Australian Government
Department of Defence
Defence Science and
Technology Organisation

Aerospace Division

Overview

Dr Richard Chester
Acting Chief Aerospace Division

DSTO Partnerships week

DSTO Science and Technology for Safeguarding Australia

DSTO Roles in the Aerospace Domain

Defence Operations

Sustainment

Acquisition Projects

Strategic Research

Changing Australian Air Domain platforms


Joint Strike Fighter F-35 Lightning II


P- 8


F/A-18G Growler


ARH Tiger


Wedgetail AEW&C

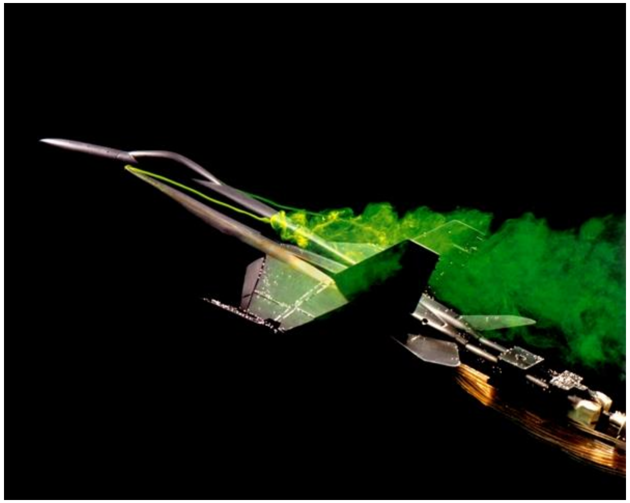

MRH-90


C-17 Globemaster


KC30B Multi-Role Tanker Transport


C-27J

DSTO Aerospace Division



Purpose:

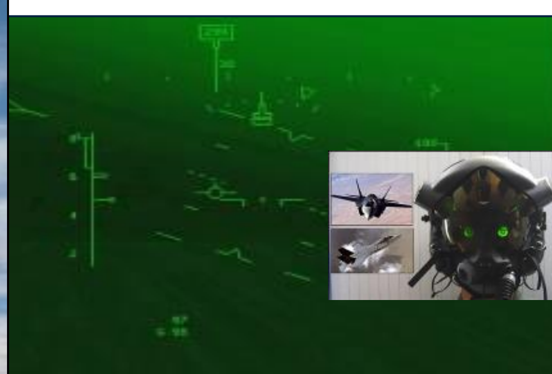
To provide advice on the exploitation of aerospace science and technology in support of Australian Defence Force (ADF), operations, the acquisition of ADF aircraft, the cost-effective sustainment of ADF aircraft and to conduct strategic research in selected areas.

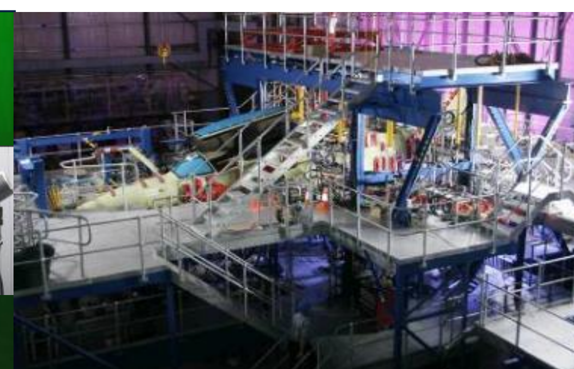
6 Branches:

- Aircraft Structures
- Airframe Technologies & Safety
- Applied Hypersonics
- Aerospace Systems Effectiveness
- Aircraft Performance & Survivability
- Aircraft Health & Sustainment
- 300 staff and contractors

Aerospace Division Major Recent Projects

- HIFiRE Hypersonics program 2006->, wins ICAS Von Karman award 2012
- Helicopter gearbox fault diagnosis by application of time frequency analysis
- Live Virtual Constructive Simulation Exercises, - Black Skies, Coalition Virtual Flag
- Development of Joint Air Warfare Battle Lab, JAWBL at RAAF Williamtown
- C-130 J - Full Scale Fatigue test, Main wing
- JDAM-ER gliding weapon, extended range
- F/A-18 - Centre Barrel fatigue life extension
- Hawk Mk127 - Full Scale Fatigue Test





Aerospace Domain

Aerospace Operations	Aerospace Systems and Mission Effectiveness	Aircraft Performance and Health		Aircraft Structural Sciences		Strategic Research Program
Aerospace Capability Analysis	Aerospace Systems Effectiveness	Aircraft Performance & Survivability	Aircraft Health & Sustainment	Airframe Technology & Safety	Aircraft Structures	Applied Hypersonics

JOAD Joint & Operations Analysis Division

AD Aerospace Division

MD Maritime Division

LD Land Division

WCSD Weapons & Combat Systems Division

CEWD Cyber & Electronic Warfare Division

NSID National Security & Intelligence, Surveillance & Reconnaissance Division

↔ = Strong synergies

Aerospace Systems Effectiveness

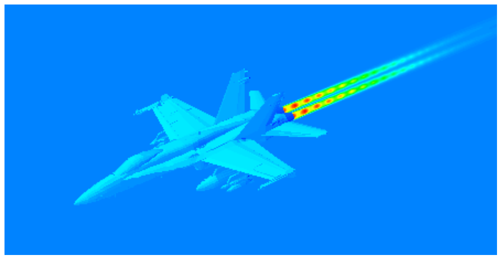
<u>Interaction of humans & systems for optimal performance</u>

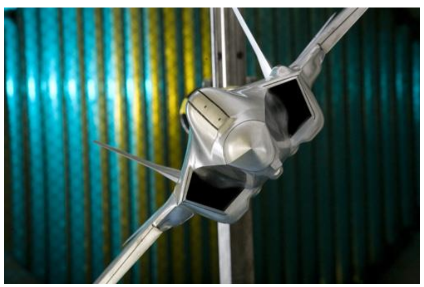
- Synthetic Collective Training
- Live Virtual Constructive Simulation
- Team training in realistic multi-aircraft & multi-national mission scenarios

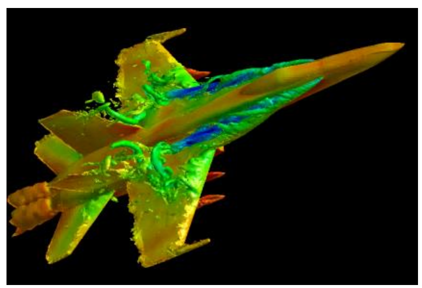
- Helicopter Systems Effectiveness
- Flight models, ship wakes, slung loads, degraded visual environment
- Human Factors, Vision, Perception, Autonomy, Training, Cognitive Modelling

Aircraft Performance & Survivability

Aerodynamics, Aerothermodynamics, Aeroelasticity, Aerial Autonomy

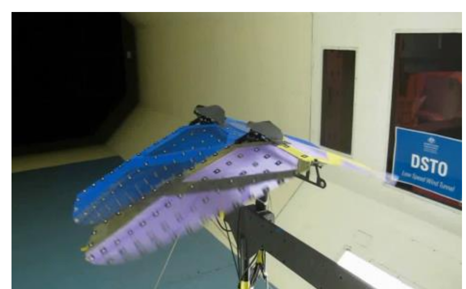






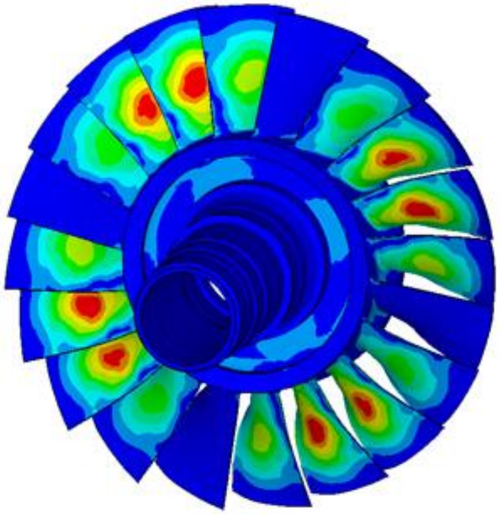
- Aerodynamic Test Facilities, Transonic and Low Speed (Subsonic) Wind Tunnels
- Advanced Computational Fluid Dynamics, including Fluid-Structure Interaction

- Aircraft IR Signature Modelling , Measurement and Control
- Aero-Thermodynamic Test Facilities, Combustion Test Facility
- Trusted Autonomy
- Novel UAV Technologies: Alternative Navigation, Power & Energy

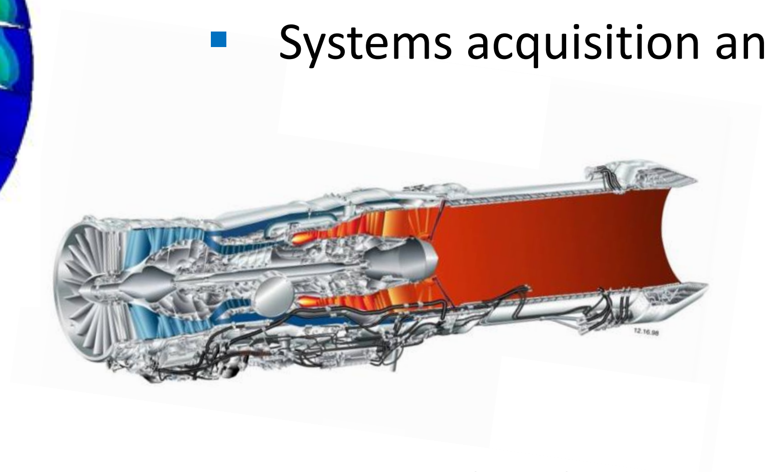


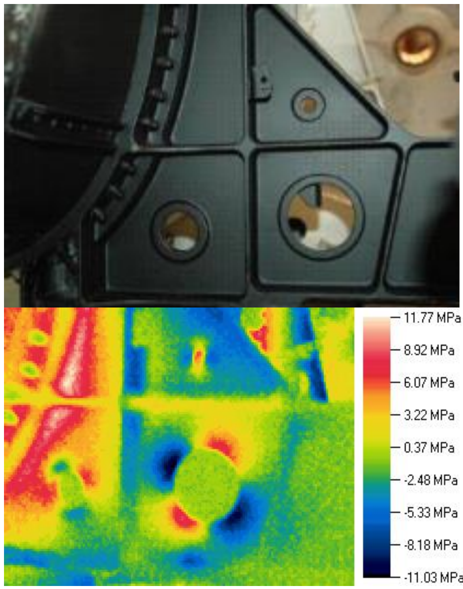
Aircraft Health & Sustainment

Asset management strategies & health management technologies



- Vibration based condition monitoring
- Acoustic signature measurement & modelling
- Wear debris analysis and HUMS
- Systems acquisition and sustainment analysis

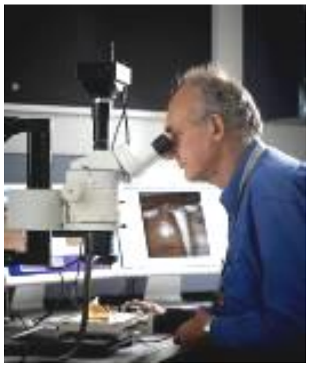




- Fuel technology
- Advanced Experimental Stress Techniques (TSA)
- Diagnostic Systems for Airframe Structural Management
- Aero-engine life prediction, risk and durability analyses

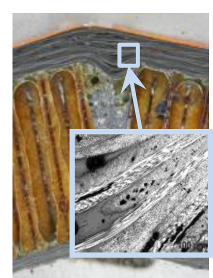
Airframe Technology and Safety

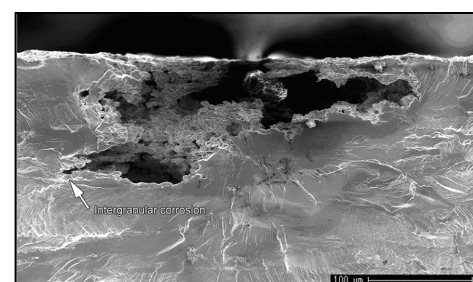
Structural & Damage Mechanics, Composites, Metallics , Forensics



- Aircraft Forensic Engineering & Accident Investigation
- Additive metallic repair and manufacturing technologies

- Crack growth modelling
- Structural mechanics
- Advanced composite systems
- Composite sustainment support
- Corrosion structural life modelling





Aircraft Structures

Aircraft Structural Integrity

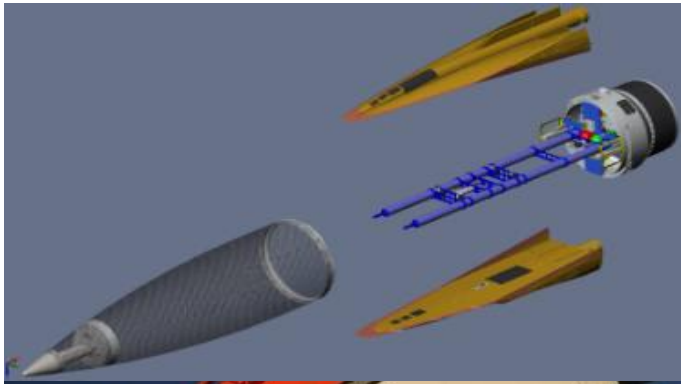
- Fatigue Crack Analysis
- Advanced Investigative Techniques

- Full Scale Fatigue Test Capability
- Structural Life prediction capability
- Airframe Life extension expertise

Applied Hypersonics

Hypersonic Flight Research & Flight Test Trials

- Research, Design, Build, Fly, Analyse
- An aero-thermodynamic problem



- Hypersonic air-breathing combustion for sustained controlled flight
- Integration of complex systems operating in extreme environments

Presentations to follow

- An Opportunity to Revolutionise Airframe Testing — Dr Albert Wong
- DSTO Rework Shape Optimisation Technology — Dr Stephen Galea
- Trusted Autonomous Systems — Dr Michael Skinner
- Ultra High Temperature Materials — Dr Ross Antoniou

Australian Government
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Defence Science and Technology Organisation

An Opportunity to Revolutionise Airframe Testing

Dr Albert K. Wong
Research Leader – Aircraft Structures

Full Scale Fatigue Tests (FSFTs)

form the cornerstone of the certification process for any new aircraft type


Comet FSFT, Farnborough UK, 1954


Airbus A380 FSFT, Dresden, 2005-2009

…at tremendous costs!


F-35 FSFT, Ft Worth & Brough, 2010 - …

Some major F-35 STOVL FSFT failures:

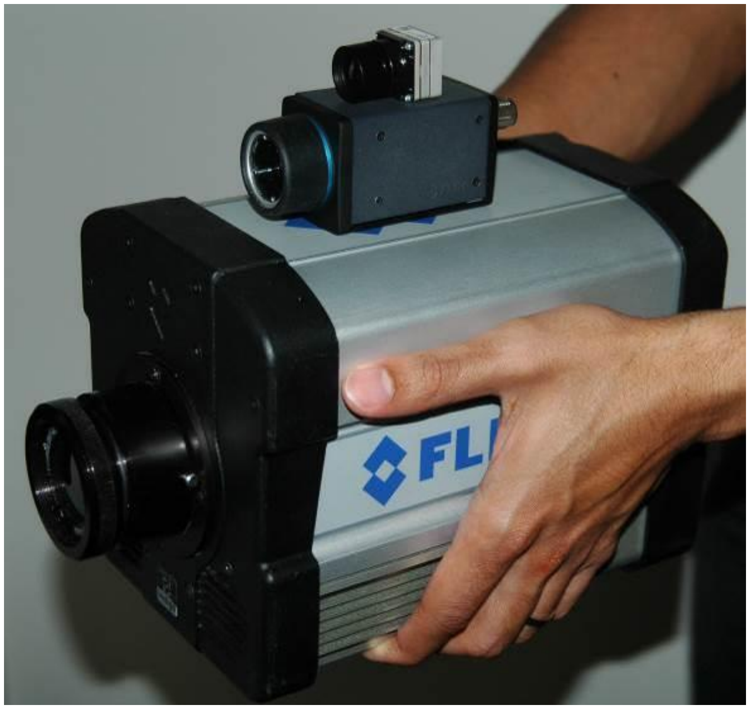
2010: bulkhead cracking @ ~1500 hrs (cf 16,000 hrs scheduled testing)

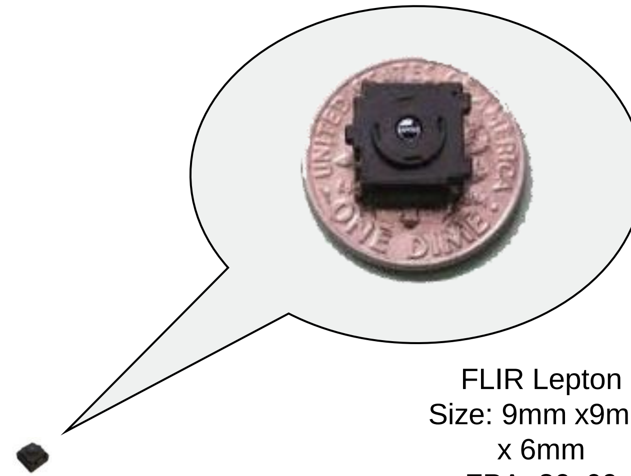
2011: wing root cracking @ ~2100 hrs

2013: bulkhead cracking @ ~9100 hrs

A Unique DSTO Technology…

that can change how FSFTs are conducted in the future
viz., Thermoelastic Stress Analysis (TSA) using microbolometers





FLIR Lepton
Size: 9mm x9mm
x 6mm
FPA: 80x60

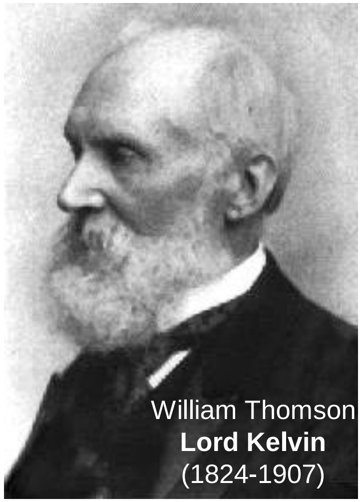
Free trial microbolometer TSA (MiTE) software: http://www.dsto.defence.gov.au/mite/

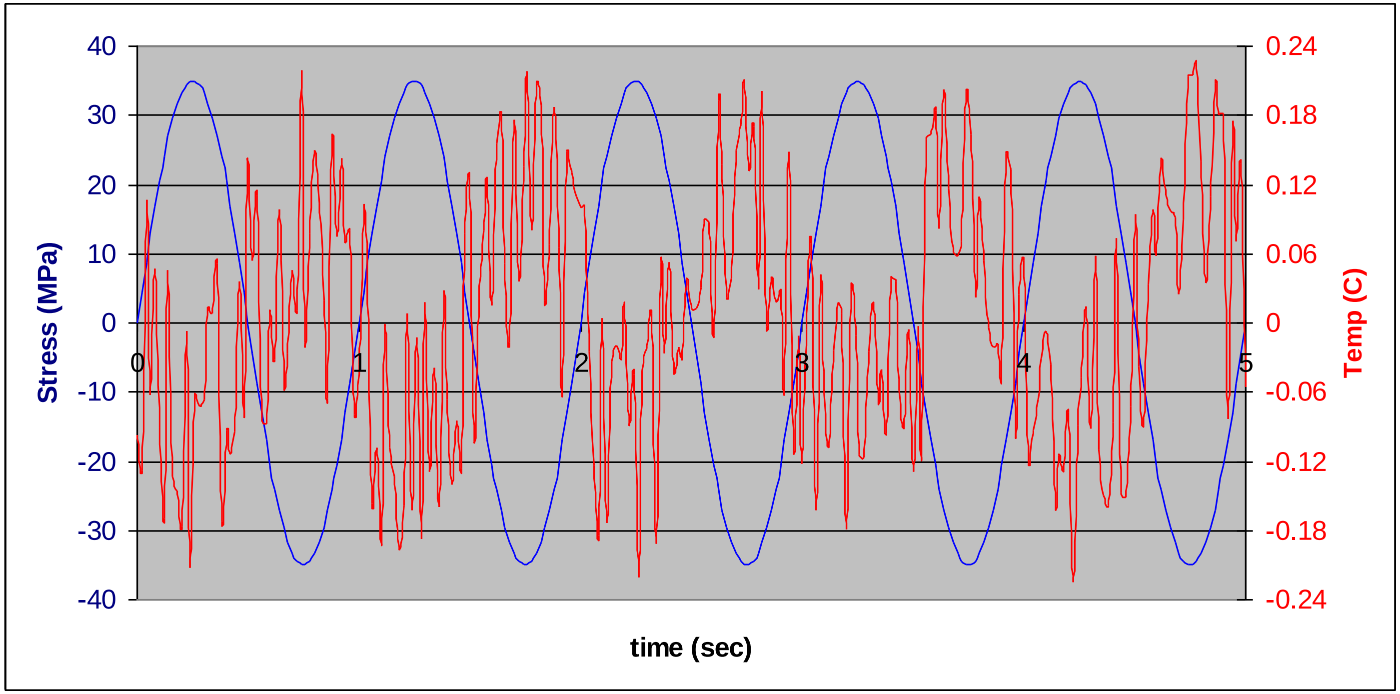
Reference: http://onlinelibrary.wiley.com/doi/10.1111/str.12116/epdf

POC: nik.rajic@dsto.defence.gov.au

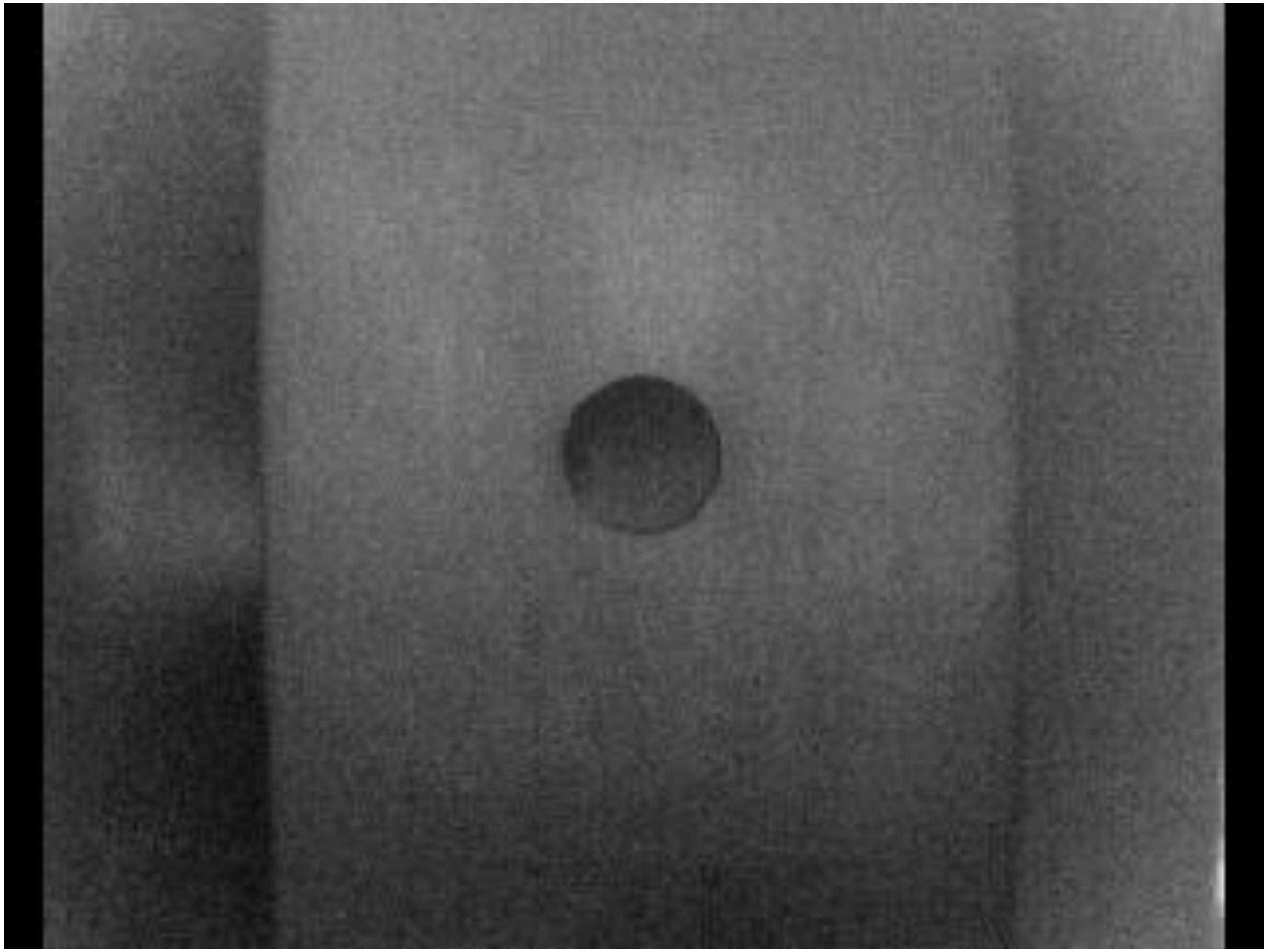
The Thermoelastic Effect

$$\frac{\partial T}{T_0} = -K \partial s$$

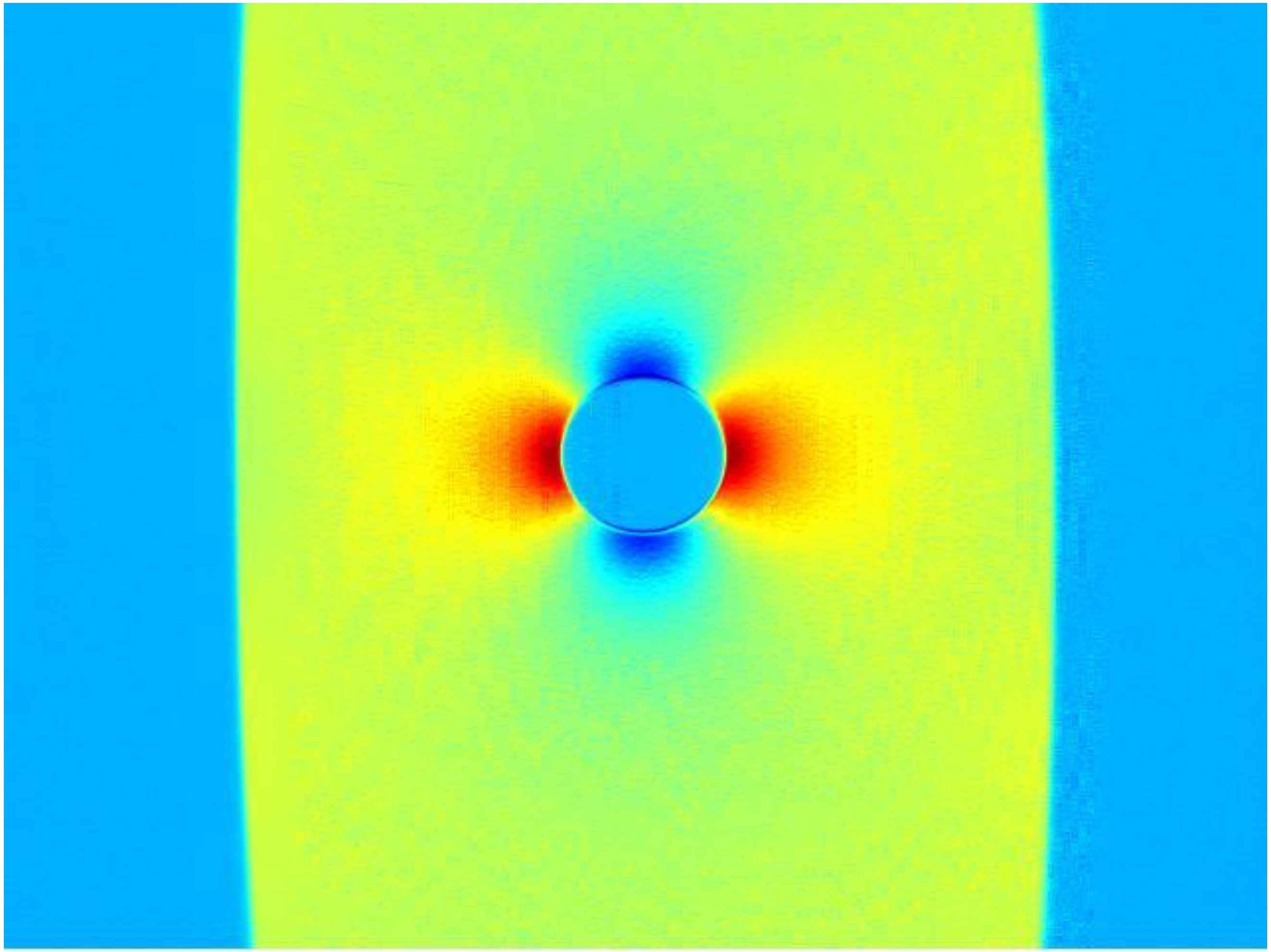




The Thermoelastic Effect

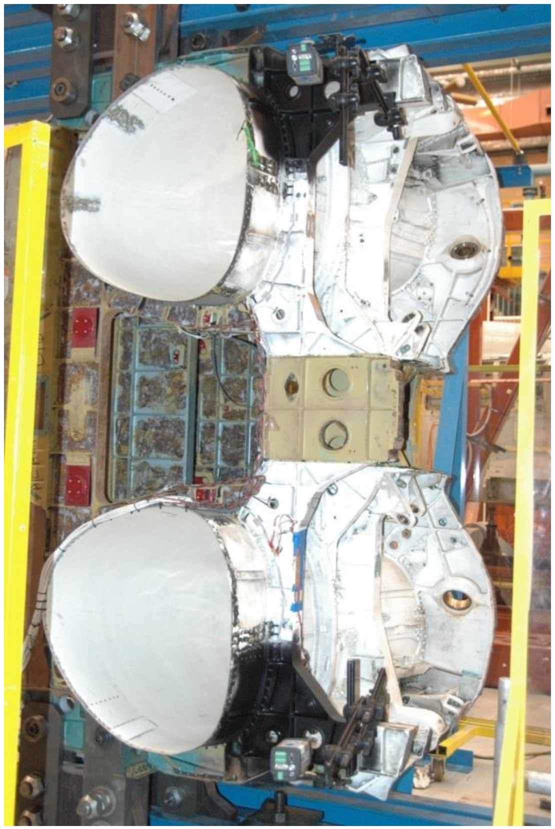


The Thermoelastic Effect

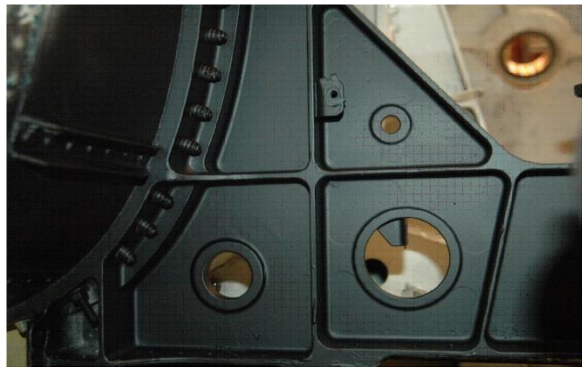


Applications to F/A-18 Centre Barrel Fatigue Test

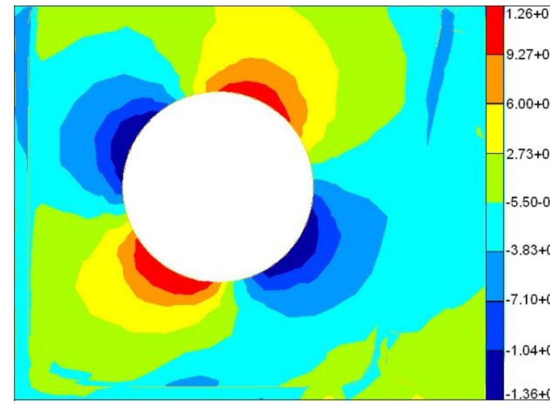
TSA used to validate stressing model



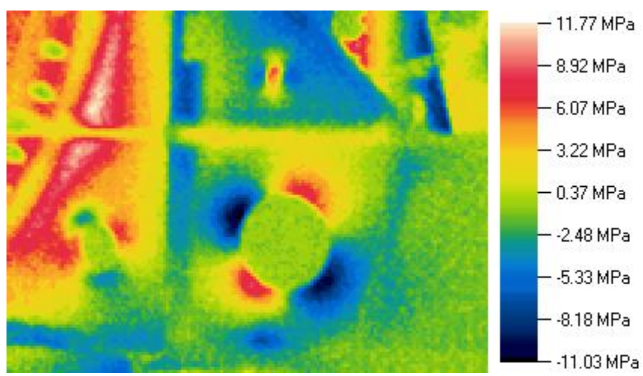
F/A-18 CB fatigue test



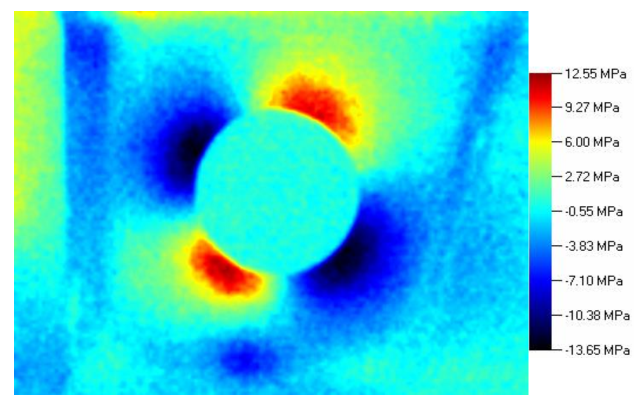
region of interest



computed stresses



TSA scan



close-up TSA scan

TSA Robot (TSAR) Demonstrator

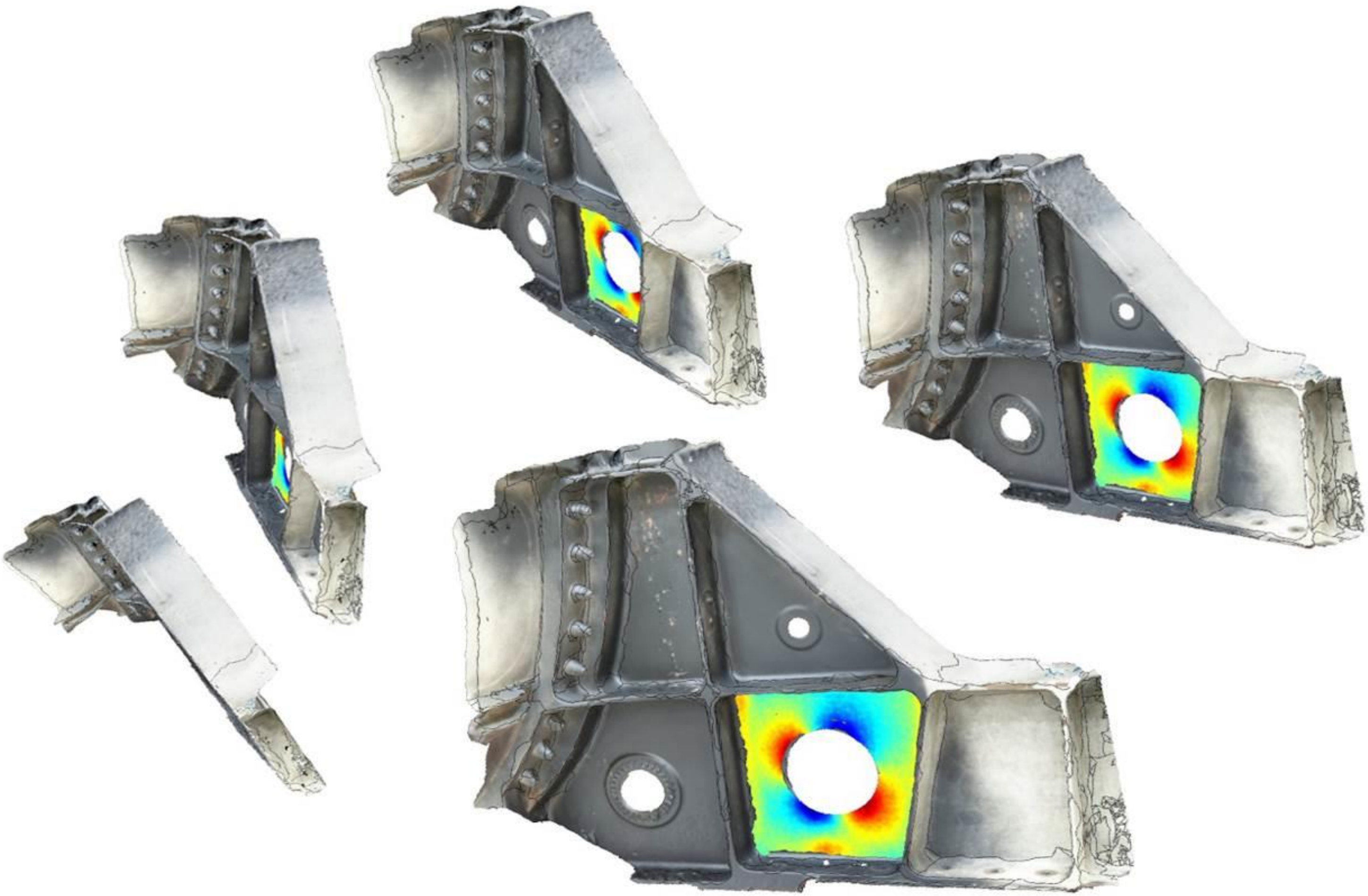
Hardware:

- 6DOF Robotic Arm
- A35 IR microbolometer
- digital camera for 3-D reconstruction

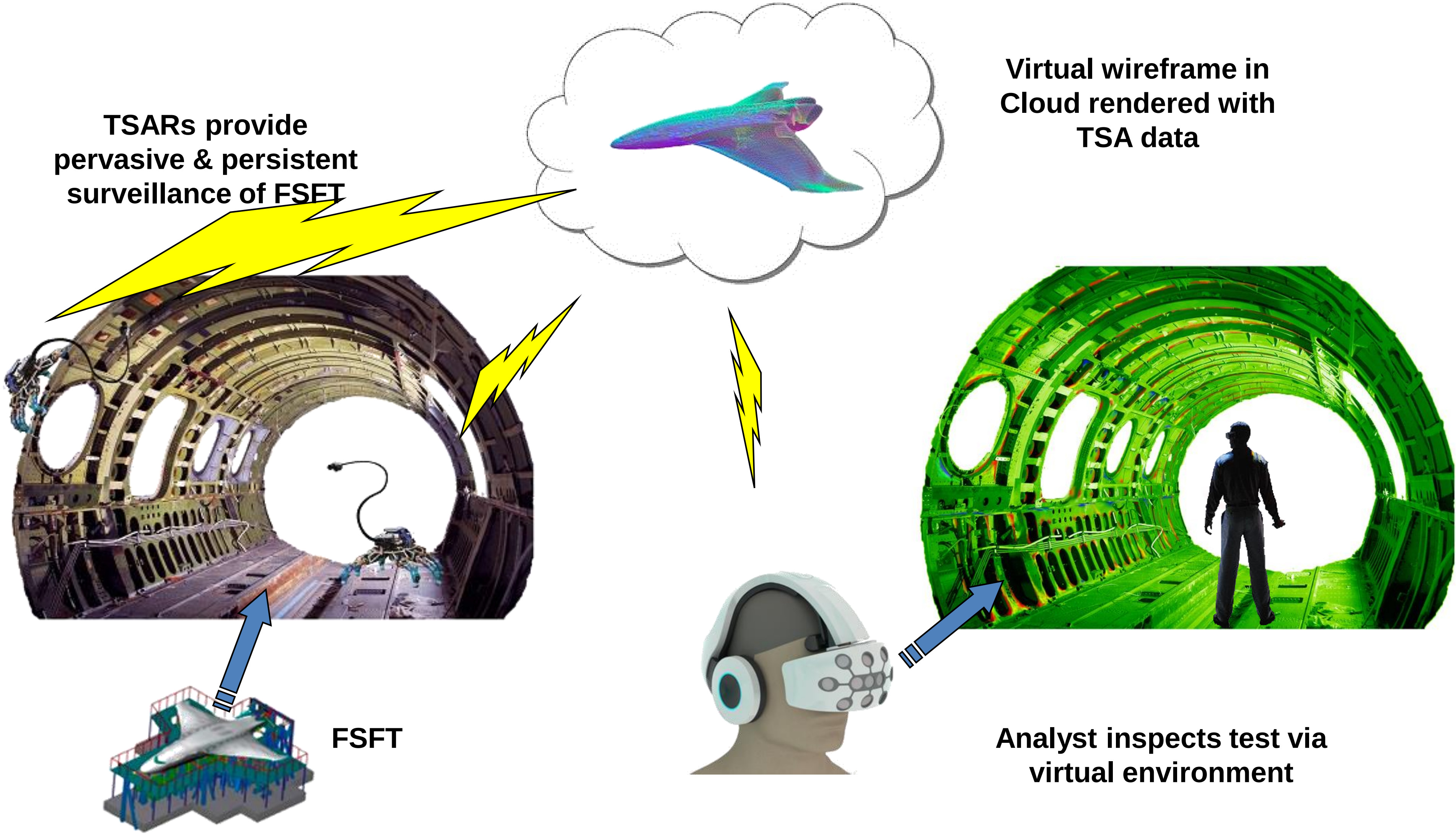
TSAR Mk I

- Perform pervasive & persistent surveillance of a large section of F/A-18 bulkhead FSFT

TSAR Preliminary Results



TSARs to Rule over Future FSFTs



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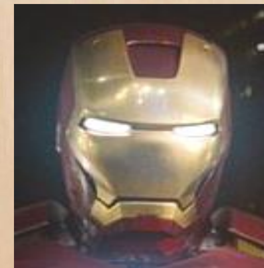


PARTNERS IN CRIME TO:

1. CO-DEVELOP Tsar Marcus 1st
2. Co-develop tsars of the future

Reward

To effect transformational impact on future airframe certification tests

Australian Government
Department of Defence
Defence Science and Technology Organisation

Rework Shape Optimisation for Structural Life Extension

Dr Stephen Galea

Acting Research Leader

Airframe Technology and Safety Branch

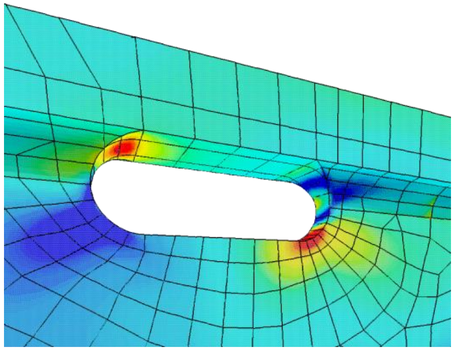
Contact POC Manfred Heller, manfred.heller@dsto.defence.gov.au

DSTO | Science and Technology for Safeguarding Australia

Structural optimisation background

- A design process to best distribute material in a loaded structure
- DSTO focus is on repair & life extension of fatigue critical airframe components by stress minimisation
- Aim is to improve aircraft availability and reduce sustainment costs
- Small shape changes can lead to significant improvements in fatigue life

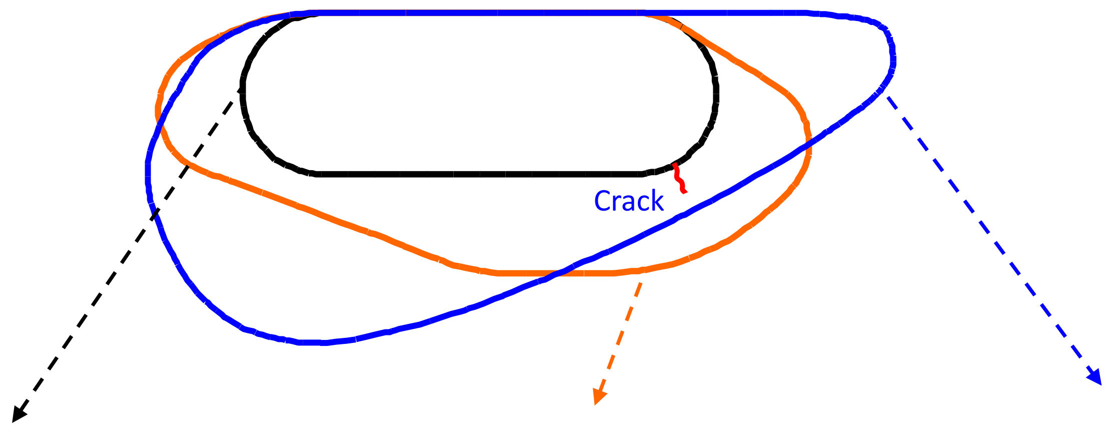
Critical regions



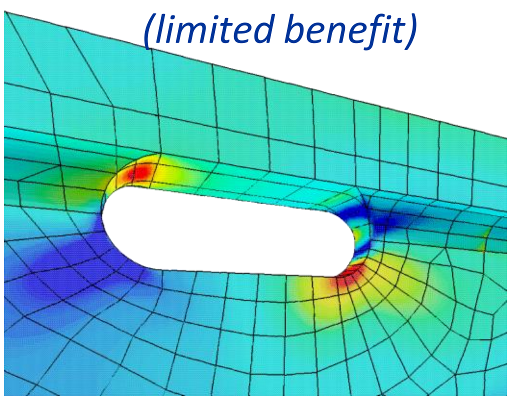
High initial stresses

Concept of optimised shape reworking

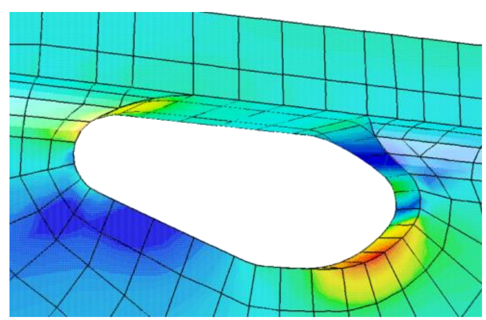
Improved rework shapes remove the damaged material and minimise stresses



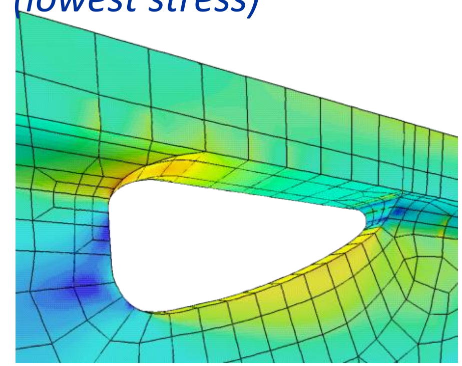
Initial shape
(limited benefit)



Traditional rework
(lower stress)



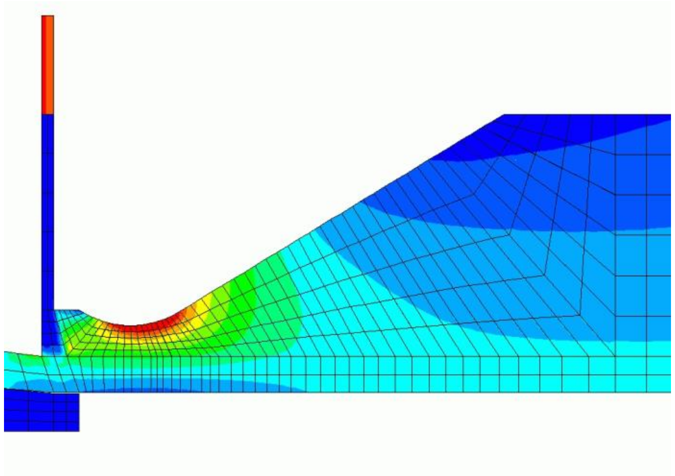
DSTO Improved rework
(lowest stress)



Features of the DSTO approach

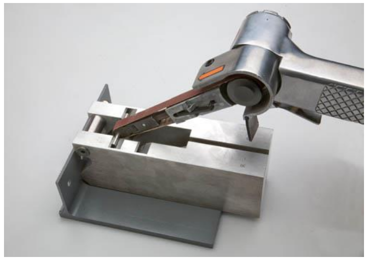
Modelling

- Aim is constant local stress via material removal
- In house software & commercial Finite Element Analysis codes
- Iterative method based on biological growth
- Can handle manufacturing constraints and load orientation variability



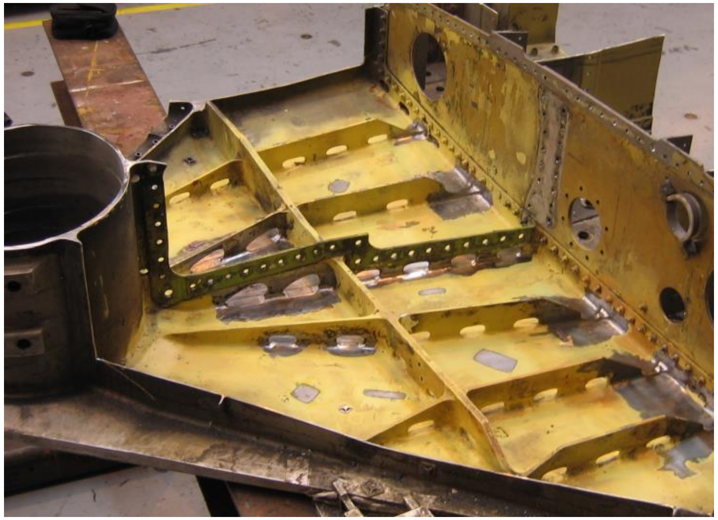
Manufacturing

- Accurate in-situ methods developed – 2.5D



Example: F-111 wing pivot fitting application

Stiffener run-outs and fuel flow vent holes



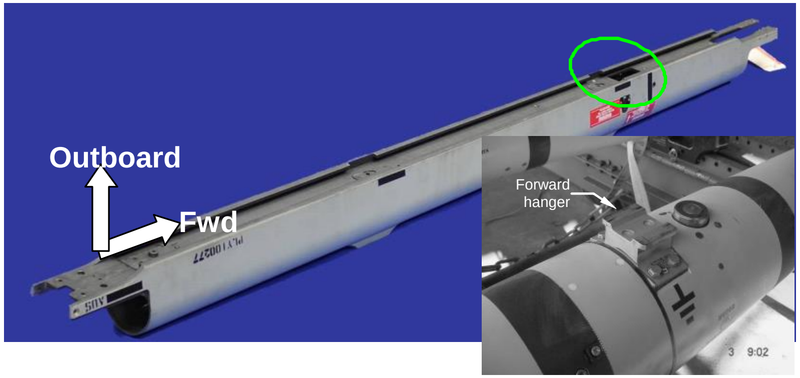
- Aim was to achieve Planned Withdrawal Date & extend inspection intervals
- 25 - 50% stress reduction
- Implemented on 6 aircraft
- 16 locations per aircraft

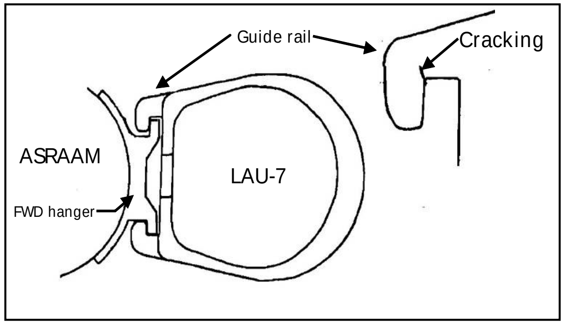
Optimised holes

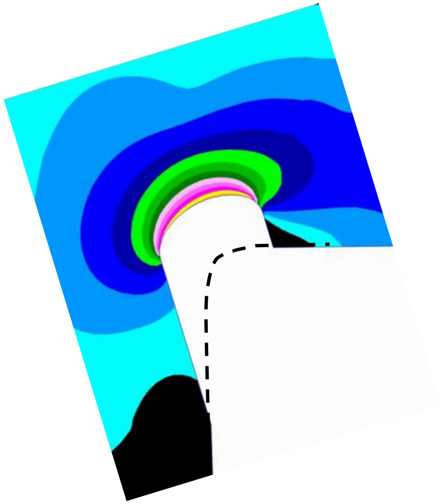
Optimised stiffener run-out

Example: F/A-18 A/B

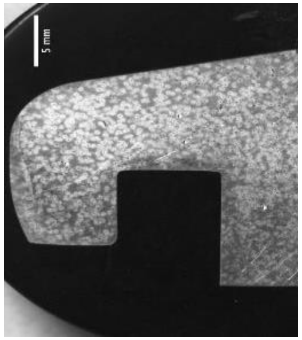
LAU-7 missile launcher optimal rework



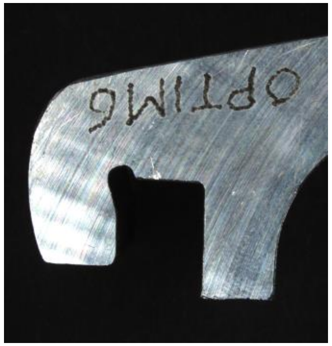




- Cracking at housing guide rails
- 33 % stress reduction
- Portable rework jig developed
- Successful flight trials completed
- Fleet wide implementation pending



Nominal

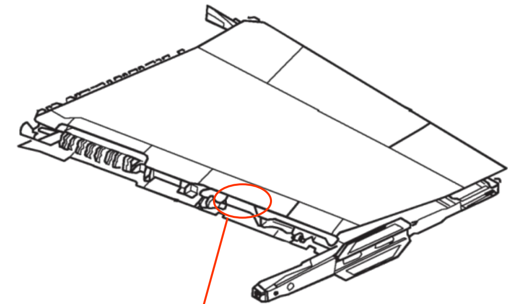


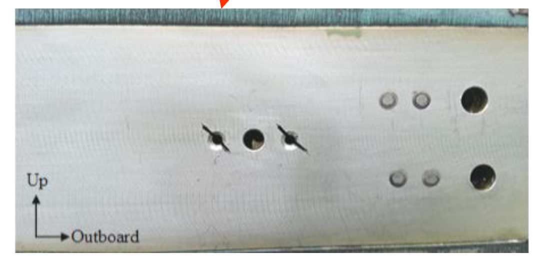
Reworked

Example: F/A-18 A/B

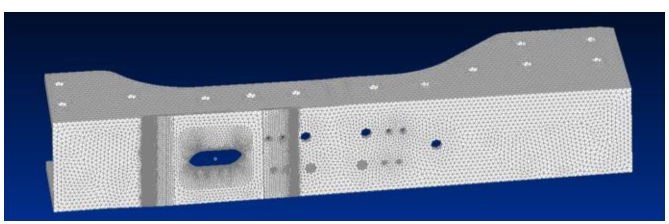
Front spar grounding hole rework optimisation

- Cracking at grounding holes
- Family of enlarged rework shapes
- 18% stress reduction
- Portable rework jig developed
- Fleet wide implementation expected





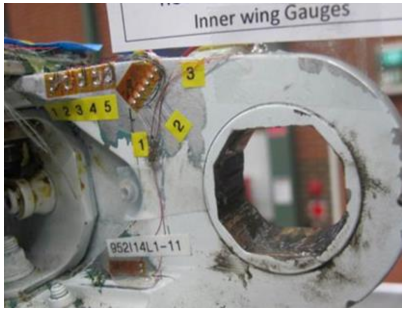
Before rework

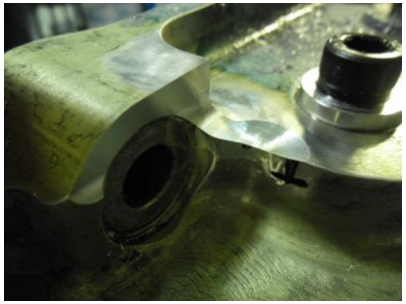


After reworking

Partnering opportunities

- Potential to transition technology more widely
  - Airframes
  - Other vehicles
- Potential collaboration to further develop the current capabilities to full 3D
  - Modelling
  - Machining via compact robotics





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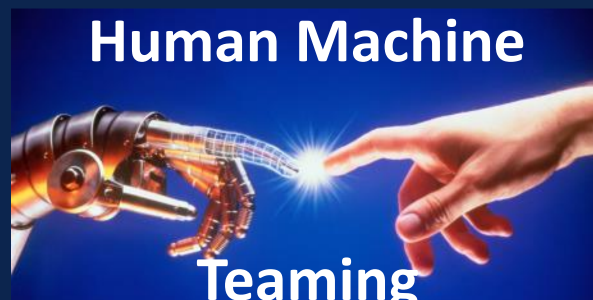
Trusted Autonomous Systems



Dr Michael Skinner

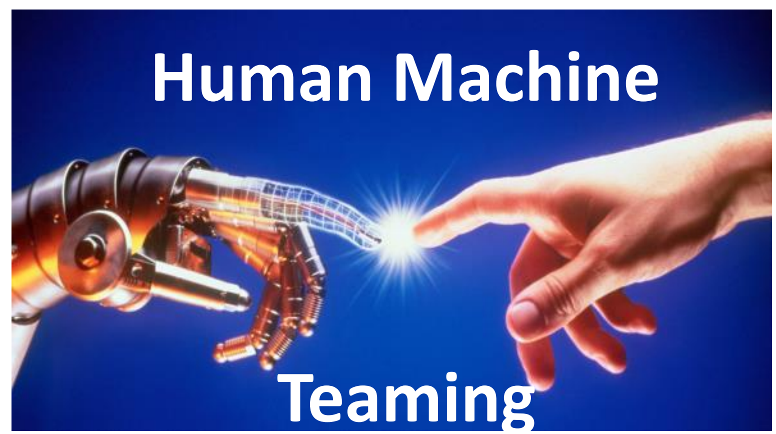
Autonomy Team Leader

Aerospace Systems Effectiveness

What are Trusted Autonomous Systems?

- Automation versus Autonomy
- What will Trusted Autonomous Systems Deliver?

Intelligent machines seamlessly integrated with humans – Maximising mission performance in complex and contested environments (*AFRL Autonomy S&T Strategy*)



TAS Strategic Research Initiative: Research Themes

Foundations of Autonomy

Philosophical and mathematical basis;
Significantly reduce exposure to harmful consequences;
Guaranteed to not exceed boundary conditions; new means to certify for ADF use.

Cognitive Machines

Fast reactive and simultaneous slow logical "thinking";
Machine high-level fusion, planning and intent subject to uncertainty;
Large scale control of machines; Machine-machine interaction and tasking.

Trustworthy Partners

Interacting hybrid teams more effective than human-only teams;
Understand organisation changes required to acquire and operate;
Trust of machines; Mission Command of machines.

Platforms, Sensors & Effectors

Exploit existing and develop new: sensors, platforms, materials & propulsion;
Sound validation and test with increasing accuracy of uncertainty (simulation to field);
Innovations with high technical risk, but low strategic program risk.

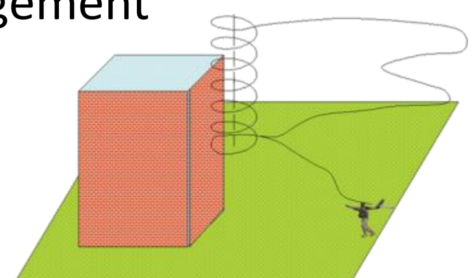
Uninhabited Aerial Systems

Key enabling challenges for trusted autonomy in aerial systems

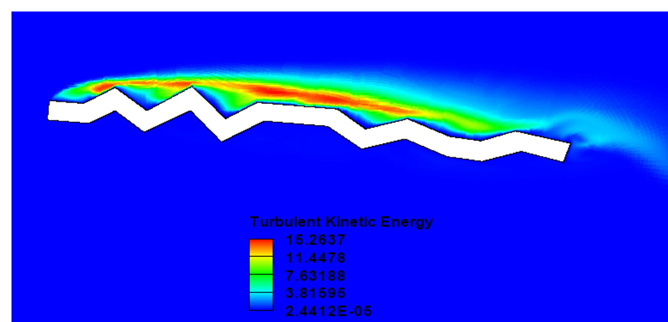
Autonomous UAS Platform Management

Alternative Navigation for UAS

Hybrid Propulsion and Power Management



Bio-inspired micro-UAS



Uninhabited Aerial Systems

Tactical Urban Operations for Micro-UAS

- Challenges of the urban environment
- Current system limitations

http://en.wikipedia.org/wiki/List_of_slums#mediaviewer/File:Petare_Slums_in_Caracas.jpg

http://www.darpa.mil/uploadedImages/Content/NewsEvents/Releases/2014/FLAMissionGraphicMedium.jpg

Human Machine Teaming

- Research themes
  - Integration of Human and autonomous systems
  - Advanced interfaces for Adaptive Supervisory Control
  - Artificial Intelligence approaches to optimised human-machine teaming

Partnering Opportunities

- Uninhabited Aerial Systems
- Human Machine Teaming
- Trusted Autonomous Systems Strategic Research Initiative

Australian Government
Department of Defence
Defence Science and
Technology Organisation

Ultra-High Temperature Ceramic (UHTC) Materials Development Program for Hypersonic Applications

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Motivation

Sustained Hypersonic Flight

Velocities >Mach 6+

Heat flux at leading edges >4 MW/m^2

Thermal equilibrium!

- The next step beyond 'heat-sink' experimental vehicles
- Develop materials suitable for leading edges of experimental hypersonic air vehicles
- Geometric stability essential over flight duration
- Explore use of these materials in other applications

The Development Program (1)

- Research candidate materials;
  - Refractory metals, carbon composites, UHTCs considered
  - UHTCs identified as the most viable way ahead
    - High temperature properties
    - Ability to fabricate
    - Cost
- Develop UHTC compositions and fabricate test specimens
  - Focus on carbide and boride-based compositions
  - HfB_2, ZrB_2, HfC, etc.
  - Hot-pressing and spark plasma sintering (SPS) processing routes

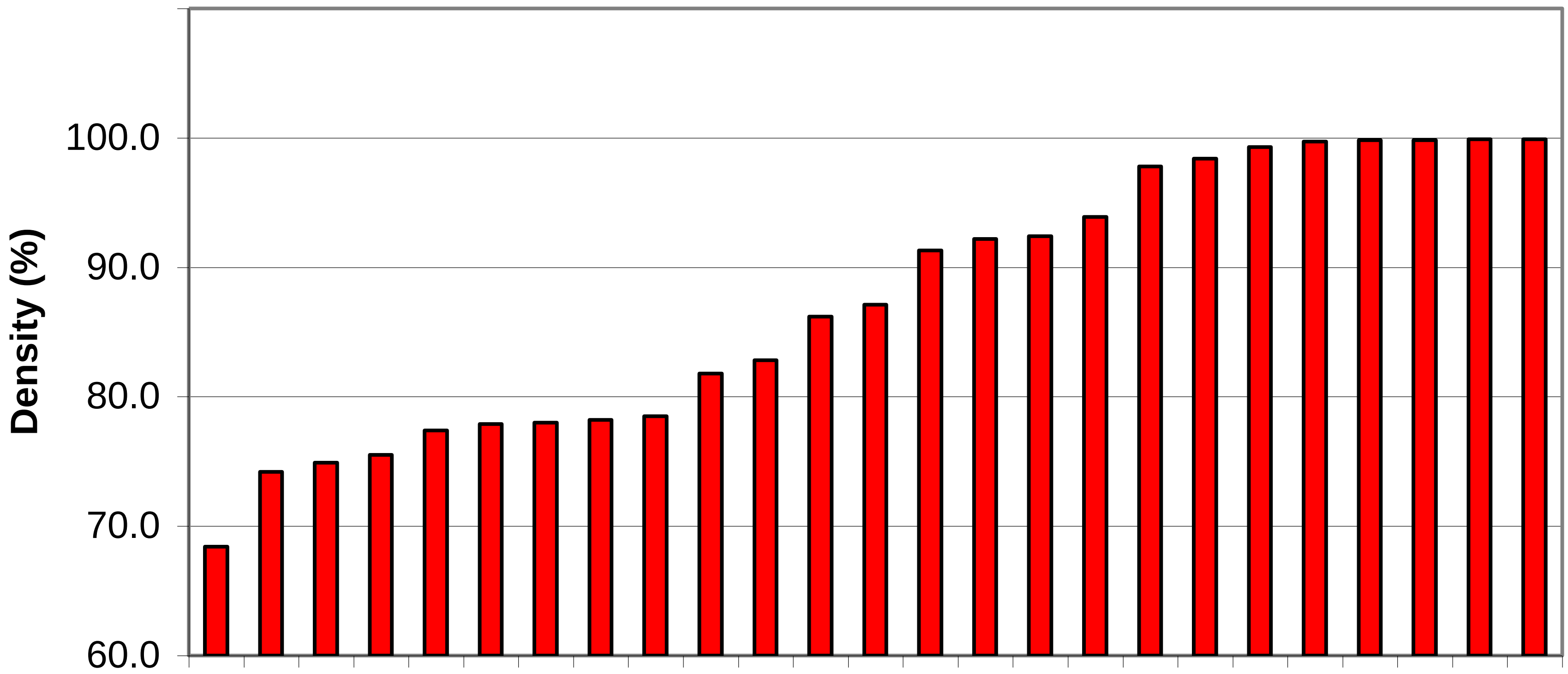
The Development Program (2)

- Microstructural characterisation of densified UHTC specimens
  - Assessment of microstructure, phases, porosity
- Thermal testing of UHTC specimens
  - High-temperature exposure of leading edge geometries
- Microstructural characterisation of heat-exposed UHTC test specimens
  - Material changes
  - Oxide layers
  - Oxide adherence

Development of UHTCs

Densification of test specimens

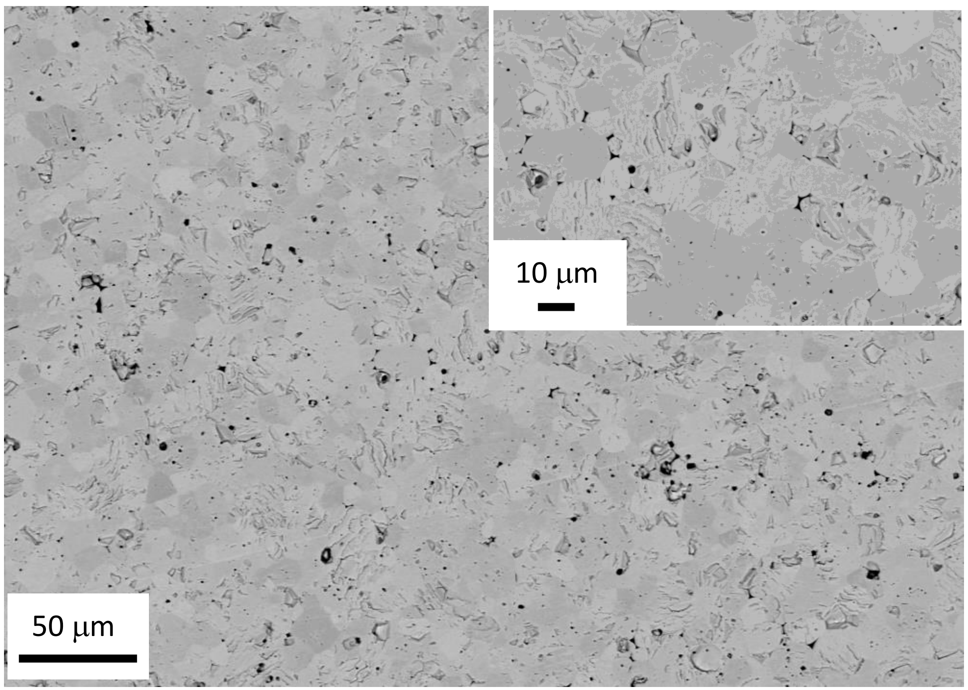
- Hot pressing
- 1900°C, 25 MPa



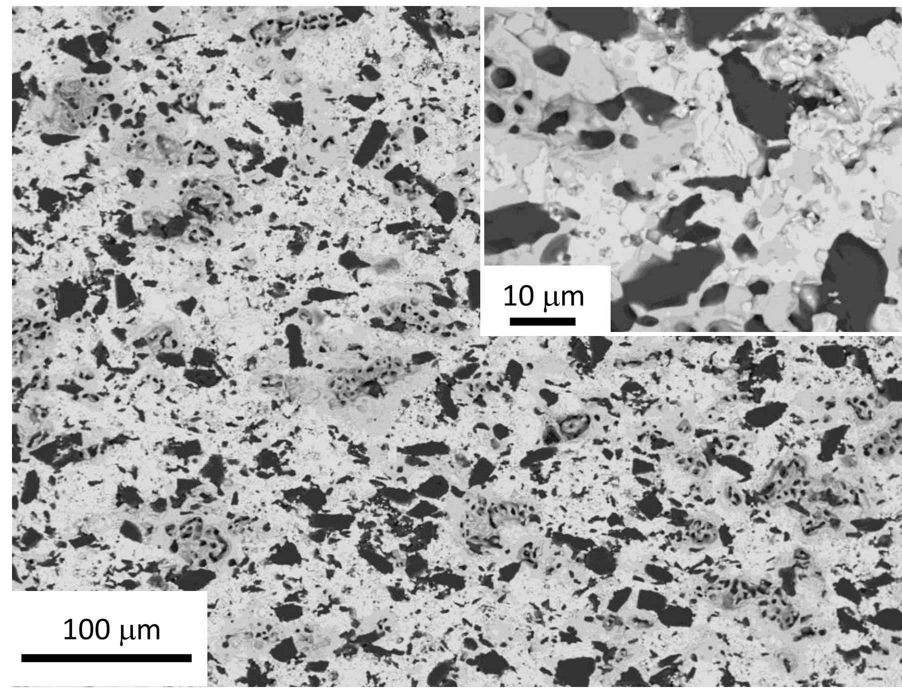
Development of UHTCs

Microstructures

- Single and multi-phase microstructures
- Carbides, Diborides, Oxides, Nitrides, Silicides
- 1900°C, 25 MPa



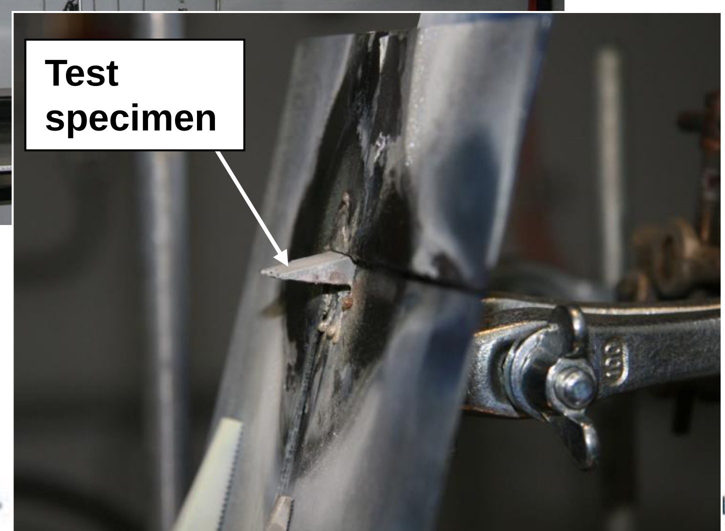
HfC-based material



HfB_2-based material

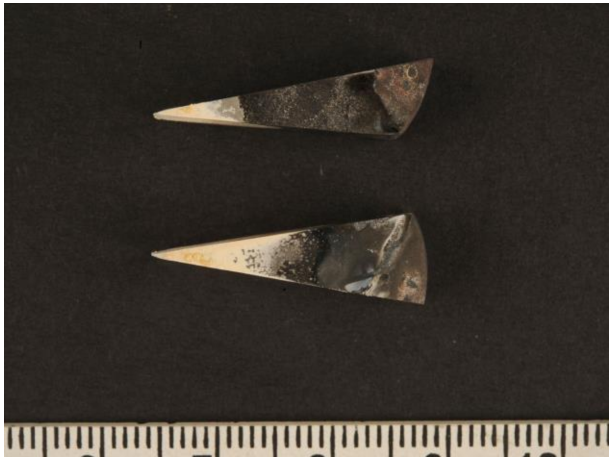
Introducing HoMER - High-temperature Materials Evaluation Rig

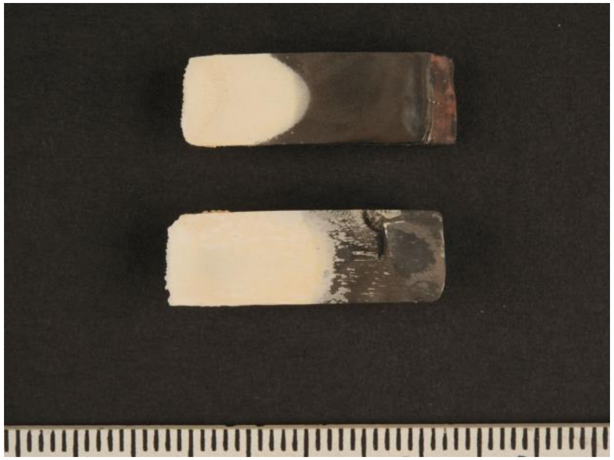
- Oxygen-acetylene flame; Flame temp >3300°C; Heat flux >8 MWm^{-2}
- Programmable X-Y stage; H.T. pyrometer; video acquisition



Thermal test specimen geometry – 20 degree wedge

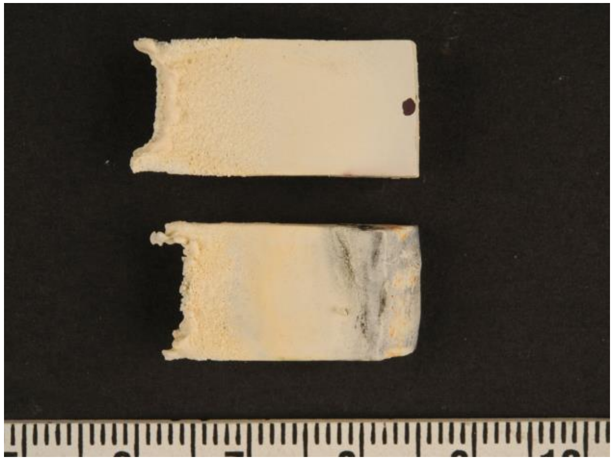
Post-Test Results (1)





- Good performance, above.

  Sharp leading edge geometry maintained after 3 minutes.

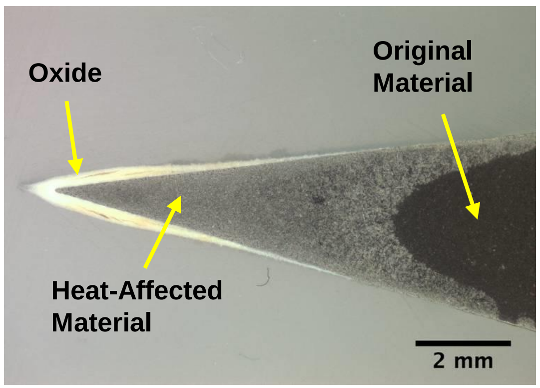
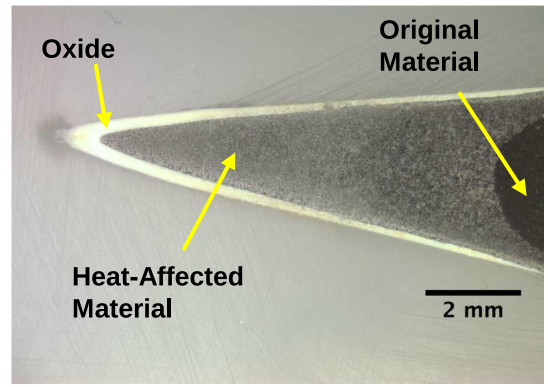
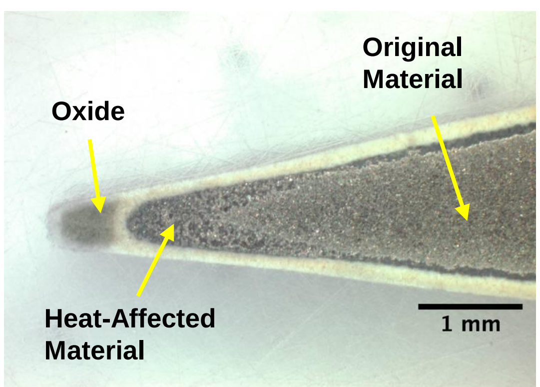
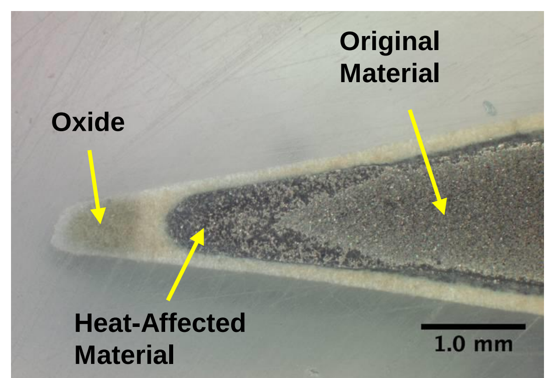


- Poor performance, right.

  Low melting point phase causes rapid LE recession.

Post-Test Results (2)

Cross-sections show leading edge geometry, oxidation products and material changes after high-temperature exposure.

	1 minute	3 minutes
Specimen 4		
Specimen 30		

Where to next…

- Benchmark tests against refractory metals
- Explore different processing routes
  - Pressure vs. Pressureless processing
  - Contrast dry vs. Colloidal processing
- Composition refinement of best performing materials
- Fabrication of full-scale leading edge geometries
  - Traditional and EDM Machining (potential for collaboration)
  - Near Net Shape Formation
- Thermal Testing of full-scale leading edge geometries
  - HoMER
  - Arc-jet

Aerospace Division