ARFF Special Projects

2005 to 2017

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

ARFF Working Group
Future Aviation Safety – A Global Conference
June 1-2, 2017. Copenhagen, Denmark

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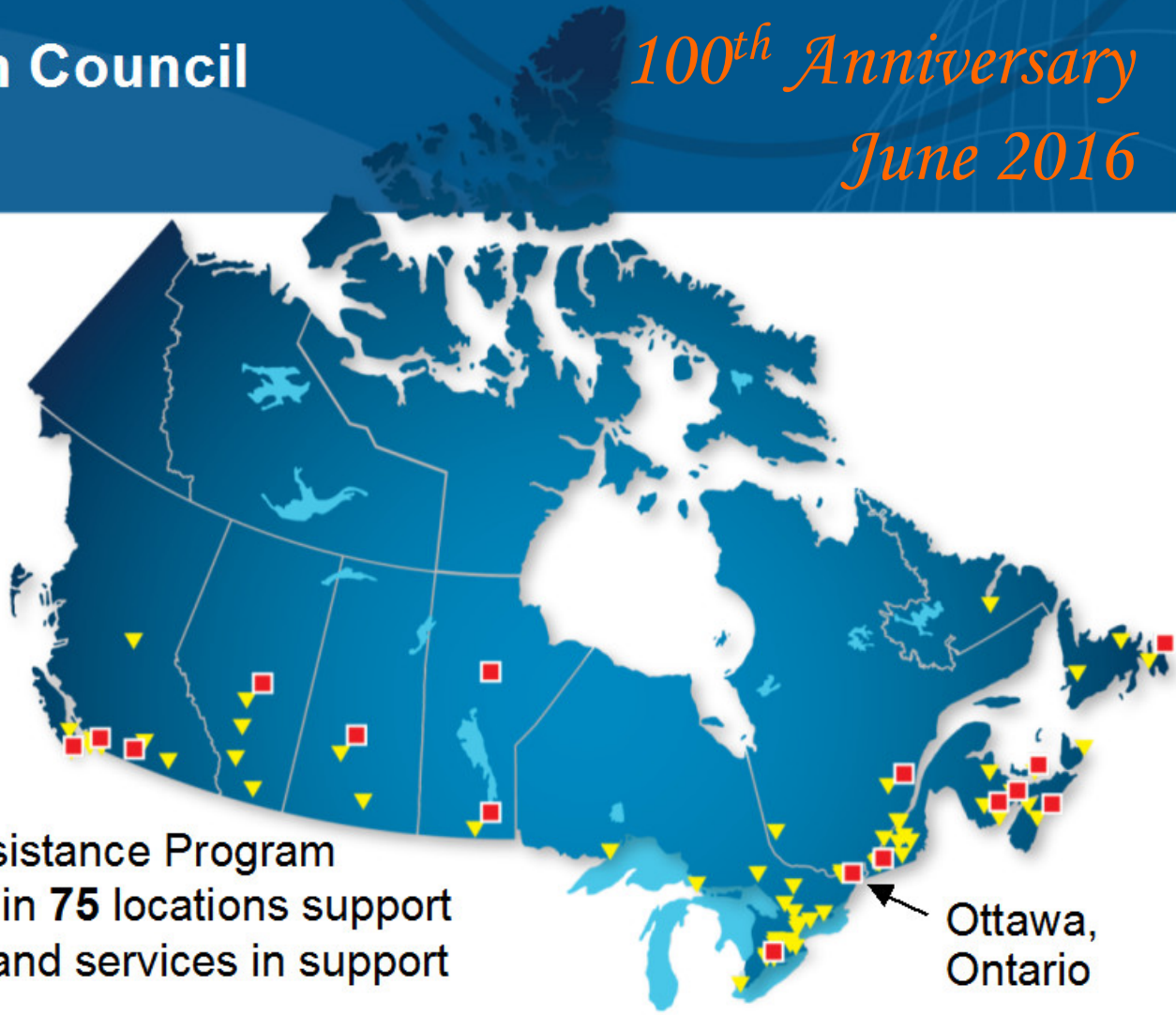
Ottawa

National Research Council Canada (NRC)

100th Anniversary
June 2016

- Approx $900M annual budget
- **12** Portfolios in **3** Divisions
- **3,670** employees and **575** volunteer and independent visitors



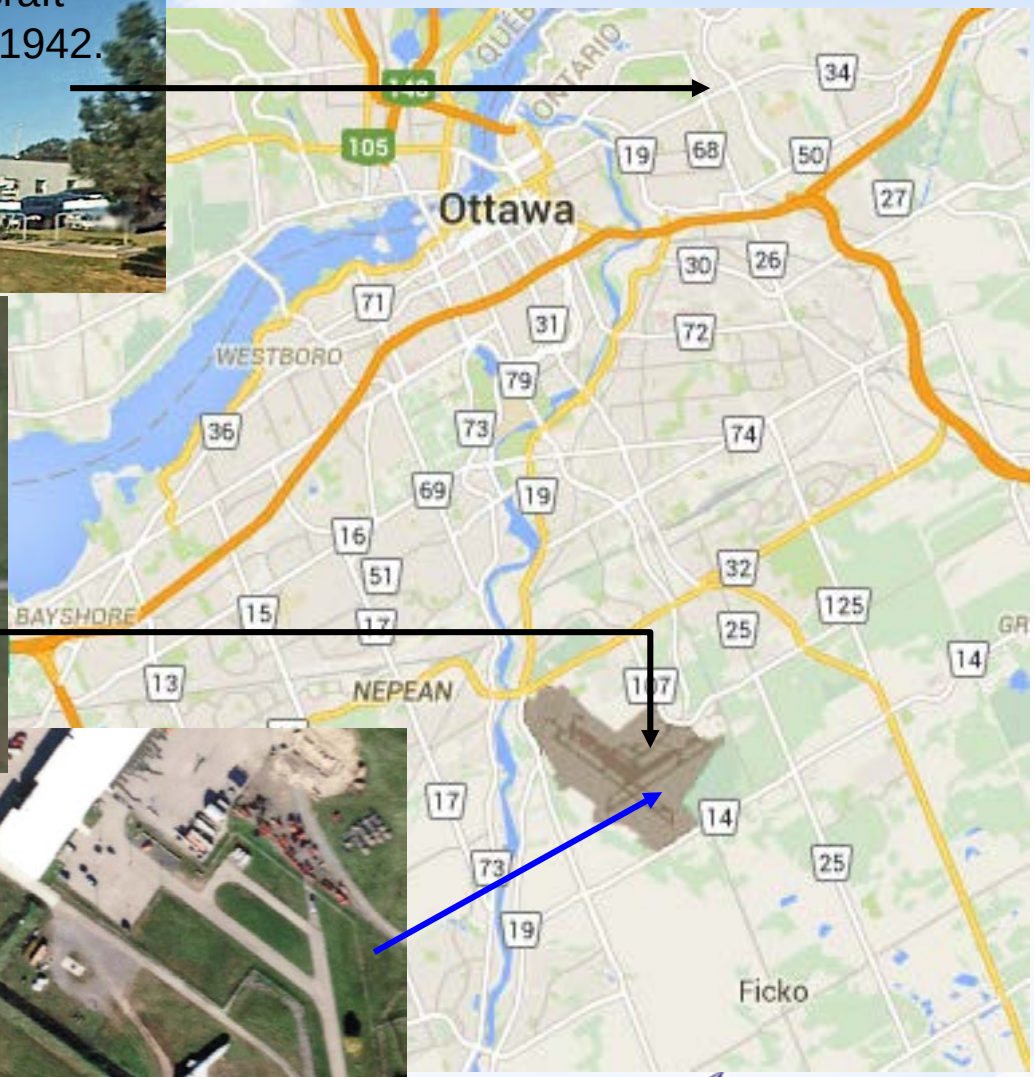
▼ Industrial Research Assistance Program (IRAP) representatives in **75** locations support a variety of disciplines and services in support of industry

■ Research facilities in **16** locations provide strategic research & development and technical services to national and international clients

82 buildings across Canada

NRC Main Campus.
M-14 Structures Lab where full-scale aircraft testing & composites research started in 1942.

NRC Aerospace Labs at YOW



OIAA ERS Fire hall

Training area

nal Airport thority

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Ottawa

First Encounter

OIAA ERS supported the wing clipping of NRC's first B727. The wings had to be cut so that the aircraft could be moved through the airport perimeter fence. No gate is wide enough.

Fuel tanks were sniffed for explosive vapours before cutting

XB-727 (XB-70 Valkyrie emulator)

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Cabin Windows Heat & Fire

2005

90 sec

Adjacent gasoline pool fire caused outer surface self-ignition.

Heat causes 40% shrinkage

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On the Crash Chart, only 4 pressurized oxygen bottles are shown in the FWD hold cheek area. There were 6 bottles and #5 exploded.

2005

Time in RH corner (@29.97 frames/sec) is from first appearance of fire in cabin window.

Approx 19 seconds to explosion of breathing oxygen bottle.

Kaboom 1, AFT Cargo Hold Fire

2007

1 bomb + real luggage produced a toxic fire.

Manual piercing to access aft cargo hold fire.

Too much foam.

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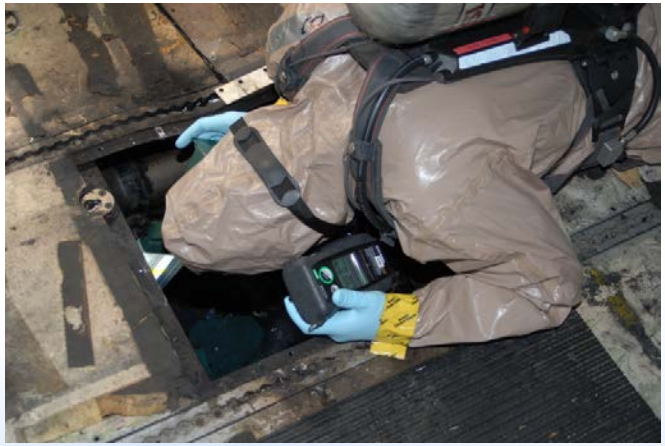
Kaboom 1, AFT Cargo Hold Fire

2007

80 seconds elapsed time



Cargo hold environment still too toxic
1 day after fire (CO_2 > 200 ppm)

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Aircraft Scrapping

2007

Scrapping an aircraft provides training opportunities for city, airport and military firefighters to try out their forced entry equipment and techniques. Training aids can be cut out too.

Metal cutting chain saws and hydraulic shears/spreaders are useless on an aircraft.

This hole took 15 minutes to make - not counting the time to set-up.

3 chains ruined very quickly.

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Two bombs are better: one in the AFT cargo hold for elastic deformation measurements and a bigger one in the FWD hold to create critical damage.

2009

No cargo hold fire. Firefighters said they would not attend next test if there was no fire…see cargo hold battery fire.

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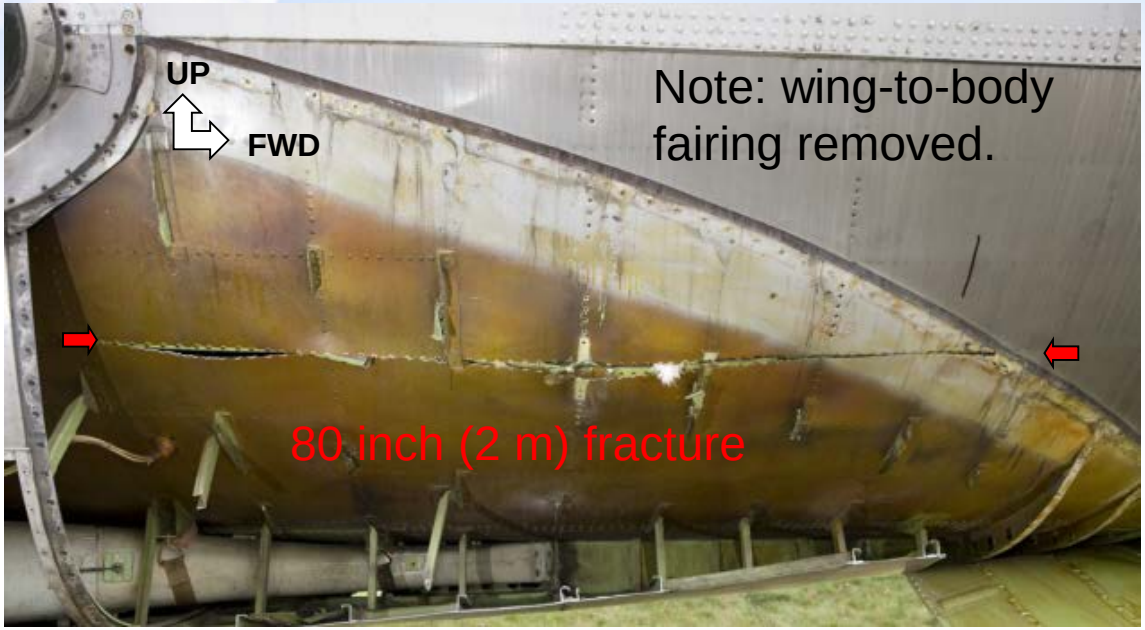
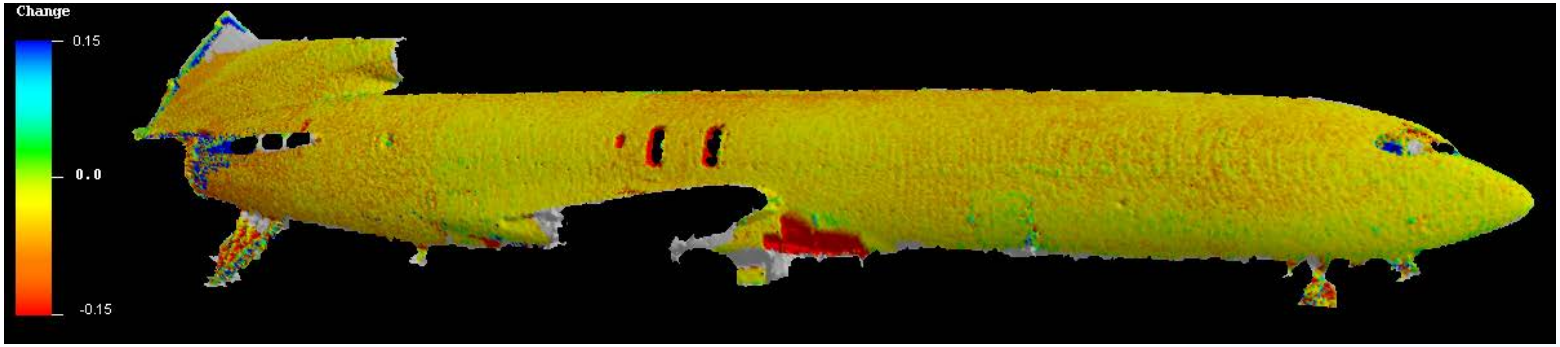
Kaboom 2

2009

Blast created “critical length” fracture in the skin and broke 4 frames in 7 places.





LIDAR mapping of aircraft was done pre- and post-blast.

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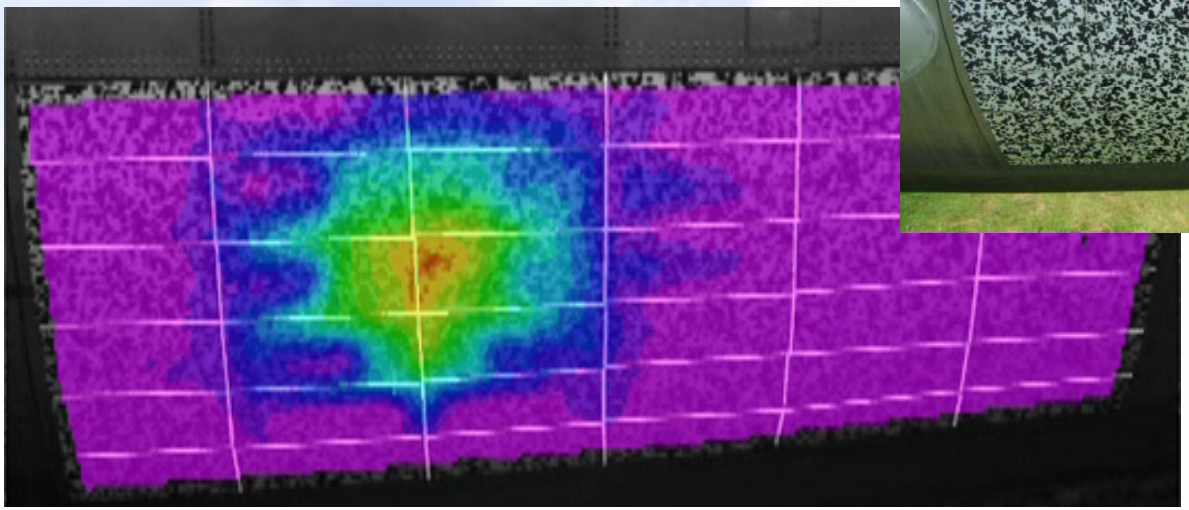
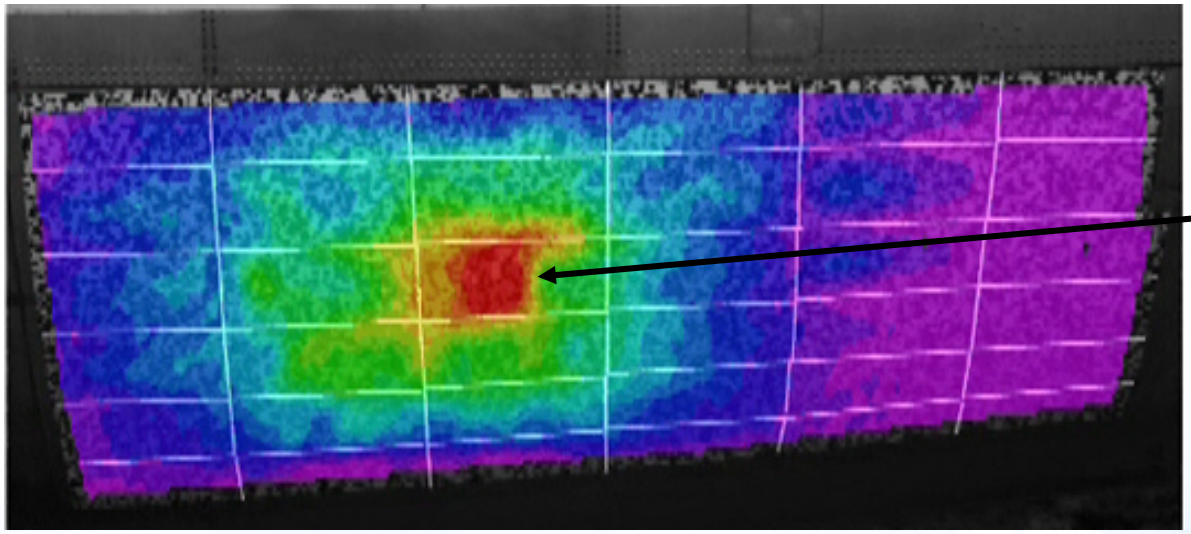
Blast Measurements

2009





Speckle pattern applied to PORT AFT skin for Digital Image Correlation which provides full-field displacement and strain data during the blast.

There was a square internal skin repair patch exactly in line with the bomb site.

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Small Component Burn Tests

2009

CFRP

GLARE or FML

O2 generators may exceed 550°F (288°C) on the outside but they burn at over 1100°F (593°C) internally. So if they are activated and then damaged…

Jan 2009

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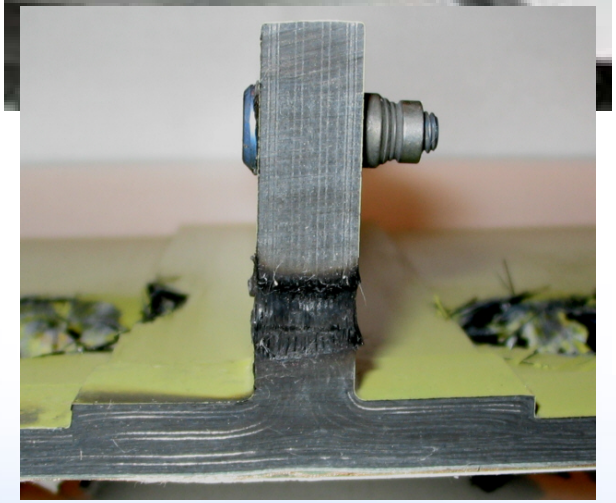
Cutting Composites

2010

Water spray not just for dust abatement.

F-18 wing root has titanium fir tree core. Composite skin easy to cut but molten Ti is sufficient to set your pants on fire.



Cutting through metal fasteners in composite structures can start a smouldering fire.

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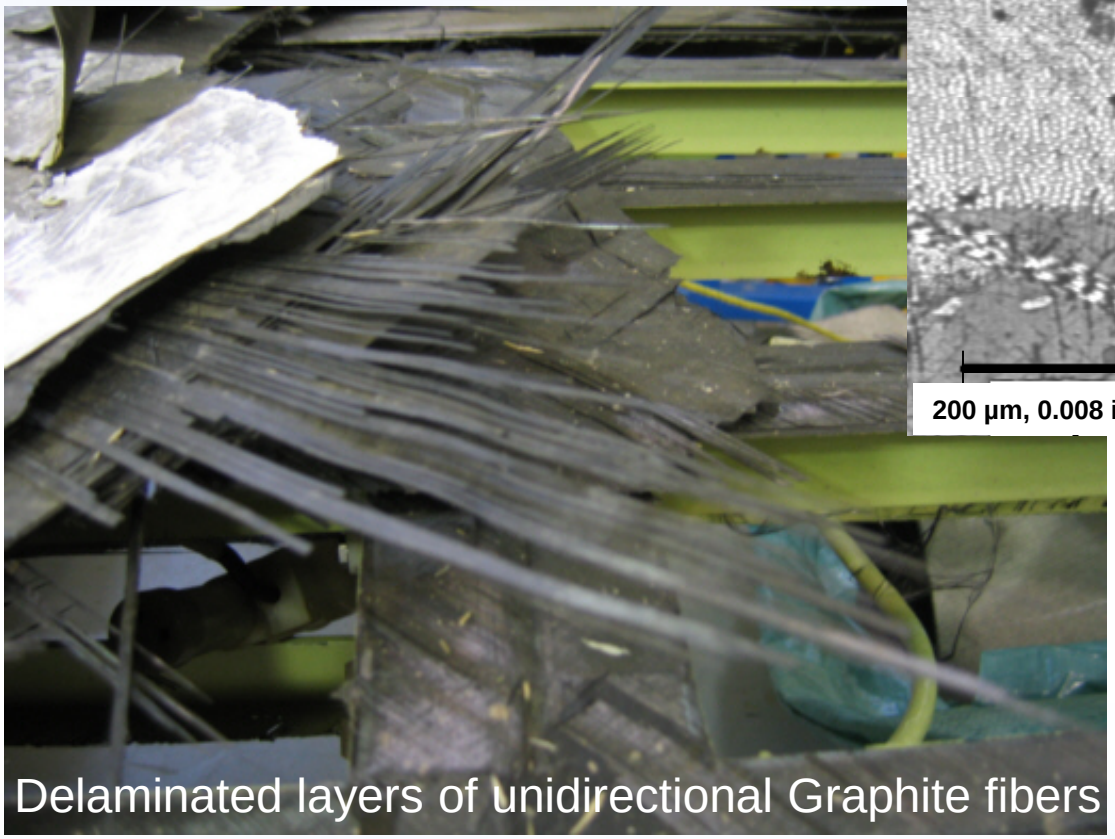
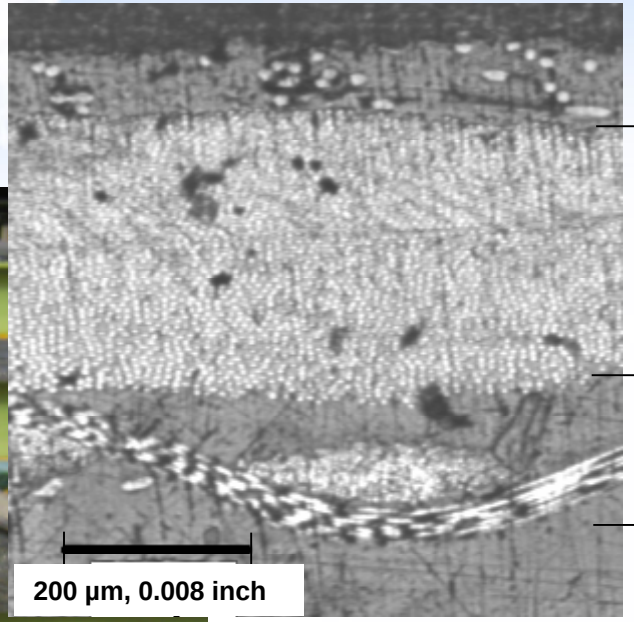
Composite Issues

Penetration wound



A340 composite Horizontal Stabilizer



Micrographic section through CFRP/GFRP hybrid layup

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Stinger Piercing Maps

2011

B727 piercing map

We have only one HRET piercing tool so we don't want to break it or trap it in a confined space.

Other than windows and doors – there are no landmarks for piercing on a fuselage.

Too much effort to generate a piercing map - even for one aircraft type.

Too much to ask a firefighter to flip through a database to find where to pierce.

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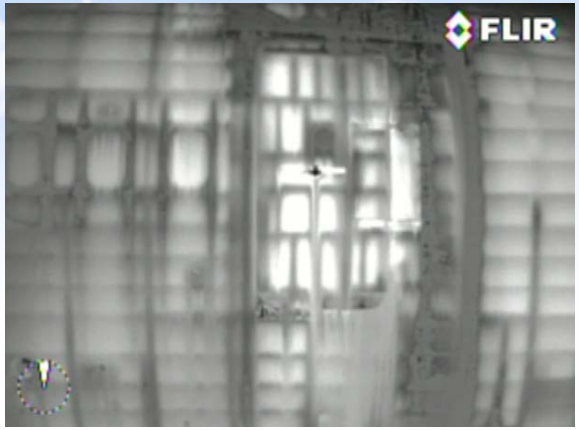
Thermal Imaging for Sub-structure Read-through

2011



- The substructure of an aircraft can be revealed in real time in a thermal image when the structure is subjected to differential heating either internally or externally.
- Real time imagery is preferred as a visual aid to piercing over off-line referencing of colour-coded maps.
- The location of attached substructure is revealed and to some extent the relative thickness.
- Water stream delivers more heat than deluge spray.

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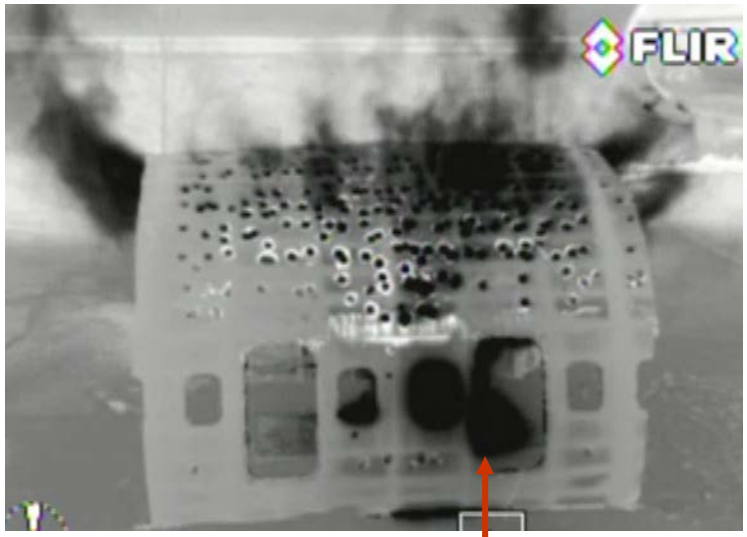
Thermal Sub-structure Read-through

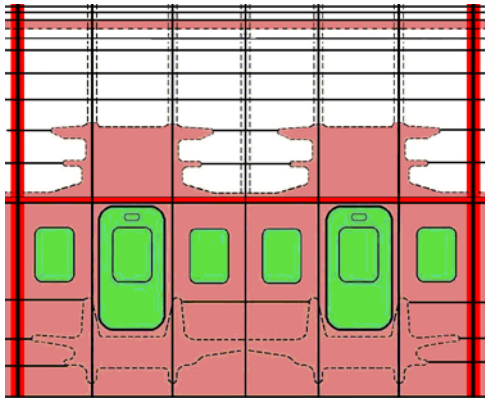
2011

A pool fire in a pan inside our B727 centre section piercing trainer gave us our first example that sub-structure could be detected by the thermal camera and provide the piercing tool operator guidance on where NOT to pierce.

B727 centre section



Pool fire



Frames, stringers and skin doublers

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Truck ID

2011

We have two identical Panther 6x6 trucks, Red 8 and Red 9, but we can't tell them apart in a thermal view.

Note the sub-structure read-through on the B727 behind the truck after a CAFS training exercise.

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Emergency Responders and Aircraft

Fire and Impact Damage Hazard Awareness

or

"Things you need to know when an aircraft crashes at your place – because aircraft don't always crash at the airport"

Starting in 2009, over 1000 Ottawa city firefighters have received presentations and viewed artefacts.

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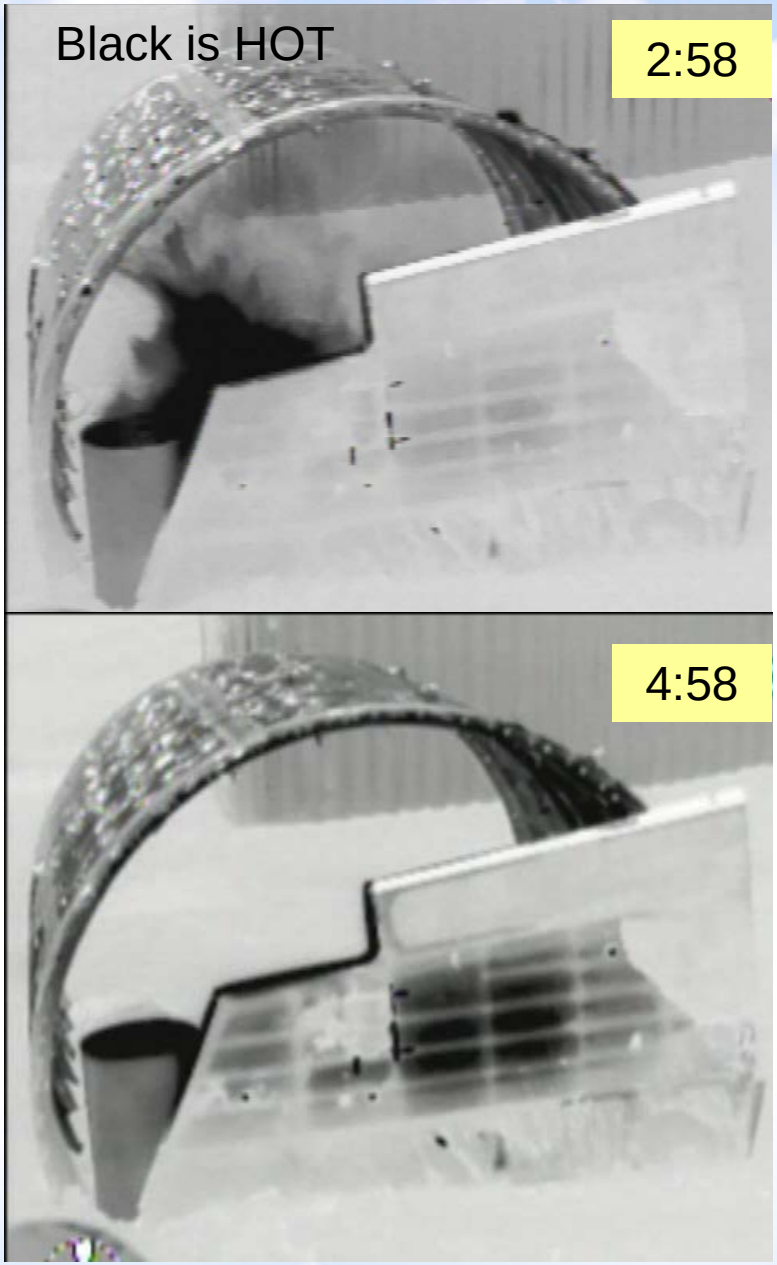
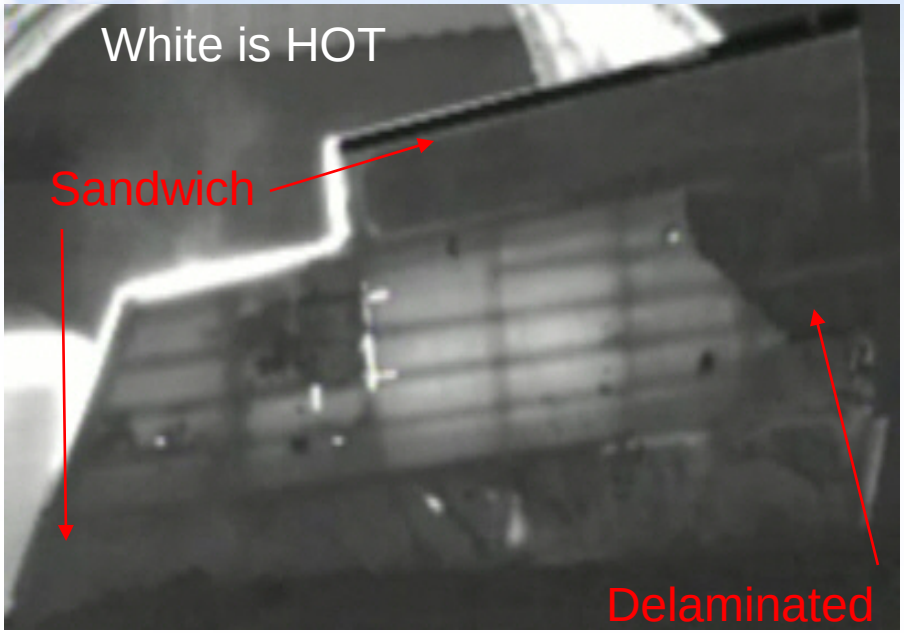
Thermal Response of CFRP

2011





Thermal read-through of internal structure with fire behind composite structure.

NO read-through in areas of sandwich construction or where solid laminate skin is delaminated.

First substructure reveled 2:58 after fire started.

Fire out after 4:58 minutes.

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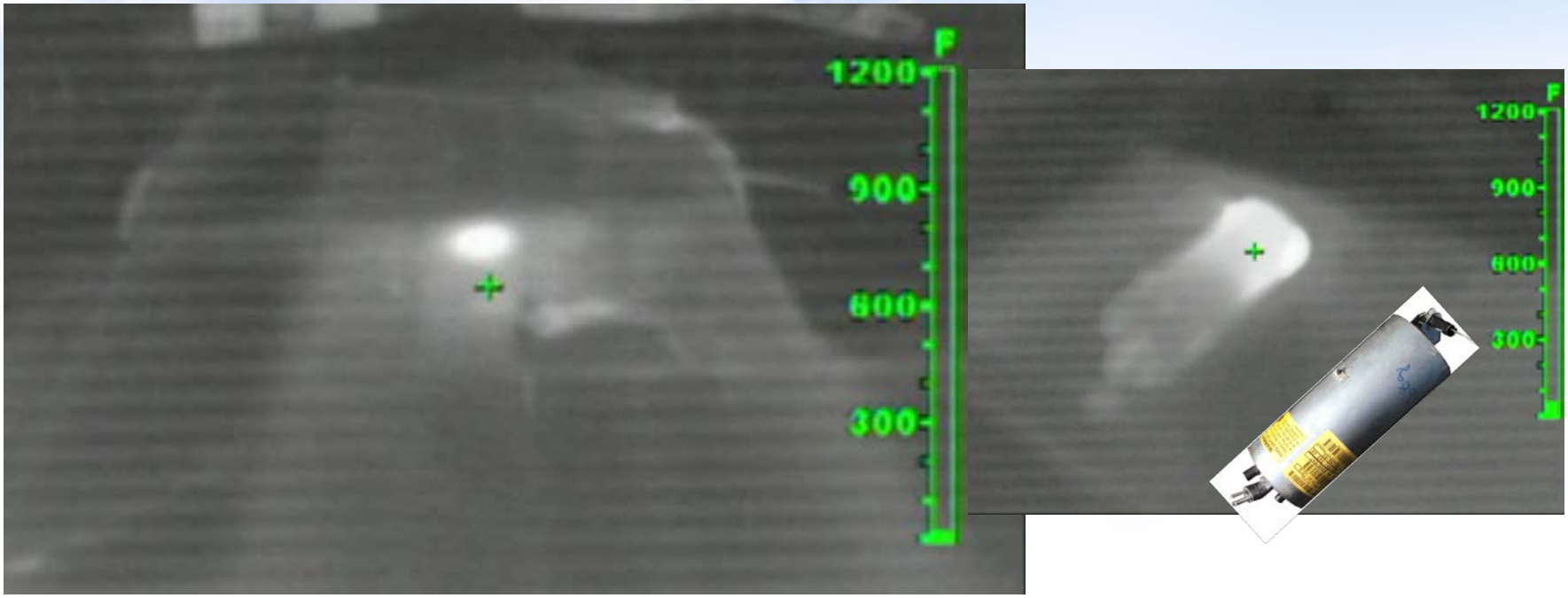
Are CFRP Fuselages IR Transparent ?

2011



A chemical oxygen generator (surface temperature >550°F, >288 °C) inside a composite horizontal stabilizer from an A340. The top skin has paint and a copper mesh imbedded over the whole outer surface for lightening protection. The generator is sitting inside the structure on top of the bottom skin so it is at least five inches (12.7cm) away from the inner surface of the top skin yet when we got close with a thermal camera it was as if the top skin is transparent (inset) as we could see the generator shape in detail.

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Where's the Fire?

2011

What do aircraft normally look like, thermally, and how does this affect your response to a call of fire/smoke/overheat?

Firefighters need to educate themselves on the normal thermal signatures such as heated windshields, air data probes and, on this A-320, the use of the fuselage skin to dissipate heat from electronics.

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Engine Fires

2011

A working group was formed to gather factual information towards developing techniques for fighting fires in engines and nacelles as well as flooding-out run-on engines.

We began imaging the engines on operational aircraft to characterize their normal thermal signatures.

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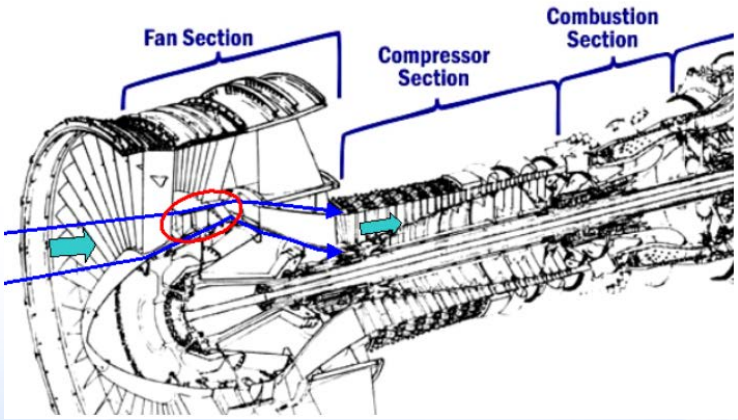
Engine Fires

2011

Engine Firefighting Working Group

- Penetrators- use on engine nacelles?
- Engine combustion and controls modeling and simulation
- Fluid ingestion modeling and simulation
- Engine failure recognition methods
  - *FAA training material*
  - *Infrared imaging and interpretation*
- Formal needs analysis and training design
  - *Initial and recurrent stages*
  - *Benchmarking and updating processes*
  - *Integrated theoretical and practical components*
  - *Simulation tools and rigs for procedures and realism*

Central ring around fan cone is target for water delivery to terminate engine run-on.



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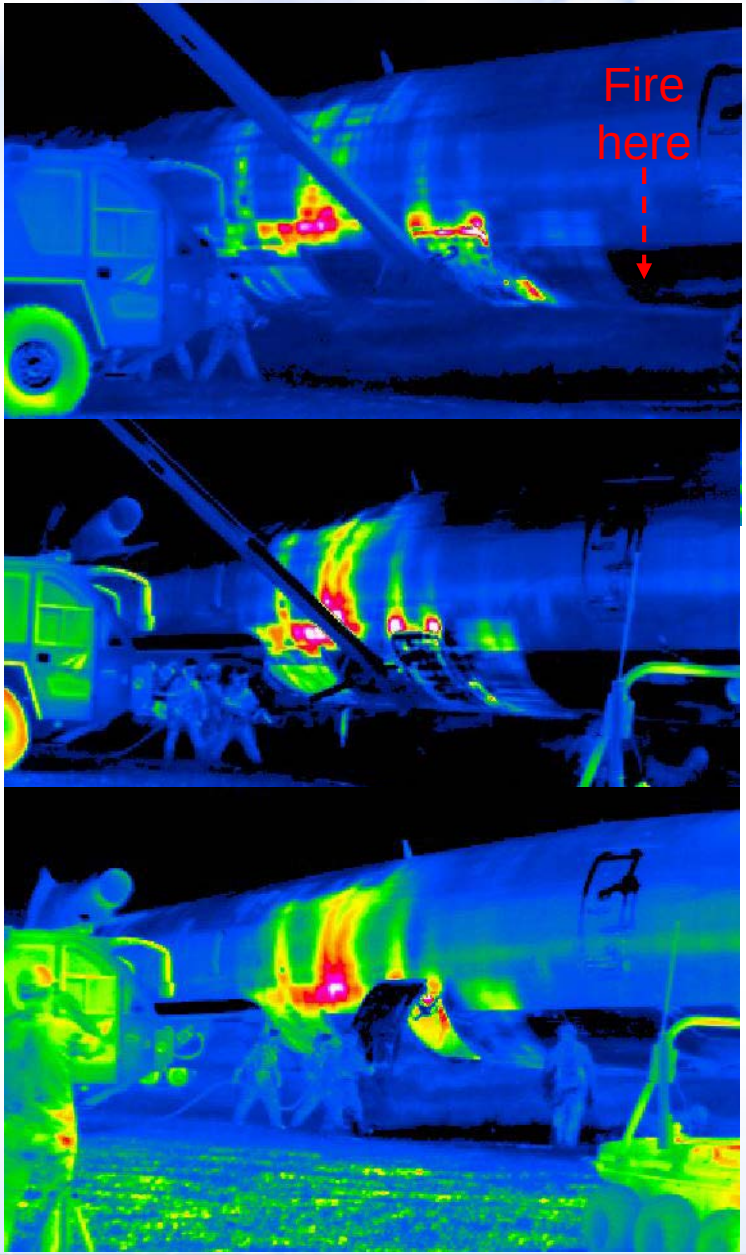
LTR-SMPL-2012-0126

Cargo Hold Battery Fire

2012



Military 10 D-cell Li/MnO_2 primary battery pack
2.87 lb (1.3 kg)

Molten Lithium

Flame jet, 90 sec each cell

Battery case trajectory

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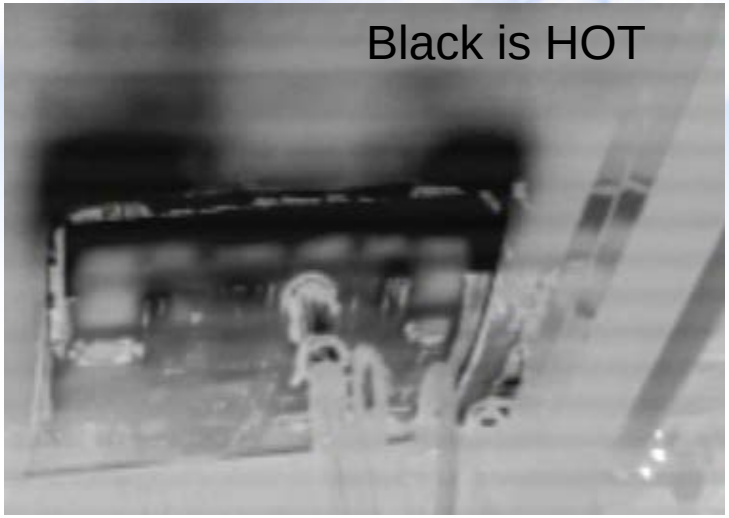
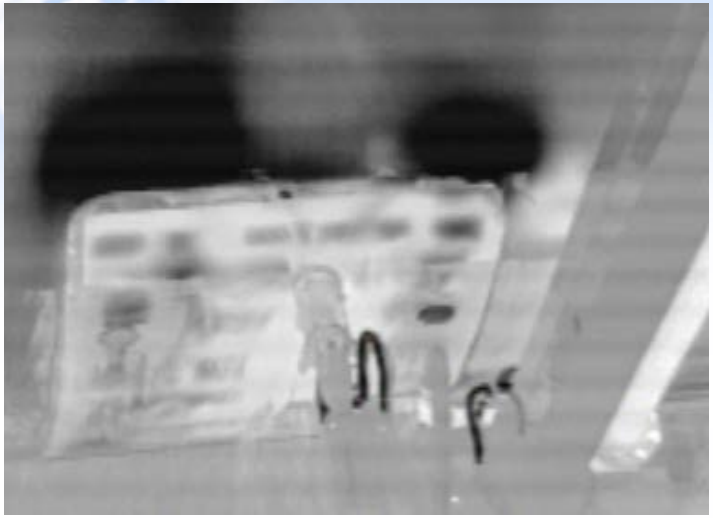
Cargo Liner Fire Damage

2012





Fire damaged the fibreglass liner on the inside of the cargo door which trapped the Stinger water spray so that only the cargo door was wetted.

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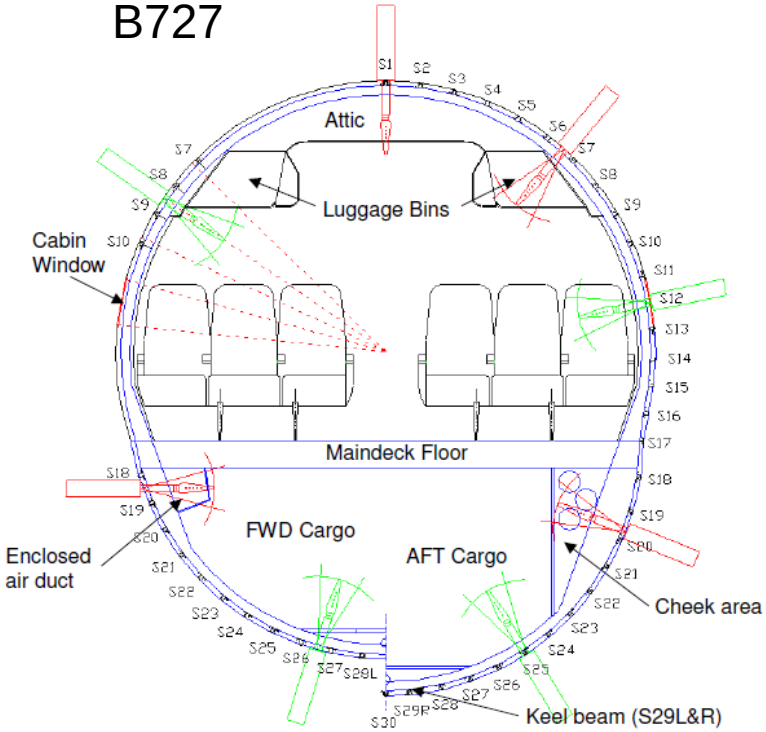
Stinger piercing effectiveness

2012

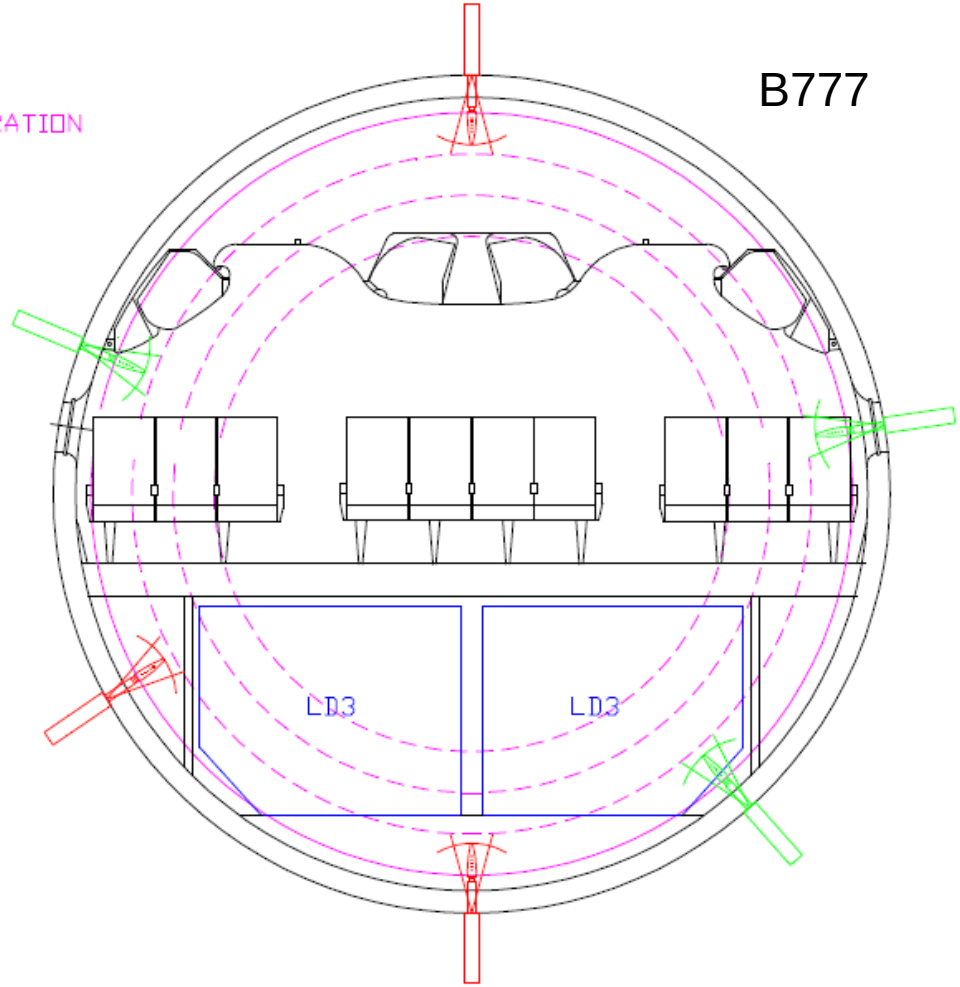
EXISTING STINGER TIP MAX PENETRATION

12 INCH EXTENSIONS

B727



B777



Understand confined spaces and limits of Stinger penetrator

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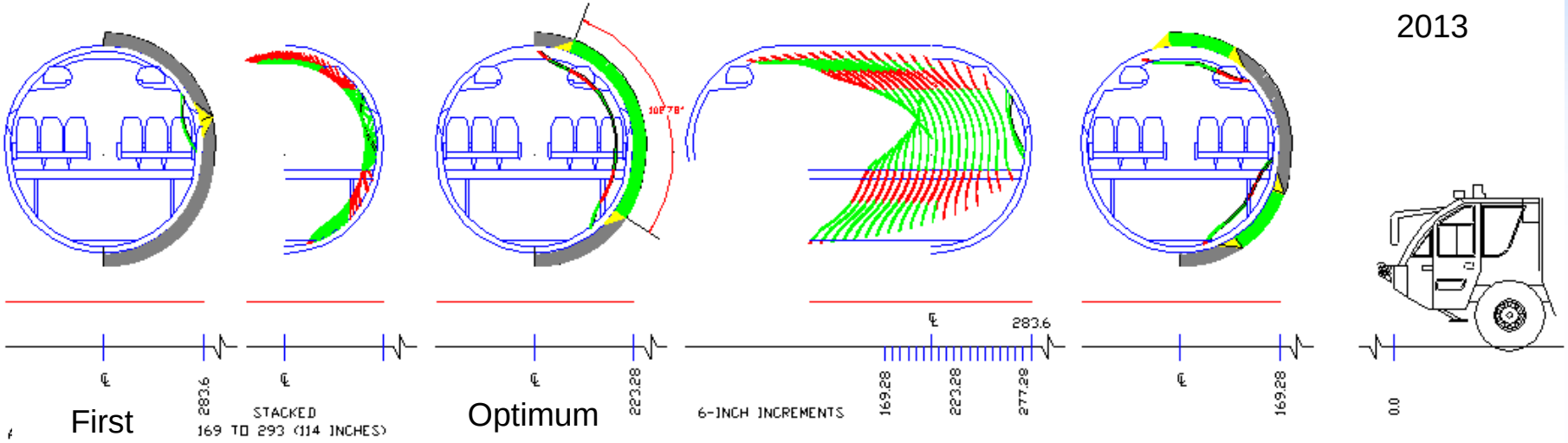
A318-321 ON- & OFF-GEAR

Stand-off Modeling for Optimum HRET positioning for Piercing.

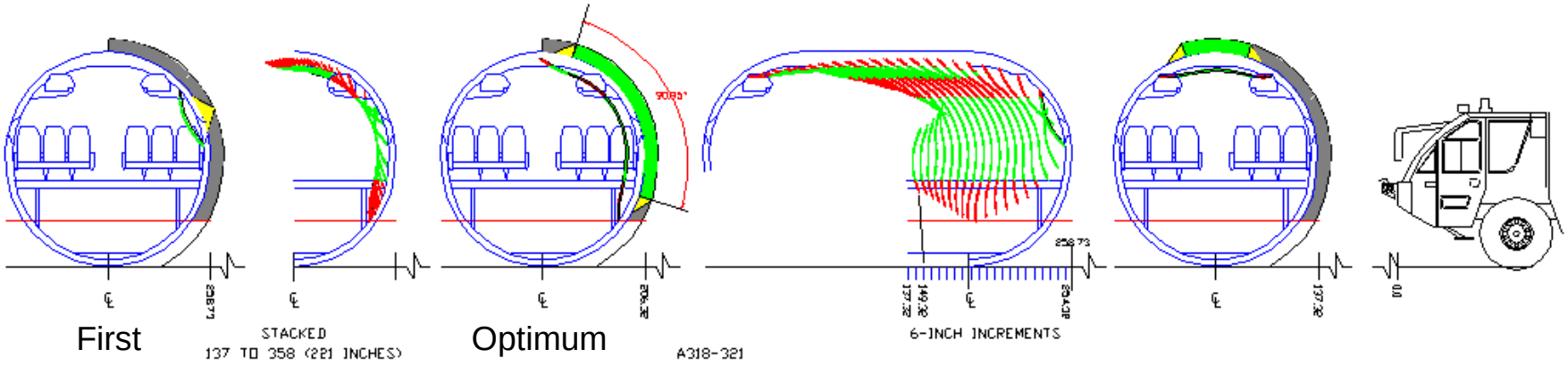
2013



First contact

Optimum

On-Gear



First contact

Optimum

Off-Gear

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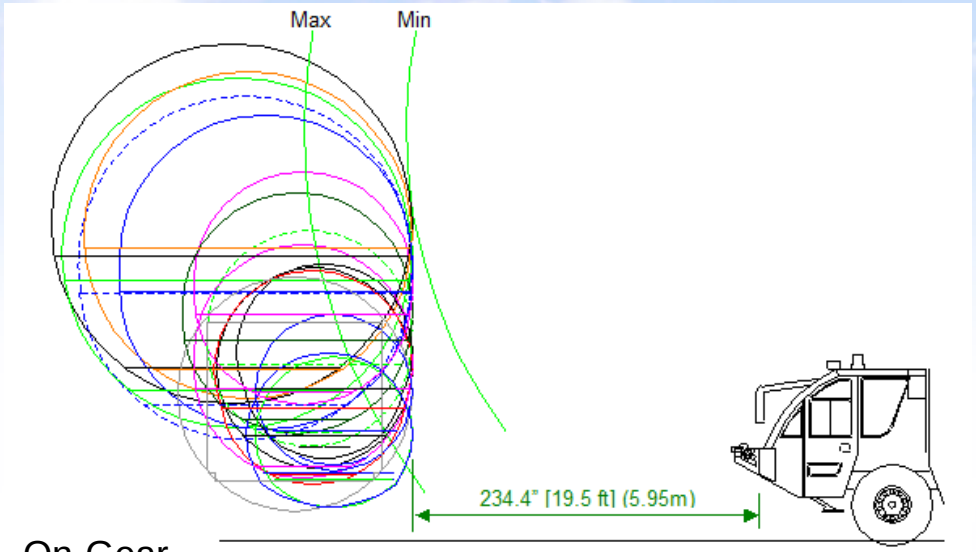
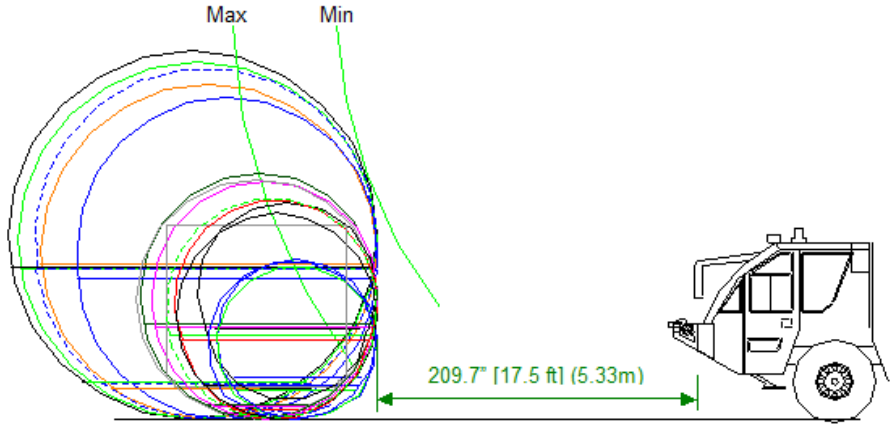
Stand-off Modeling for Optimum HRET positioning for Piercing.

2013

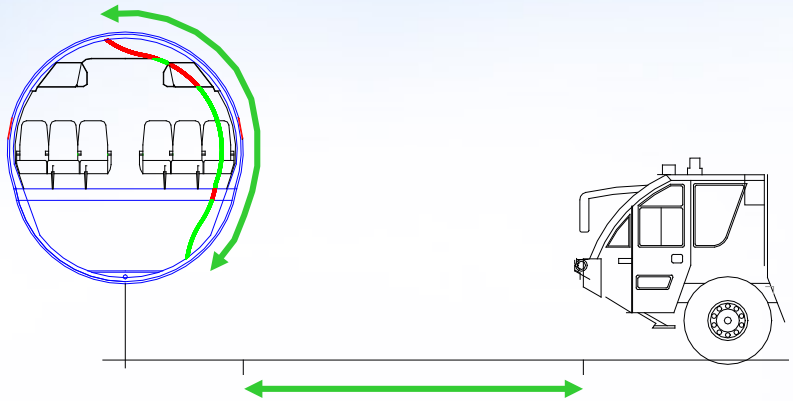


On-Gear



Off-Gear

Combined Small and Large Aircraft groups.



Optimum standoff distances were developed for 18 aircraft types.

These were grouped to establish one common distance.

The difficulty remains – how to measure/display the distance as the truck approaches the aircraft.

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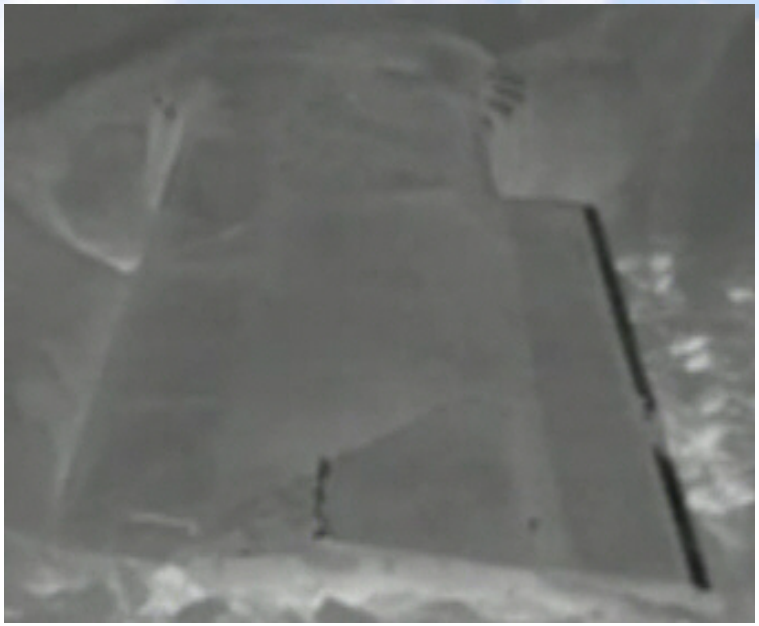
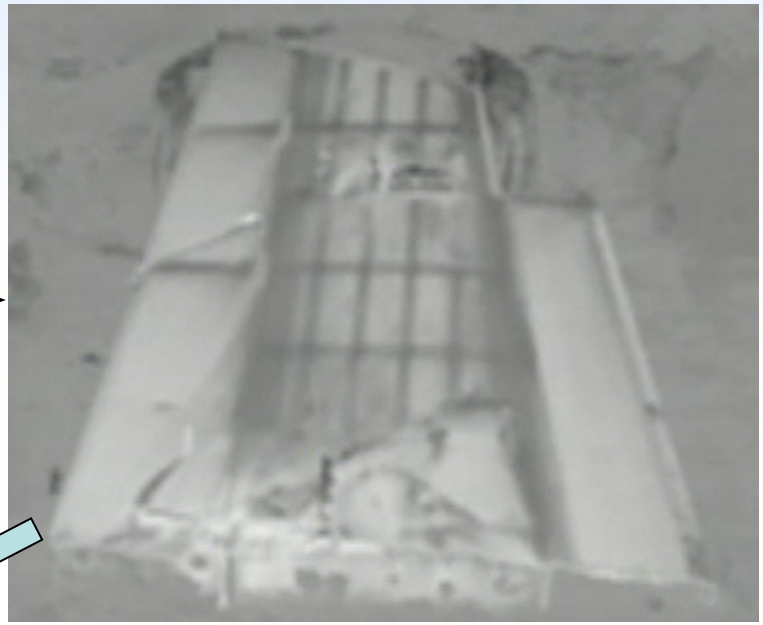
Thermal Response of CFRP

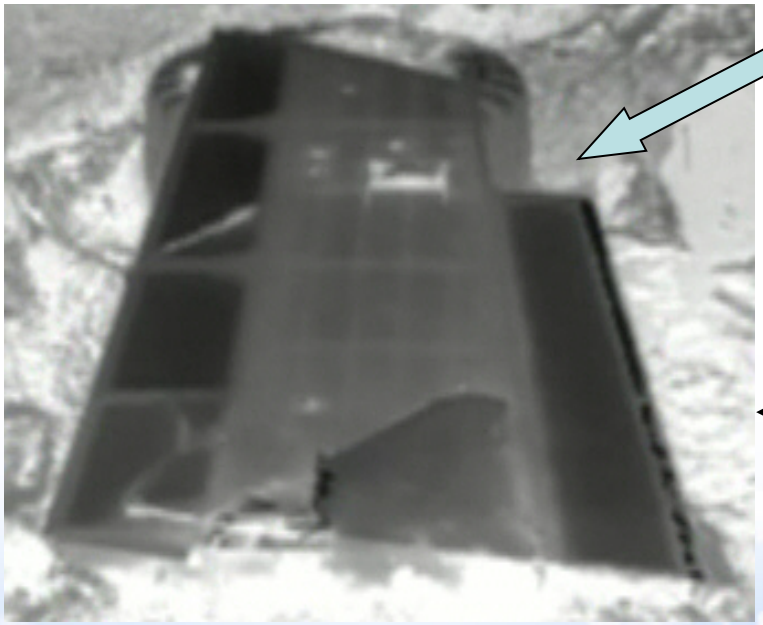
2013



White is HOT



Time 0:00
1.4°F (17°C)



35 seconds after water applied

From 9:00 to 16:35 minutes after water applied

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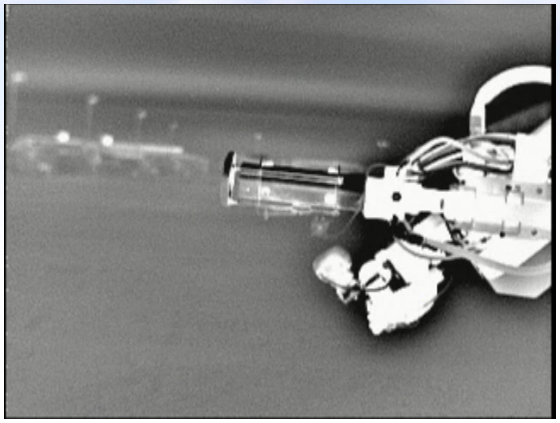
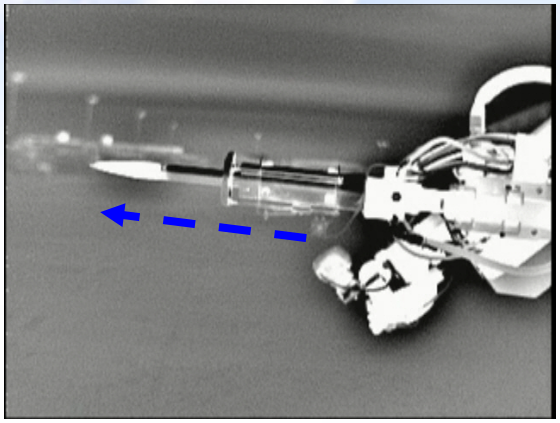
Low Temperature Effect

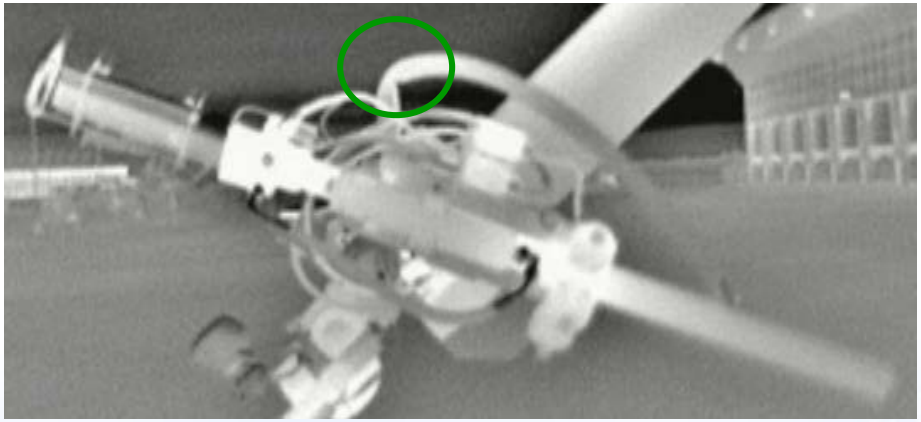
2012





A call-out in winter to await the landing of an aircraft could expose the truck to low temperature effects.

After 50 minutes exposure in –4°F (–20°C), the movement of the Stinger piercing tool had slowed by 39.6%.
Hydraulic fluid changed.



Water flow through metal swivel had gradually removed lubricant which caused swivel to jam in cold and kink the water hose (circled).
Lubrication schedule increased.

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LTR-SMM-2015-0414

Maximum Use

1970 B727-225F
ex C-FIFA

WFU 2003

To NRC 2005

Bombed 2009

Li Battery fire 2012

Transferred to
OIAA ERS 2013

Al & Composite
fires 2014

BigBurn 2015

Scrapped Dec
2015 after 45
years of service

Test 1 – Baseline Aluminium Fire Test
2 – Advanced Composites Fire

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Composites Burn

2014

Overhead thermal and video camera on boom truck.
Videos sent to command post (red van).

Pyrolance attacked off STBD wing.

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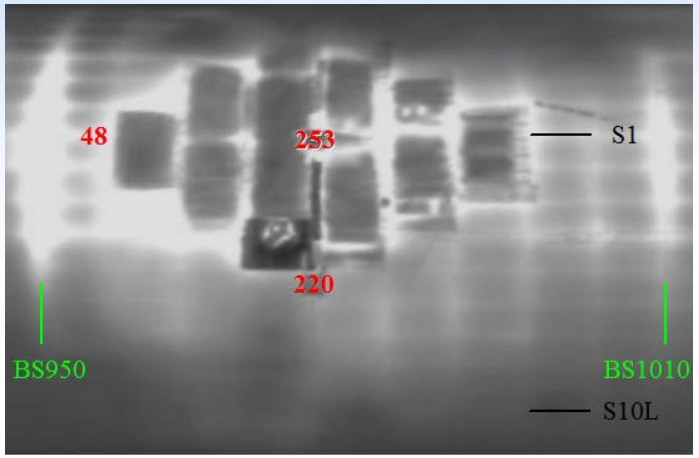
Burned Twice

2014 + 2015

SOFTWARE FAILURE

Our thermal cameras have no internal memory so we added a laptop to record the boom-truck camera view. The software split the video record into two files but at the end of the test it failed to save the data for the first file.



EQUIPMENT FAILURE

We had just added the thermal camera to the top of our HRET boom. This is the only image we have - a screen shot off the cab monitor. The video was <u>not</u> recorded on the truck road recorder.

Our trucks have been rewired. If the road recorder is not functioning – we will know - because the cab monitor is **<u>blank</u>**.

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LTR-SMM-2016-0049

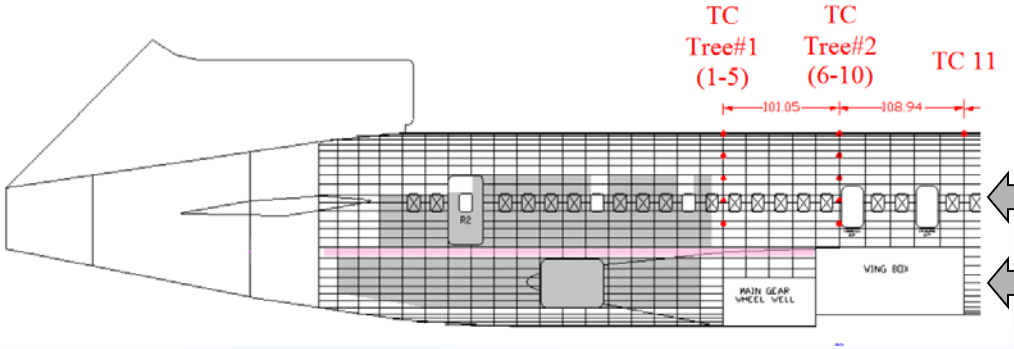
The Big Burn

2015

Sufficient fuel on aft main deck and in cargo hold to burn the tail off behind the wing.

No pre-staging of ARFF or mutual-aid personnel/equipment.

Start the fire after dark, call it in and watch what happens.



Fuel Load (shredded paper)

Main Deck 250 boxes

Cargo Hold 100 boxes

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Ottawa

Burn-through around composite crown.

2015

This sequence takes place over 40 seconds.

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The Big Burn

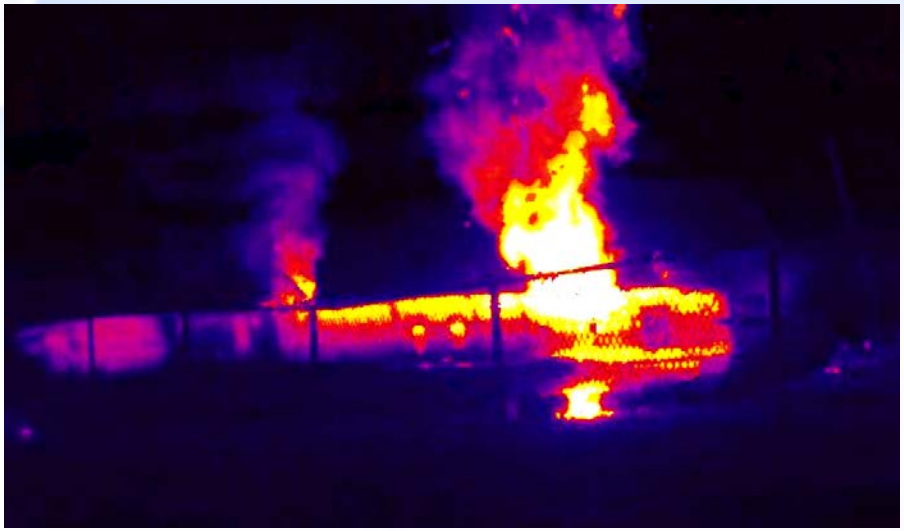
2015

Invite a Professional Photographer

International Airport Authority
Administration de l'aéroport international
Ottawa

Photo Credit: Jan Jasinski 2015

The Big Burn
2015



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ROBOTS

2015

Demonstration of a new remote-controlled firefighting robot attacking from the down-wind side.

Robot towed a 2.5-inch hose from pumper

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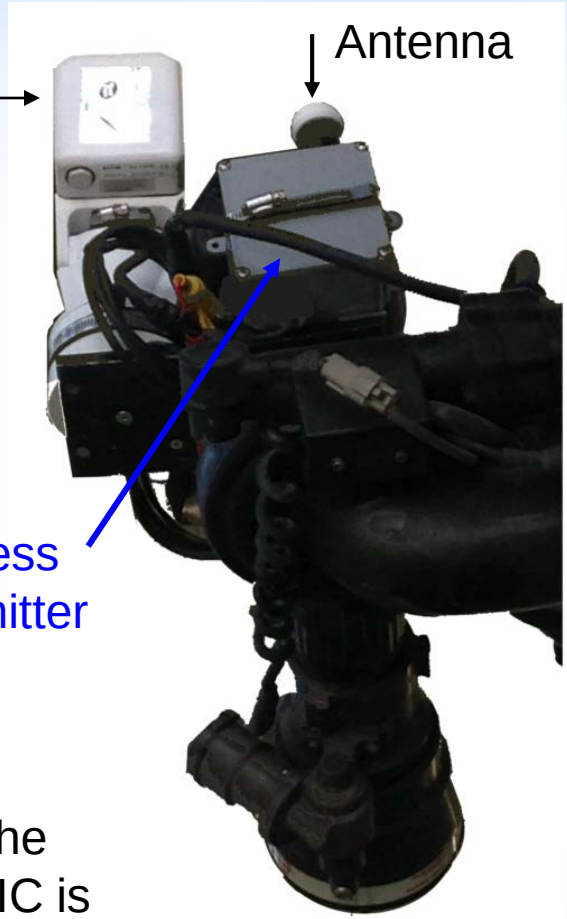
Wireless HRET Thermal Camera

2015

TIC



The Thermal Imaging Camera (TIC) is attached to the HRET turret so the pan&tilt in the TIC is disabled. TIC is always pointed with turret. Switch turns on both the 12V lamp and the TIC. Wireless transmission to receiver in cab.

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The Big Burn

2015

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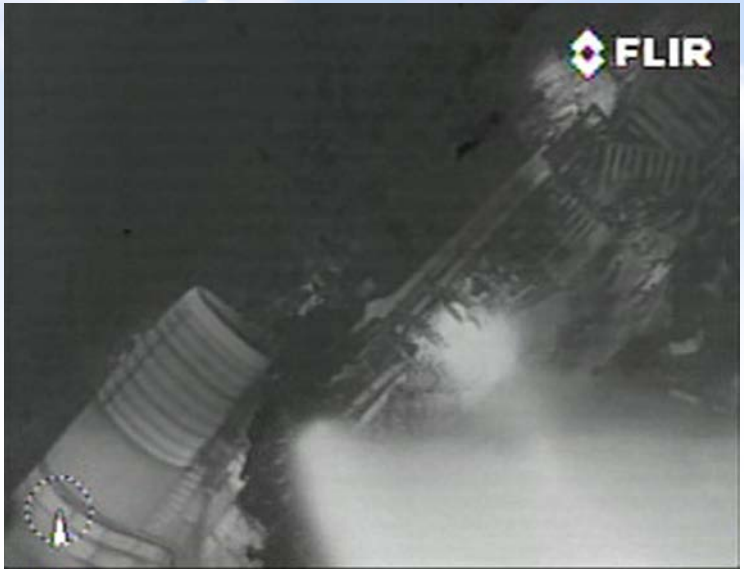
Wireless HRET Thermal Camera

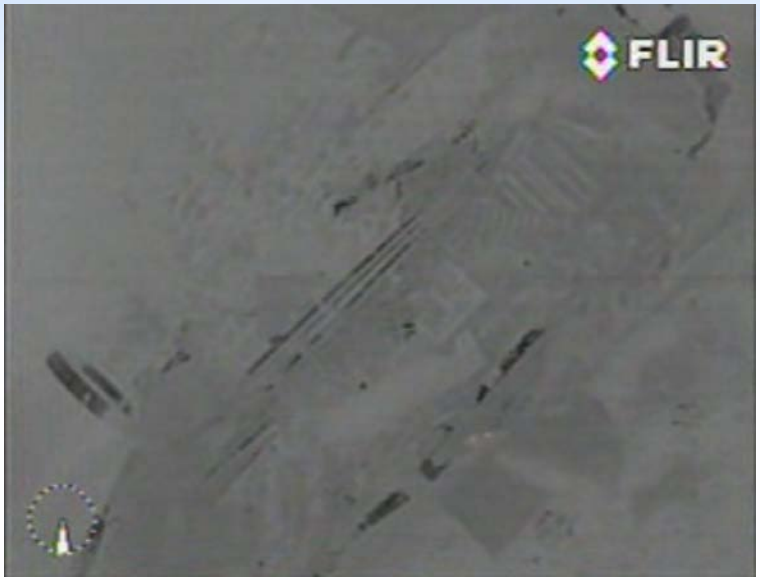
2015



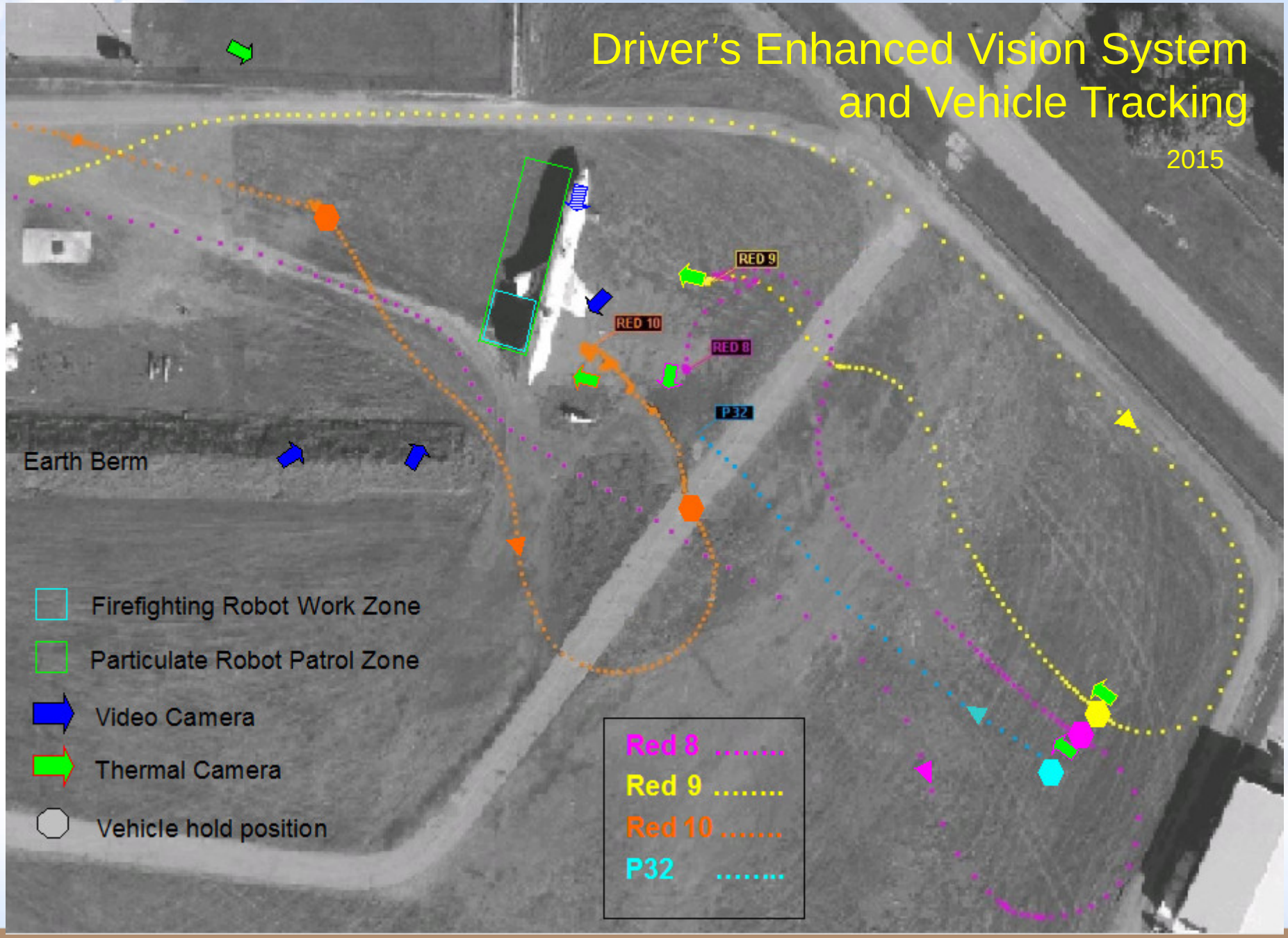
HRET turret water spray

Looking down fuselage through hole in crown

Overhead view down on burned aft fuselage <u>before</u> water sprayed to "heat" contents

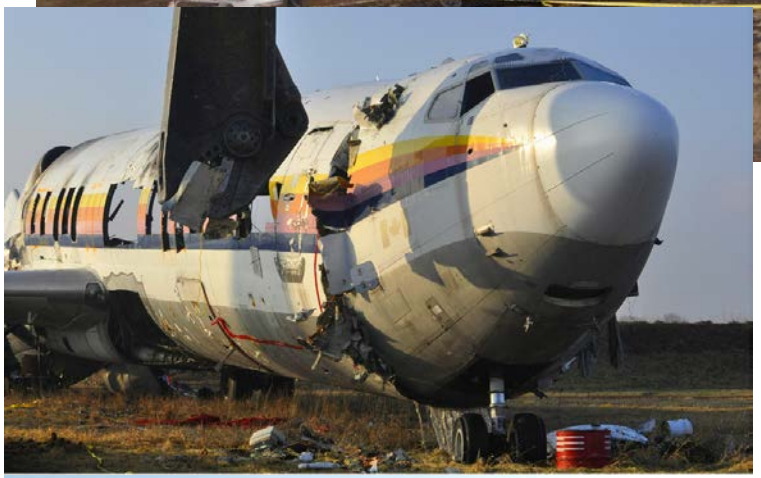


and <u>after</u>


Driver's Enhanced Vision System
and Vehicle Tracking
2015
RED 9
RED 10
RED 8
P32
Earth Berm
Firefighting Robot Work Zone
Particulate Robot Patrol Zone
Video Camera
Thermal Camera
Vehicle hold position
Red 8 ……..
Red 9 ……..
Red 10 ……
P32 ……..

Forced-entry training prior to scrapping.

2016



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Dry Chemical Refill Device

2016

The annual dry chemical certification results in a messy refill job that many firefighters do not enjoy.

A prototype device that minimizes the mess and fits three different truck arrangements was built and tested. Seven 50 lb pails of dry chemical have been loaded in 30 minutes.

Improvements are being made and we look forward to next year’s refill activity to test the device.

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What were they thinking?

2007

After the Kaboom 1 test, Bad Men came.
They were interested in “rapid forced entry”.
They used explosives on the L1 door, a cabin window and an OWE.

They succeeded in making loud noises.

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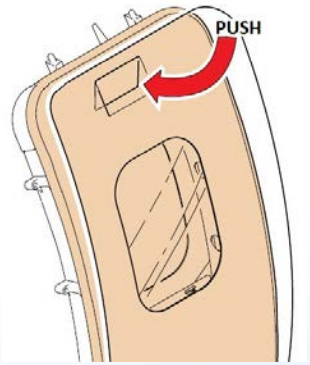
LTR-SMM-2017-0032

Things You Can Do with Water

2016

Straight stream on OWE exterior release panel for <0.5 sec



45 lb (20 kg) OWE was in motion for 2.75 sec.
Speed while crossing fuselage: 18 mph (29 km/h).

When a TYPE III overwing emergency exit door needs to be opened - it may not mean that a firefighter has to be on the wing to do it.

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Things You Can Do with Water

2016

Some cabin windows are located by metal spring clips. Firefighters are aware that they can be pushed in with a hand tool. But we can do it with water in a few seconds from beyond the wing tip.

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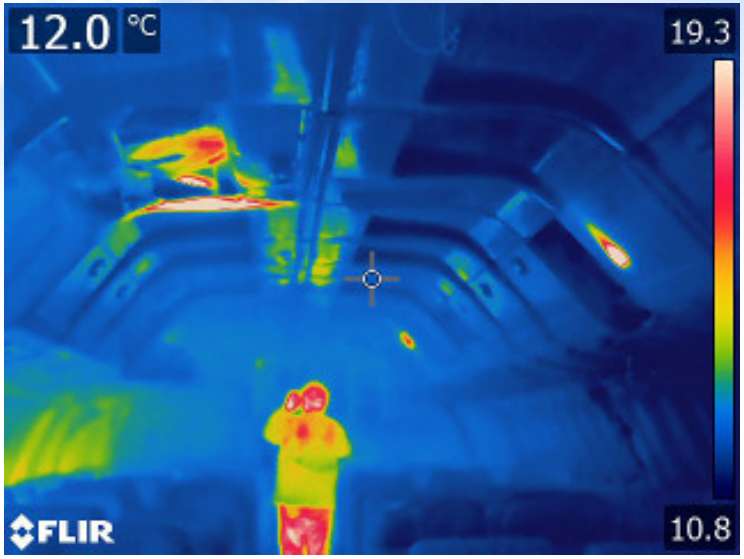
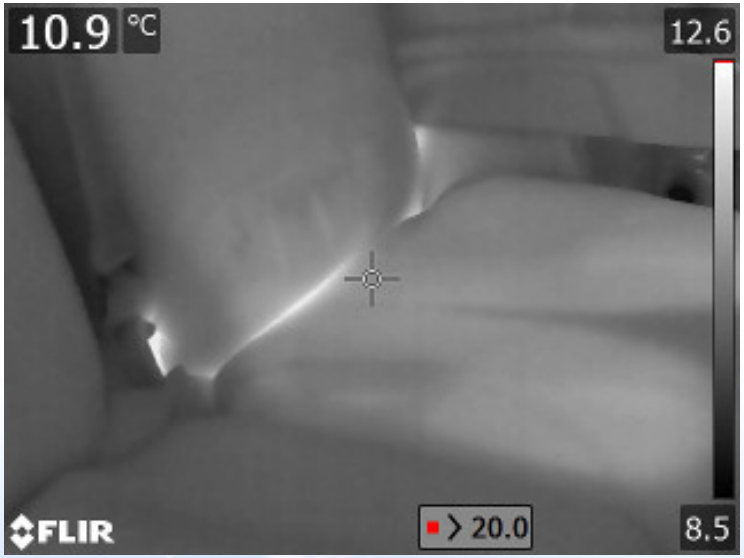
Detecting Hidden Fires

2016



Normal image shows cabin filling with smoke. Thermal image shows three “fires” in the upper cabin and an observer obscured by smoke.



Residual heat on cushion from occupant and heat rising around cushions from simulated PED that has fallen into gap between cushions and been damaged.

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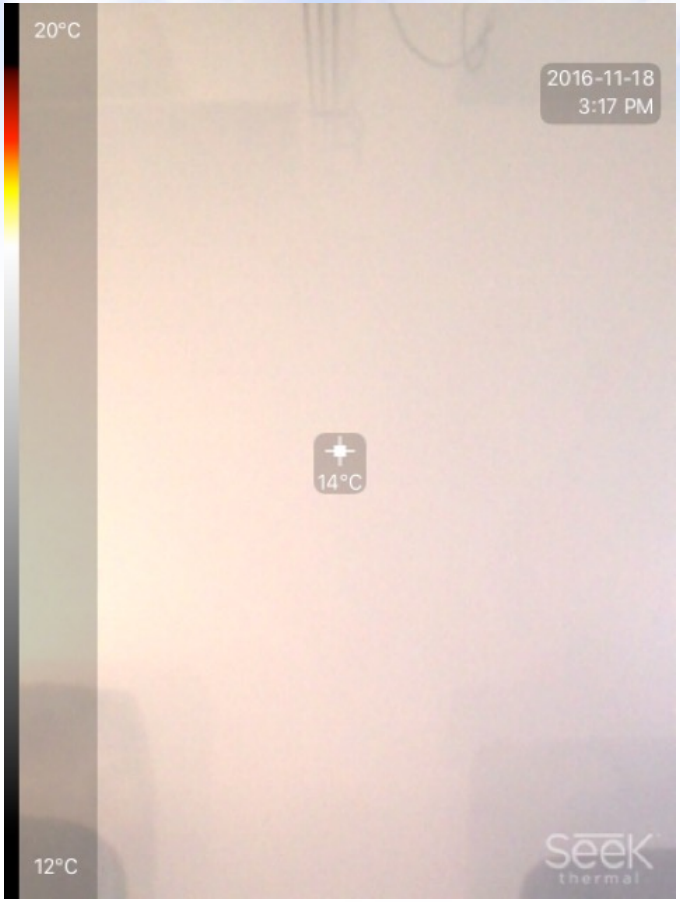
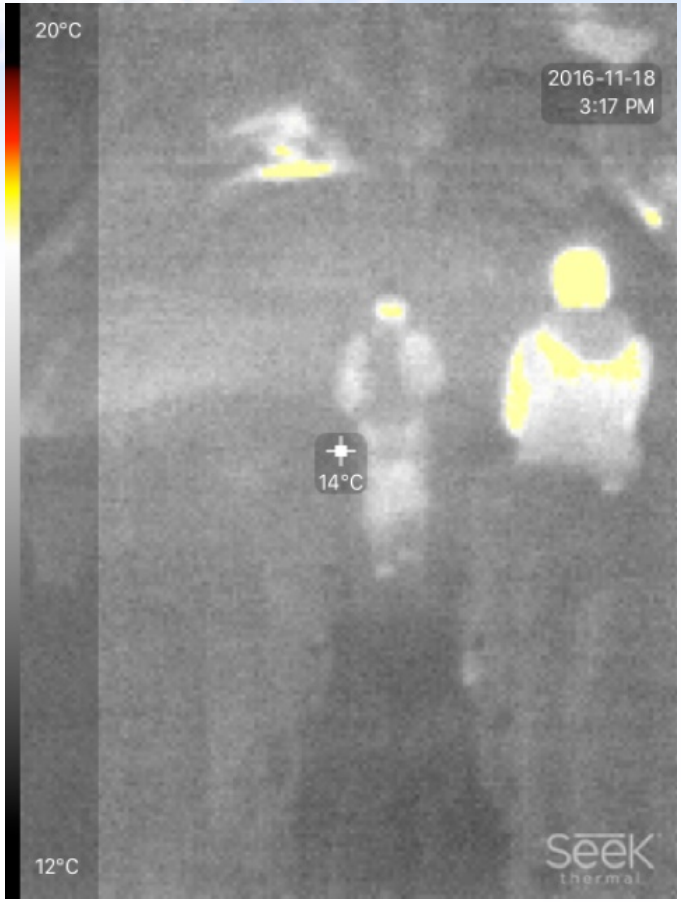
Detecting Hidden Fires

2016





Visual and thermal image pair of firefighter (centre) and test observer, looking aft. Electrical heater strip “fires” behind ceiling liner and over-head luggage bin door.

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Questions?

Replace your missing or stolen hub caps with children's cereal bowls. $1.50 each.

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