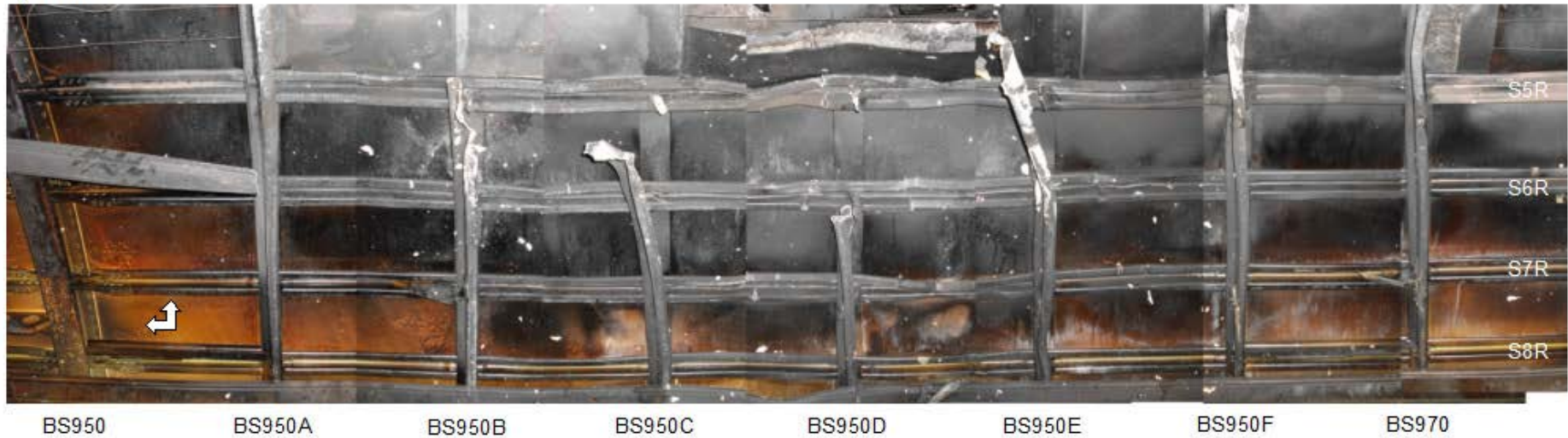
Ottawa

Administration de  
l'aéroport international





a) PORT

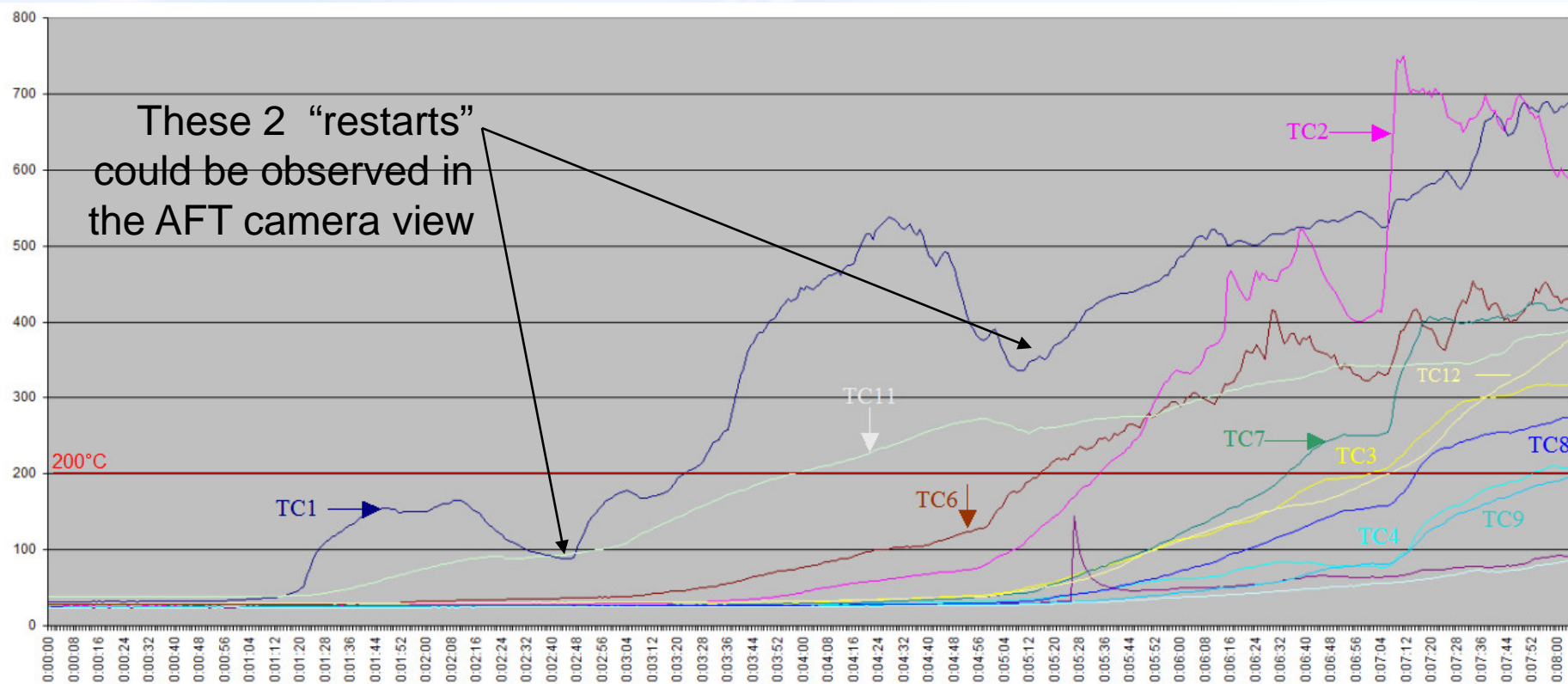


b) STBD

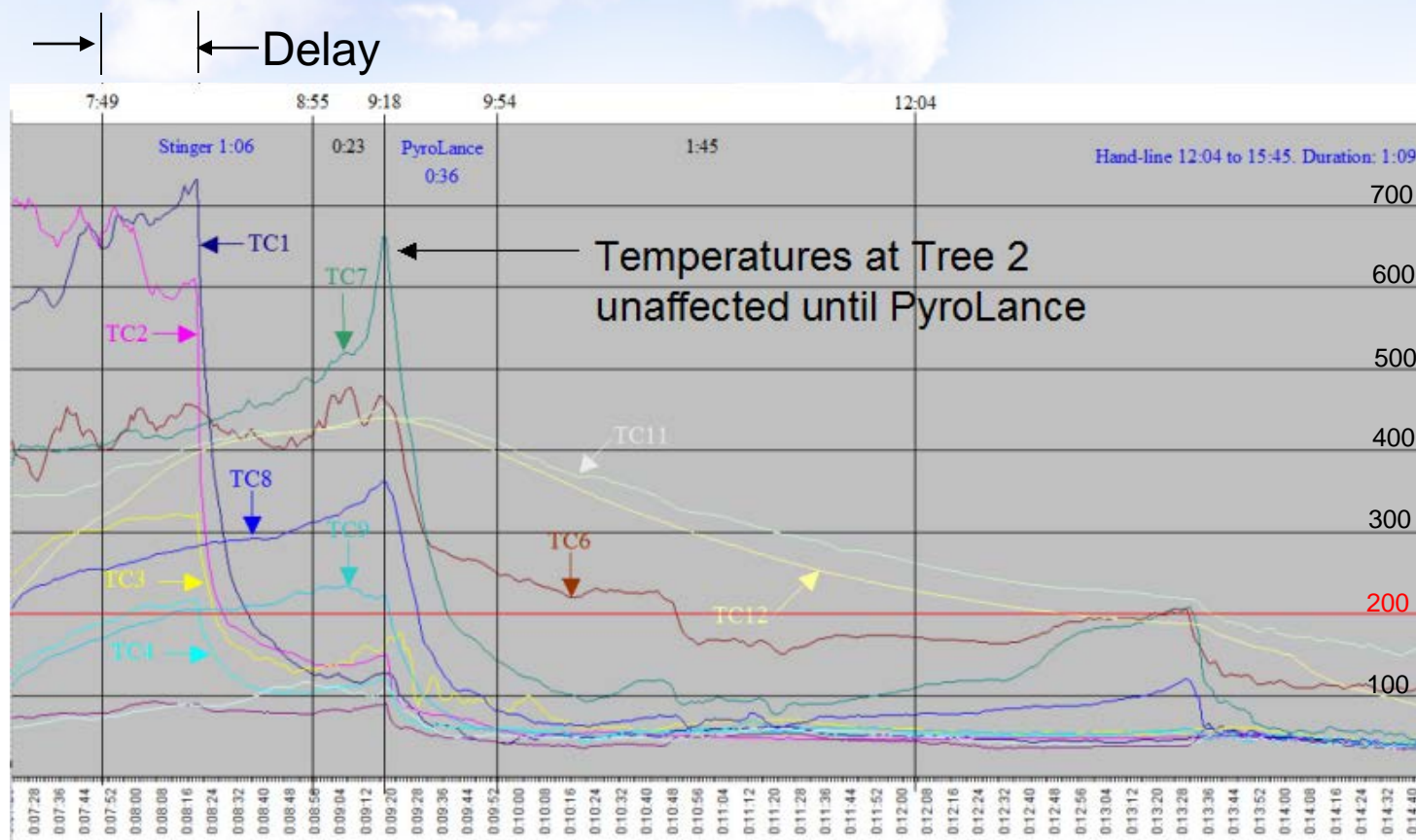
## Test 2 Interior below S6



# Test 2 Temperature Profile Prior to Extinguishments



# Test 2 Temperature Profile for Initial Extinguishments



## Peak Temps

TC#1	1348°F (711°C)
TC#2	1301°F (705°C)
TC#3	608°F (320°C)
TC#4	415°F (213°C)
TC#5	176°F (80°C)
TC#6	900°F (482°C)
TC#7	1222°F (661°C)
TC#8	682°F (361°C)
TC#9	450°F (232°C)
TC#10	239°F (115°C)
TC#11	441°F (245°C)
TC#12	455°F (235°C)

Note delayed response to Stinger application.

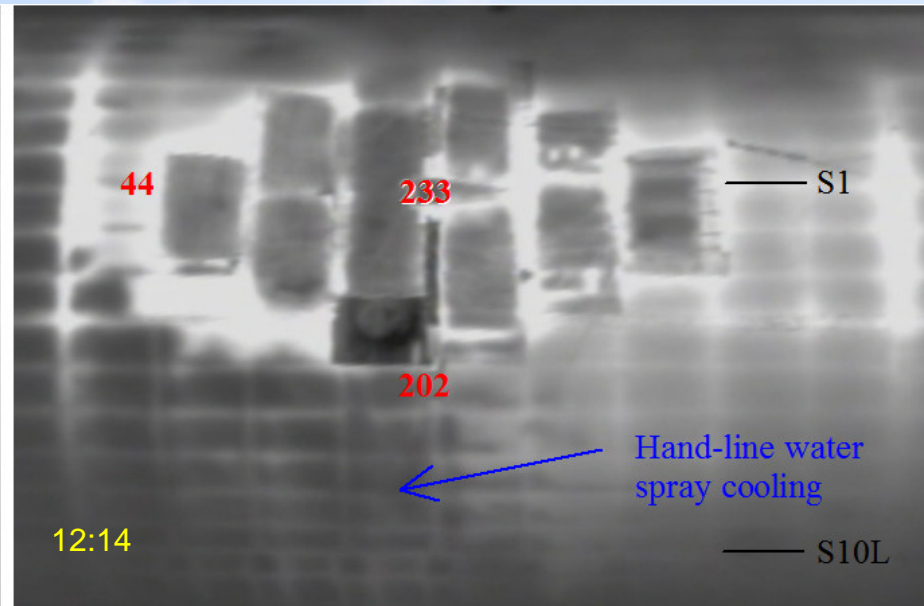
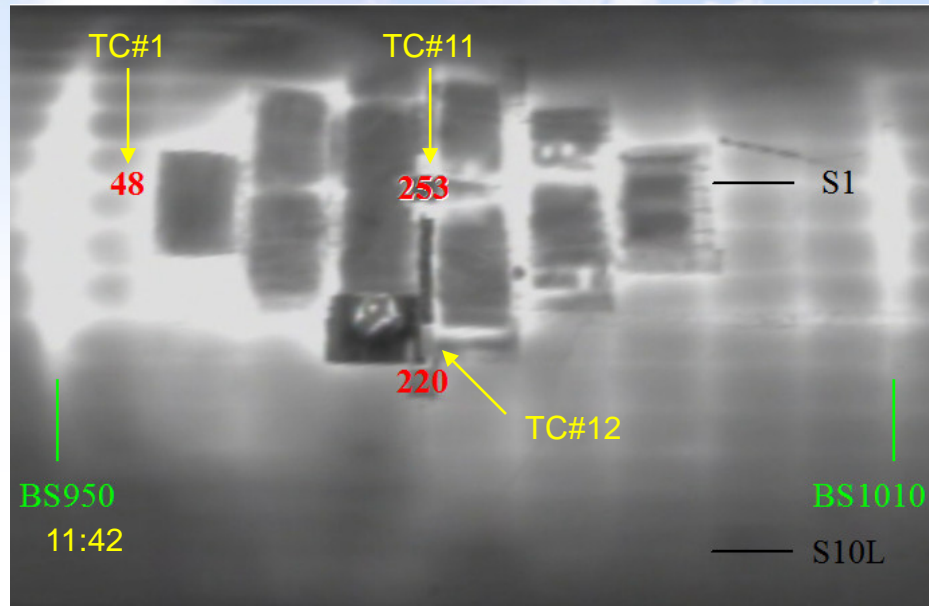
Upper cabin exceeds CFRP  $T_g$  for 10 minutes

International Airport  
Authority



Administration de  
l'aéroport international

# Does the CFRP retain heat longer or continue to smoulder?



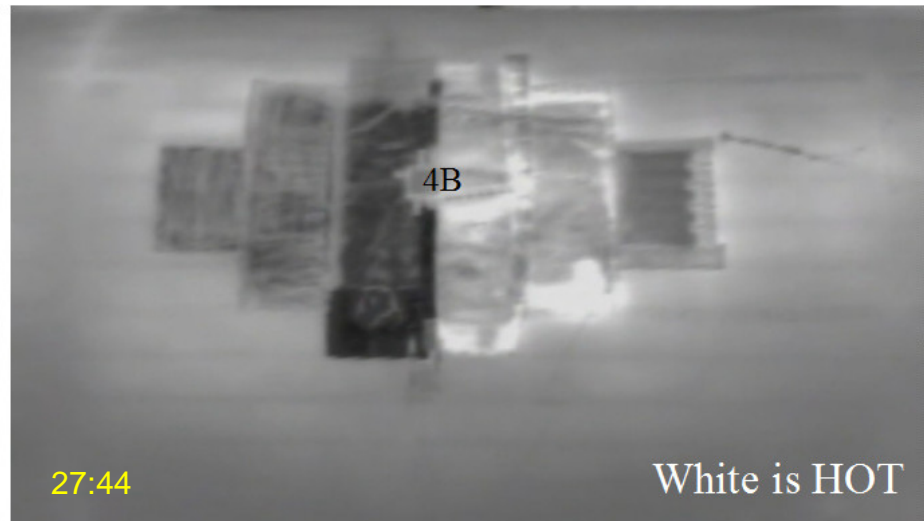
Over-wing hand-line 12:04 to 15:45.

Rear air-stair overhaul 17:43 to 27:00.

TC#1: 48°C = 118°F, 44°C = 111°F

TC#11: 253°C = 487°F, 233°C = 451°F

TC#12: 220°C = 428°F, 202°C = 396°F





# PyroLance Set-up



K. Sorensen

International Airport  
Authority



Administration de  
l'aéroport international

Ottawa



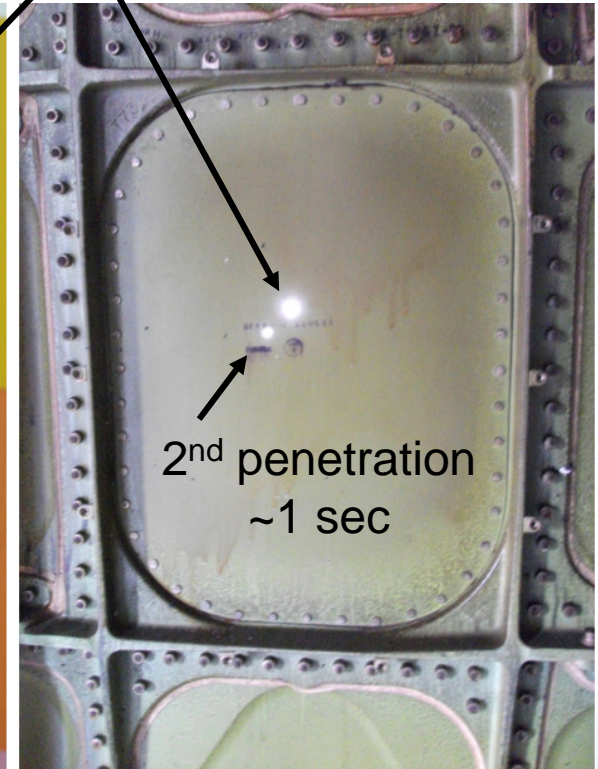
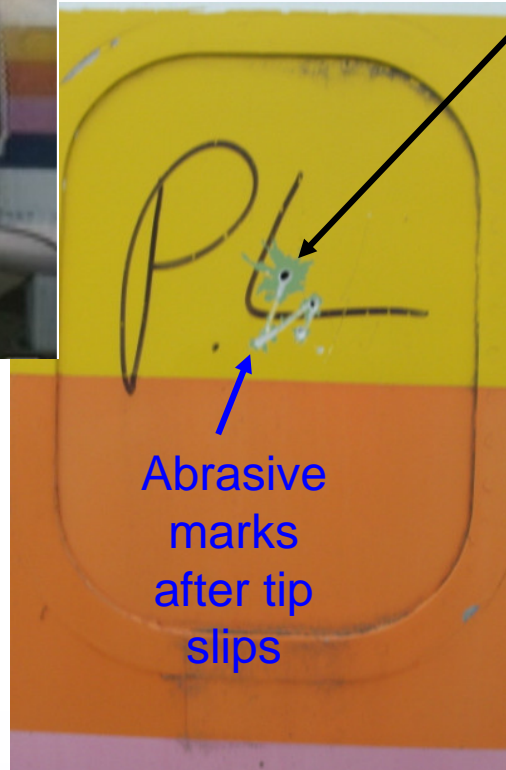
# PyroLance Piercing

Skin pierced and water flows for 36 seconds.



PyroLance attack lasted 1:06

Approximately 6.8 US Gal  
(25.7 L) of water introduced  
into fuselage.



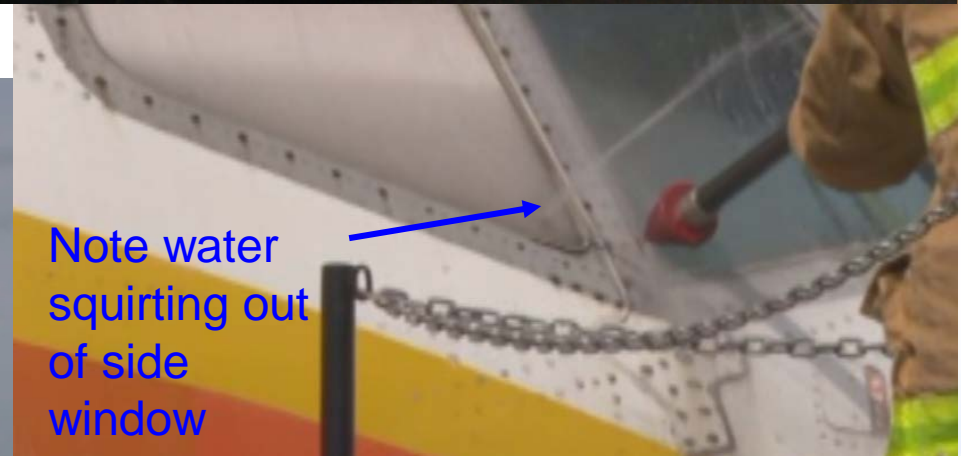
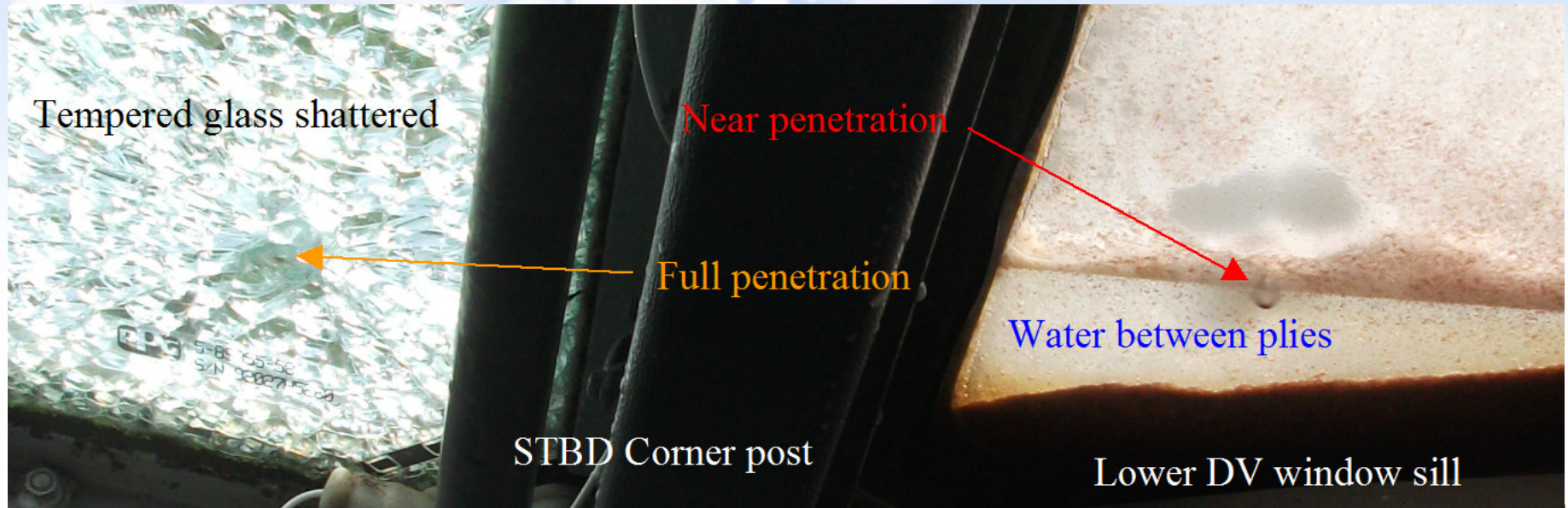
International Airport  
Authority



Administration de  
l'aéroport international



# PyroLance & Cockpit Windshields



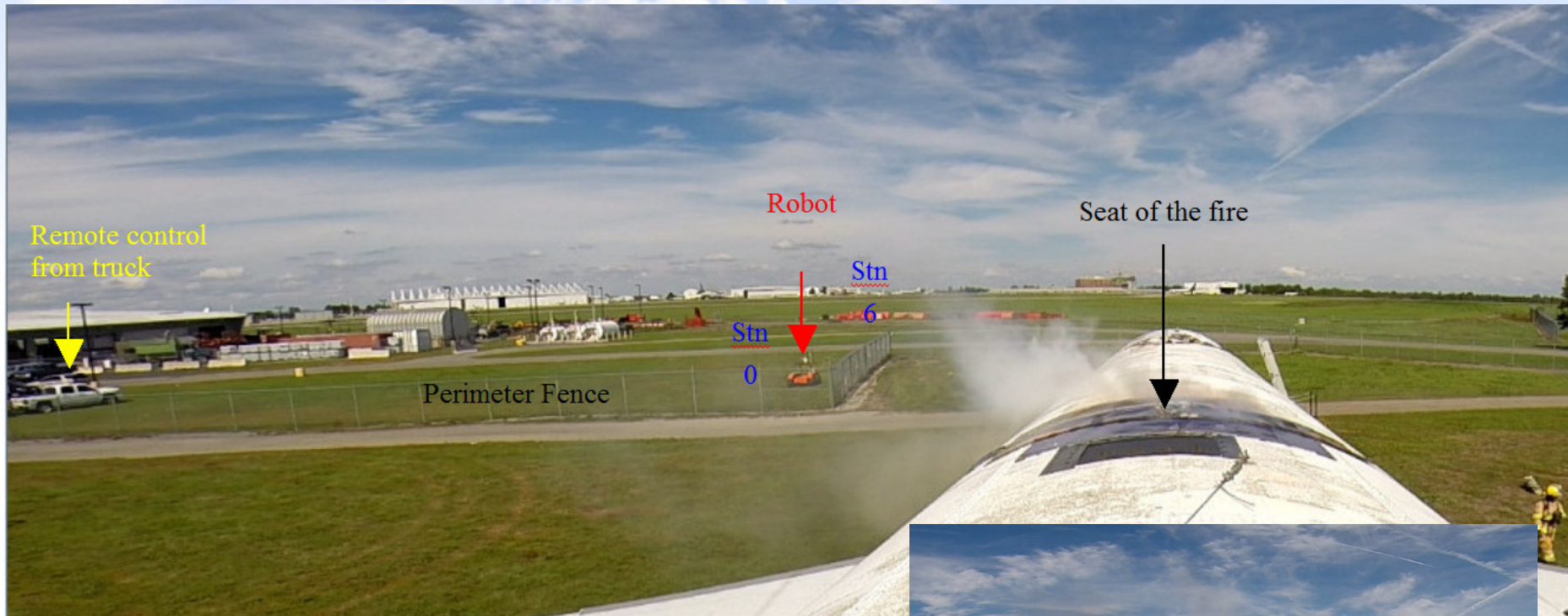
International Airport  
Authority

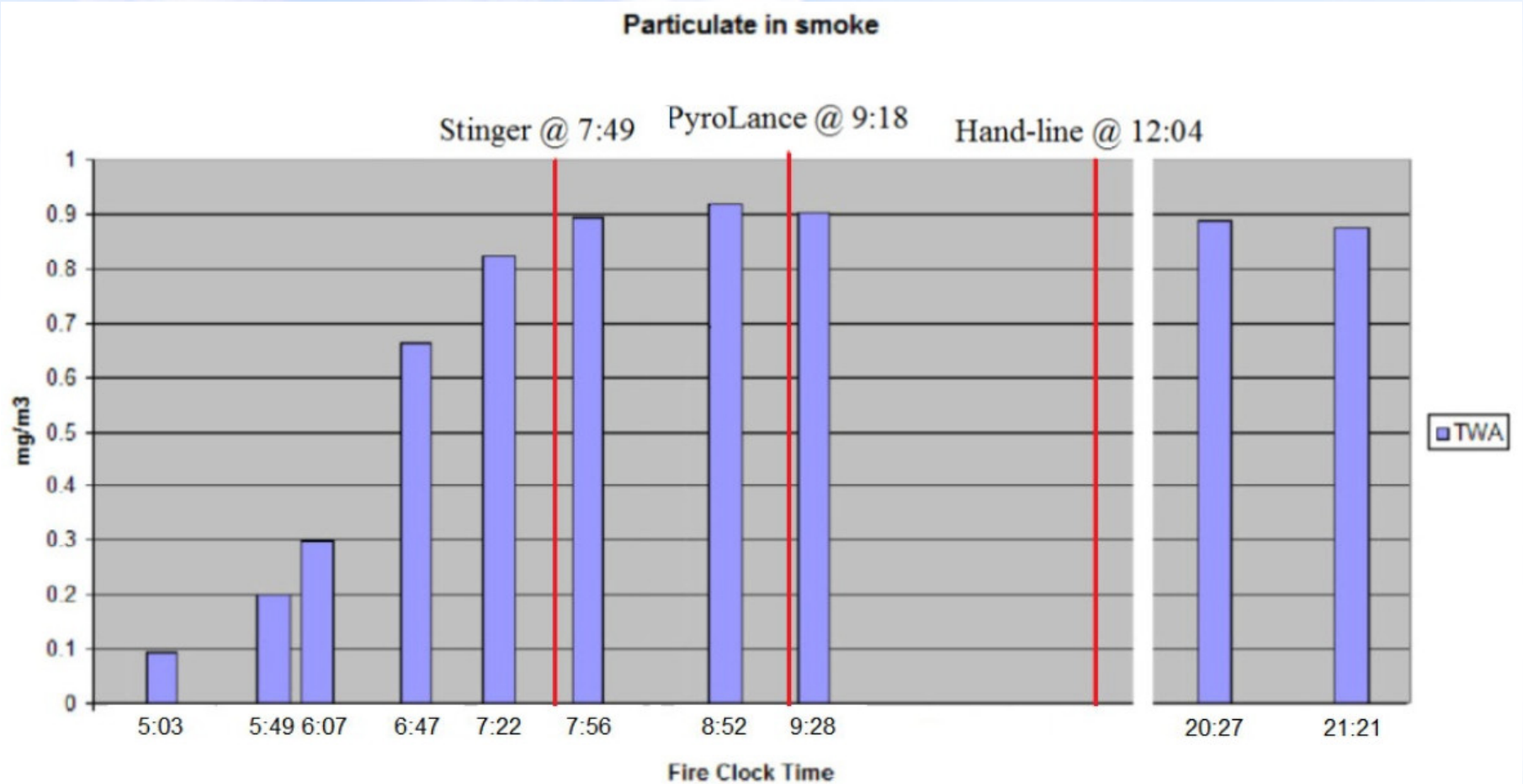


Administration de  
l'aéroport international



# Robotics & Particulate Sampling







# Firefighting Lessons Learned

Characteristics of both fires were known beforehand – that's not normal.

Test 1 Command Post & video screens were separate – co-located for Test 2.

Test 1 attack had one team downwind exposed to smoke – corrected in Test 2.

Substantial heat trapped in crown ducting after both fires could be seen with TIC.

Positive heat & smoke release after crown burn-through in Test 1.

Minimal burn-through of GLARE in Test 2 trapped heat & smoke.

Salvage tarp melted in Test 2 from higher internal temperature.

HRET TIC view too close for overall assessment. Stand-off TIC employed in Test 2.

Thick smoke & buoyant particulate produced in CFRP fire.

PyroLance effective. Useful in concealed areas. Forced entry may not be required.

PyroLance requires steady handling to maintain water flow through small hole.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international





# Firefighting Lessons Learned - continued

PyroLance quickly pierced laminated cockpit windshield and introduced agent – not otherwise easily or quickly accomplished.

Introduction of large amounts of water will affect weight and balance. Cutting drain holes in bilge may encounter thicker construction requiring non-traditional tools and significant time. PyroLance might be employed to cut drain holes.

Cabin floor was not compromised by fire or heat in such short duration tests. Cargo hold fires would have more effect on floor integrity.

Problems were encountered with robot-carried particulate sampling but analysis still points to high concentrations downwind long after visible smoke dissipates.

Smoke colour & behaviour changed once agent was applied to the fire.

More research needed on particulate geographic distribution modelling and its impact on first responders and the environment.

Daylight conditions and pre-staged equipment made communication & co-ordination easy.

International Airport  
Authority

Ottawa

Administration de  
l'aéroport international



# Conclusions

Both fires exceeded 1300°F (704°C). Aluminium skin, stringers and frames were vaporized.

Large amounts of fuel package material remained after both extinguishments.

Aluminium burn-through after 7 minutes from fire start.

Temperature drop after burn-through and before extinguishment in Test 1 did not occur in Test 2.

No burn-through of CFRP but significant loss of structural integrity.

Minor burn-through of aluminium skins in two GLARE panels but limited vertical ventilation occurred due to intact fibre layers.

Test 2 cabin temperatures exceeded 200°C (392°F),  $T_g$  of CFRP, for 10 minutes.

Particulate count downwind remained high long after open fire extinguished and visible smoke ended.

# No experience with Advanced Composite Fuselage Fires

CF-18, 2010



B-2, 2008



A340, 2005



A400M, 2015



International Airport  
Authority

Ottawa

Administration de  
l'aéroport international





Photo Credit: Jan Jasinski 2013

# Questions?