ARFF Special Projects
2005 to 2017

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ARFF Working Group
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National Research Council Canada (NRC)

- 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.
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)
Adjacent gasoline pool fire caused outer surface self-ignition.

Window did not self-extinguish

90 sec

Heat causes 40% shrinkage
On the Crash Chart, only 4 pressurized oxygen bottles are shown in the FWD hold cheek area. There were 6 bottles and #5 exploded.

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.
1 bomb + real luggage produced a toxic fire.

Manual piercing to access aft cargo hold fire.

Too much foam.
Cargo hold environment still too toxic
1 day after fire ($\text{CO}_2 > 200$ ppm)

80 seconds elapsed time
Scraping 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.
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.

No cargo hold fire. Firefighters said they would not attend next test if there was no fire...see cargo hold battery fire.
Blast created “critical length” fracture in the skin and broke 4 frames in 7 places.

Note: wing-to-body fairing removed.

80 inch (2 m) fracture

LIDAR mapping of aircraft was done pre- and post-blast.
There was a square internal skin repair patch exactly in line with the bomb site.

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

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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…
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.

Water spray not just for dust abatement.
Composite Issues

Penetration wound

Delaminated layers of unidirectional Graphite fibers

Graphite fibers

Woven Fiberglas

Micrographic section through CFRP/GFRP hybrid layup

A340 composite Horizontal Stabilizer
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.

We have only one HRET piercing tool so we don’t want to break it or trap it in a confined space.
• 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.
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.
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.
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.
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 revealed 2:58 after fire started.
Fire out after 4:58 minutes.
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.
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.
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.
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.
Military 10 D-cell Li/MnO₂ primary battery pack
2.87 lb (1.3 kg)

Molten Lithium

Flame jet, 90 sec each cell

Battery case trajectory
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.
Stinger piercing effectiveness
2012

Understand confined spaces and limits of Stinger penetrator
Stand-off Modeling for Optimum HRET positioning for Piercing.

First contact

Optimum

On-Gear

First contact

Optimum

Off-Gear

2013
Combined Small and Large Aircraft groups.

Stand-off Modeling for Optimum HRET positioning for Piercing.

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.
Thermal Response of CFRP

Time 0:00
1.4°F (17°C)

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

35 seconds after water applied

White is HOT

International Airport Authority
Administration de l’aéroport international
Ottawa
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.

A call-out in winter to await the landing of an aircraft could expose the truck to low temperature effects.
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
Overhead thermal and video camera on boom truck. Videos sent to command post (red van).

Pyrolance attacked off STBD wing.
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 not 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 blank.
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
Burn-through around composite crown.

This sequence takes place over 40 seconds.
Invite a Professional Photographer

The Big Burn 2015

Photo Credit: Jan Jasinski 2015
The Big Burn
2015
One robot roamed the scene measuring particulates.

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

Robot towed a 2.5-inch hose from pumper.
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.
HRET turret water spray

Overhead view down on burned aft fuselage before water sprayed to “heat” contents and after

Looking down fuselage through hole in crown
Driver's Enhanced Vision System and Vehicle Tracking

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
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.
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.
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.

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

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Things You Can Do with Water

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.
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.
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.
Questions?

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