JOINT ADVANCED MATERIALS & STRUCTURES
CENTER OF EXCELLENCE

Composite Thermal Damage Measurement with Handheld FTIR

October 31, 2012

Brian D. Flinn, Ashley Tracey and Tucker Howie
University of Washington

Composite Thermal Damage Measurement with Handheld FTIR

- Motivation and Key Issues
  - Damage detection in composite requires different techniques than metals
  - Incipient thermal damage occurs below traditional NDE detection limits
- Objective
  - Determine if Handheld FTIR can detect thermal damage and guide repair
- Approach
  - Characterize panels with controlled thermal damage and perform repair based on FTIR inspection

FAA Sponsored Project Information

- Principal Investigators & Researchers
  - Brian D. Flinn (PI)
  - Ashley Tracey (PhD student, UW-MSE)
  - Tucker Howie, (PhD student, UW-MSE)
- FAA Technical Monitor
  - David Galella (year 3)
  - Paul Swindel (year 1 & 2)
- Industry Participation
  - The Boeing Company (Paul Shelly, Paul Vahey)
  - Sandia National Lab (Dennis Roach)
  - Agilent (formerly A2 Technologies)

Hypertac Hypertronics
www.hypertronics.com

CECAM center of excellence for composites and advanced materials

JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Background

Continuation of existing project (year 3 of 3)

✓ Years 1 and 2 (A2 Technologies, Boeing and U of DE)

- Characterization of homogenous thermal damage
  - Ultrasound
  - Short beam Shear (SBS)
  - Microscopy
  - Handheld FTIR (ExoScan)
- Calibration curve for FTIR detection of thermal damage (SBS data)
- Mapped surface of localized thermal damage

➢ Year 3 (UW and Boeing)

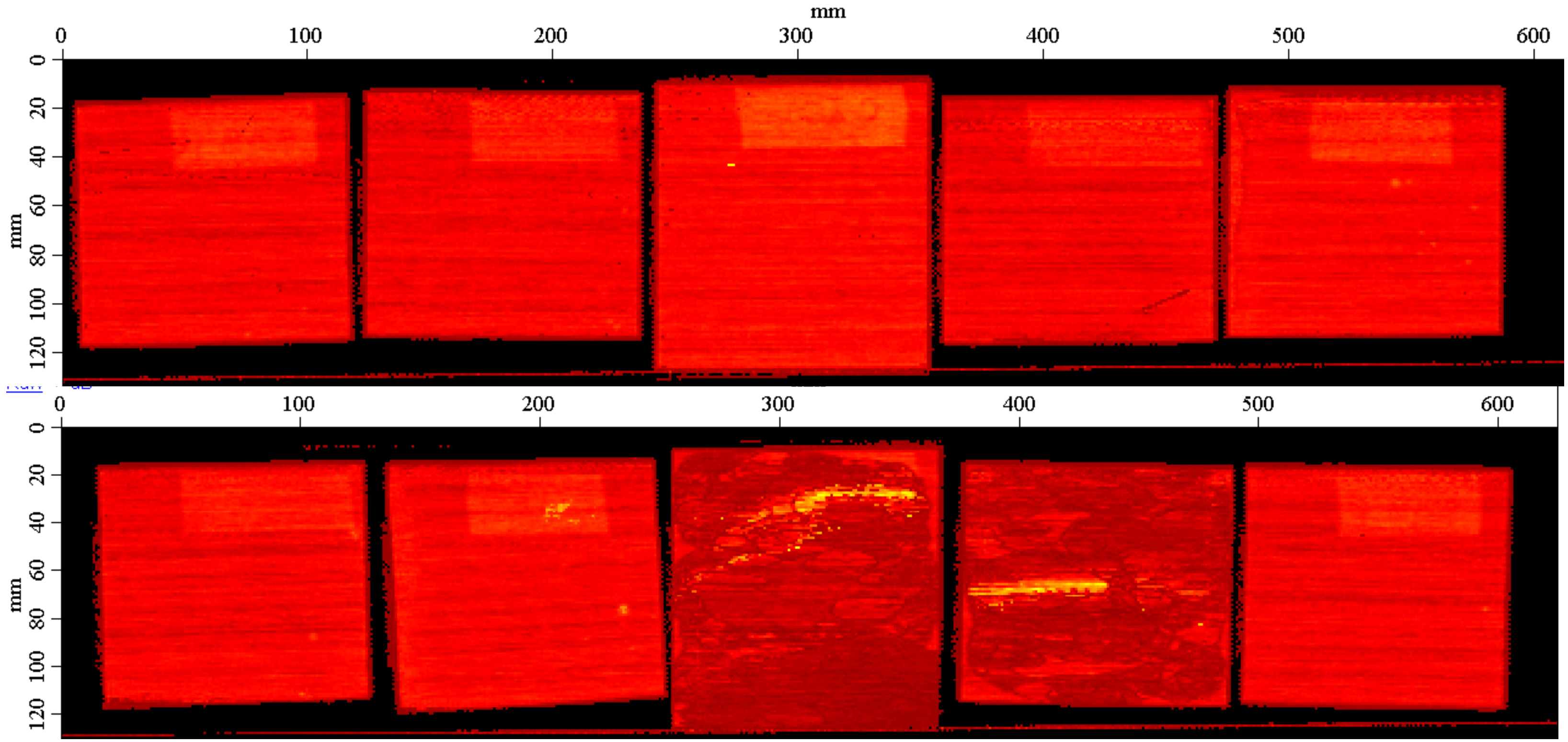
- 3-D Characterization of localized thermal damage
- Include contact angle and fluorescence spectroscopy
- FTIR guided repair of thermal damage
- Test repair

Year 1 and 2 Results: Ultrasonic NDE

- C-Scans before and after thermal exposure at various time and temperatures

Before

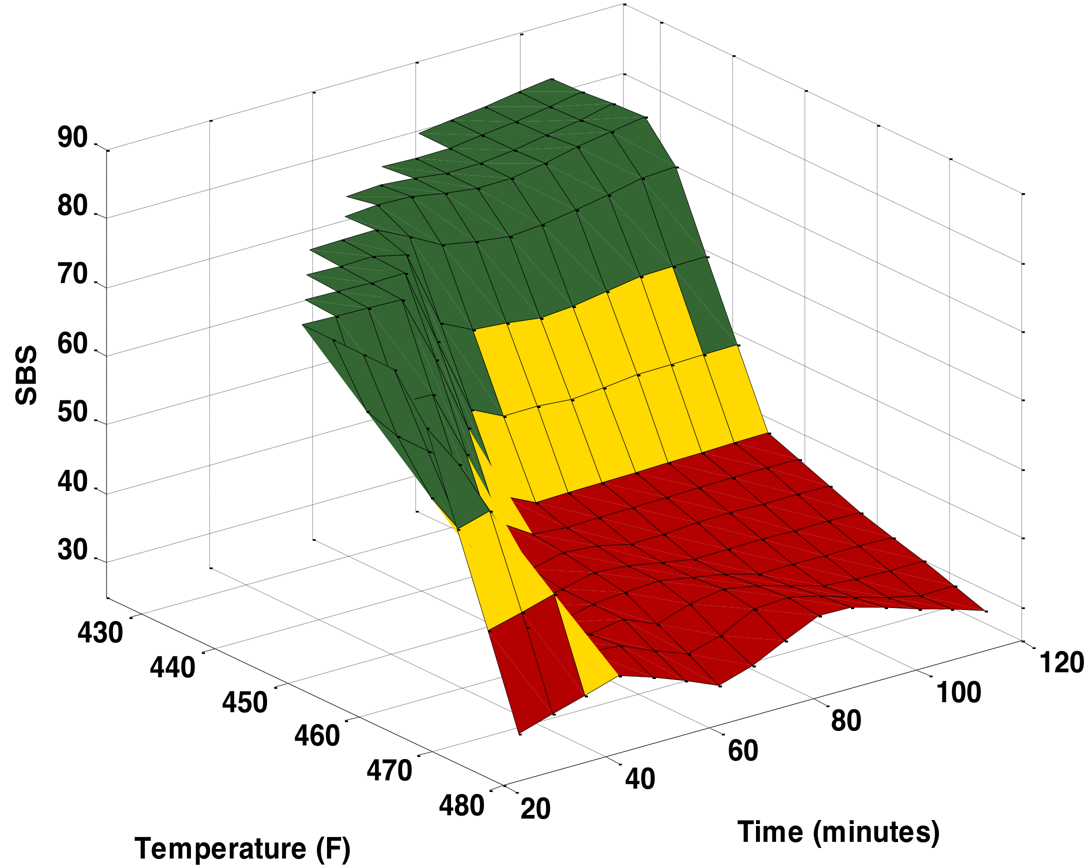
After



Exposure: Low Low High High Medium

Year 1 and 2 Results: Short Beam Shear

- Coupon level thermal exposure in oven



CECAM
JAMS
JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE
A Center of Excellence
AMTAS
Advanced Materials in Transport Aircraft Structures

Year 1 and 2 Results: Microscopy

Low Exposure
415F, 30min
5X

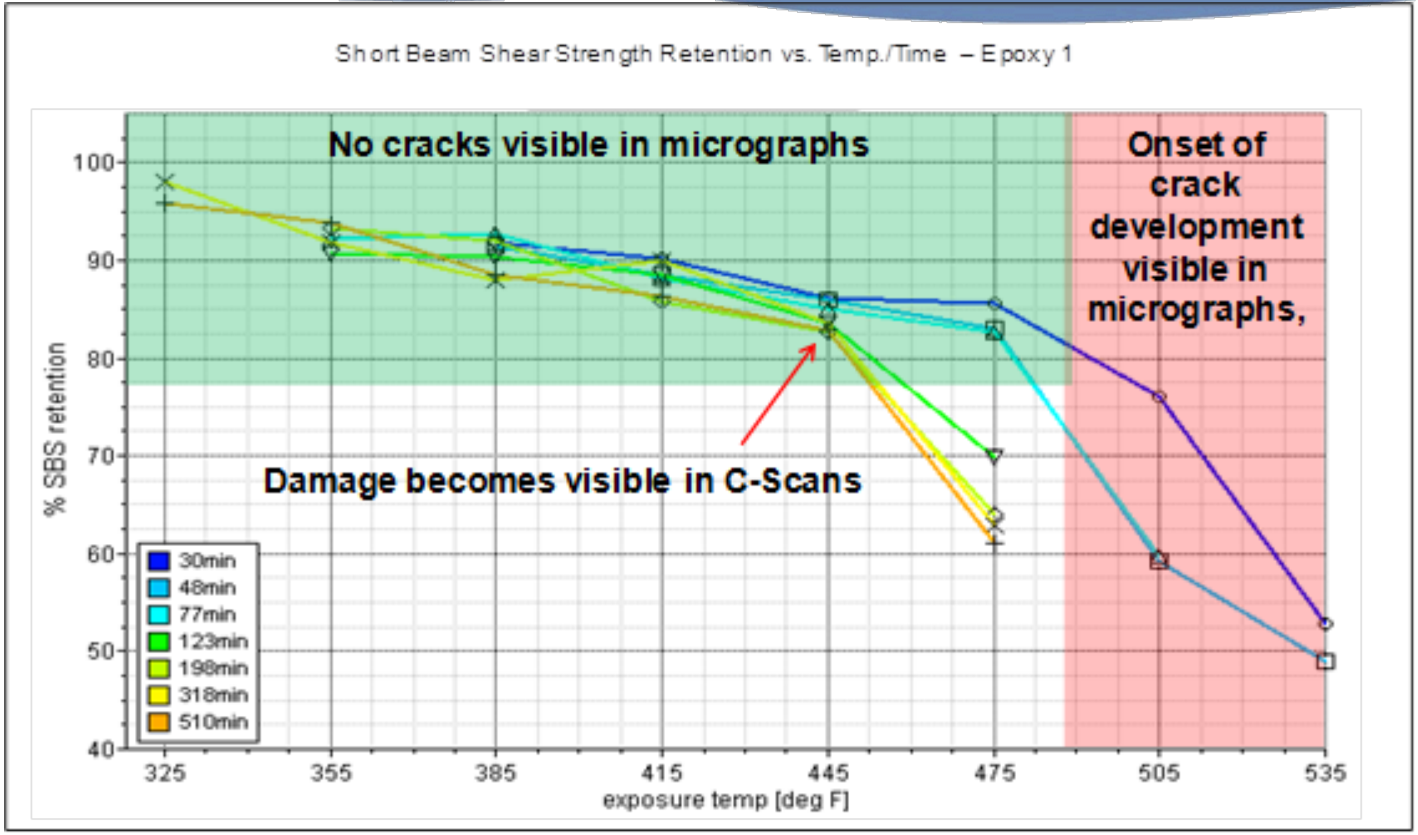
Medium Exposure 415F,
200min
5X

High Exposure
535F, 30min
5X

High Exposure
535F, 30min
50X

CECAM JAMS AMTAS

Thermal Damage vs. Detection Method



SBS, ultrasound and microscopic analysis of BMS8-276

- **Properties degrade before detection is possible**

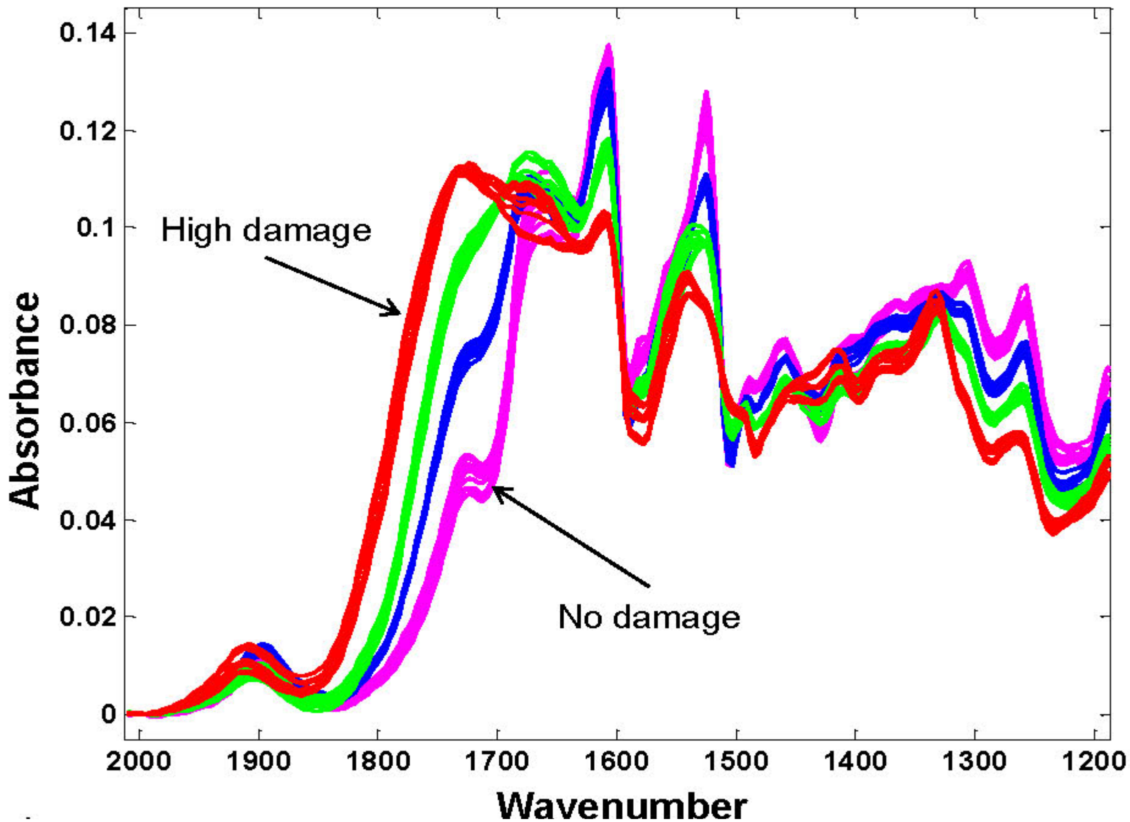
CECAM center of excellence for composites and advanced materials

JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Year 1 and 2 Results: FTIR

FTIR spectra reflect changes indicative of degradation of the chemical bonds of the resin



CECAM center of excellence for composites and advanced materials

JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

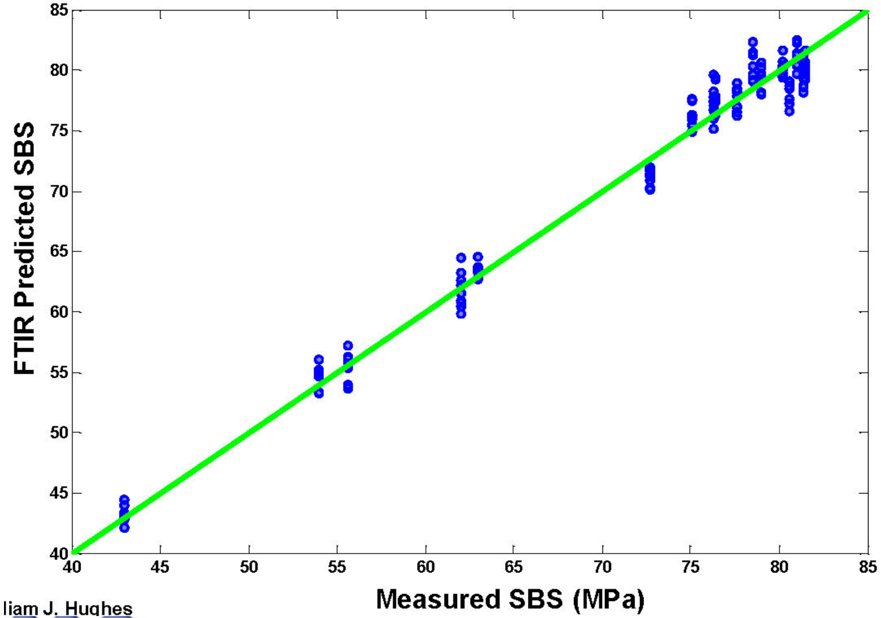
Year 1 and 2 Results: SBS vs. FTIR

Correlate chemical change (FTIR) with SBS

- Multivariate Analysis
- Neural Net Analysis

➢ Both approaches > 97% accurate

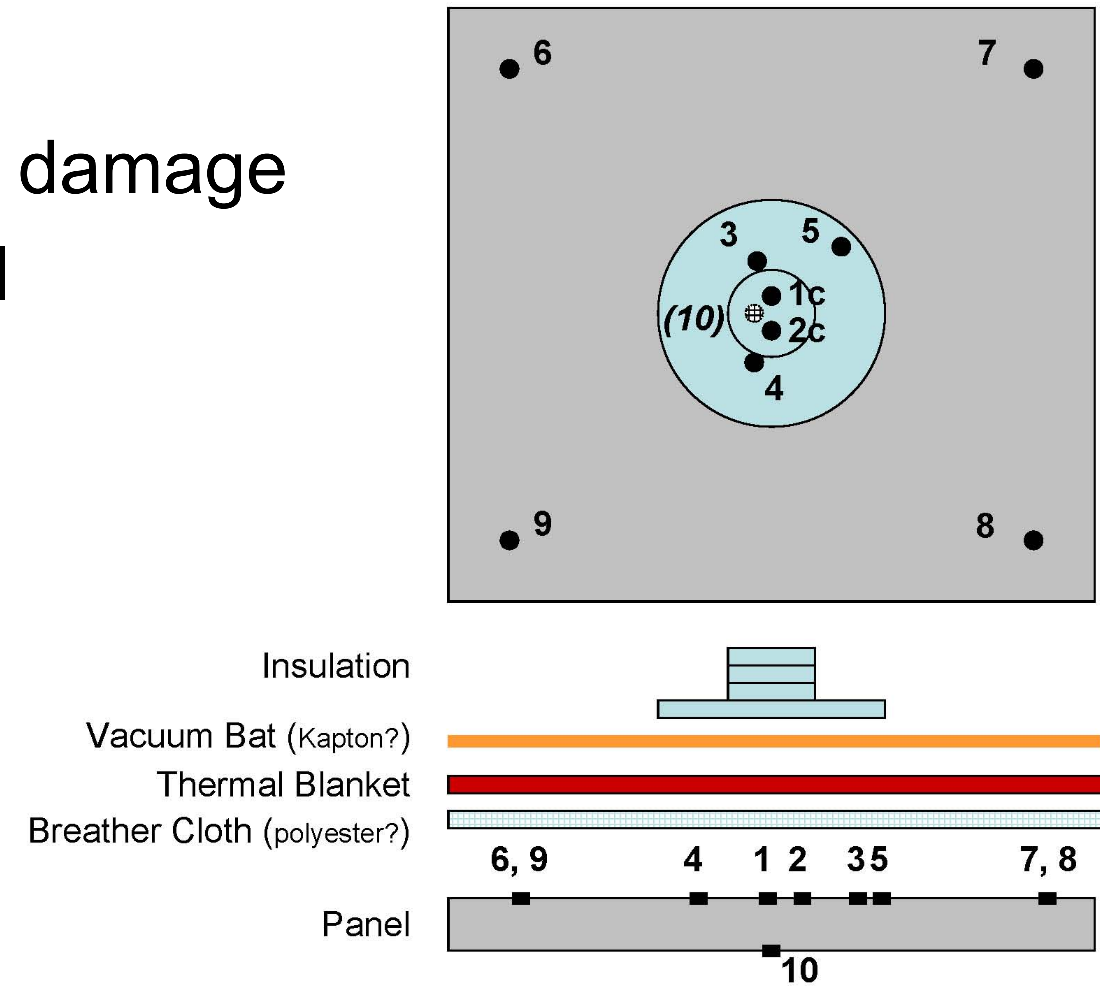
➢ Developed calibration curve for FTIR spectra for levels of thermal damage



liam J. Hughes

Year 1 and 2 Results: Localized damage

- Hot Spots created
- 3 different levels of damage
- 2 panels each level



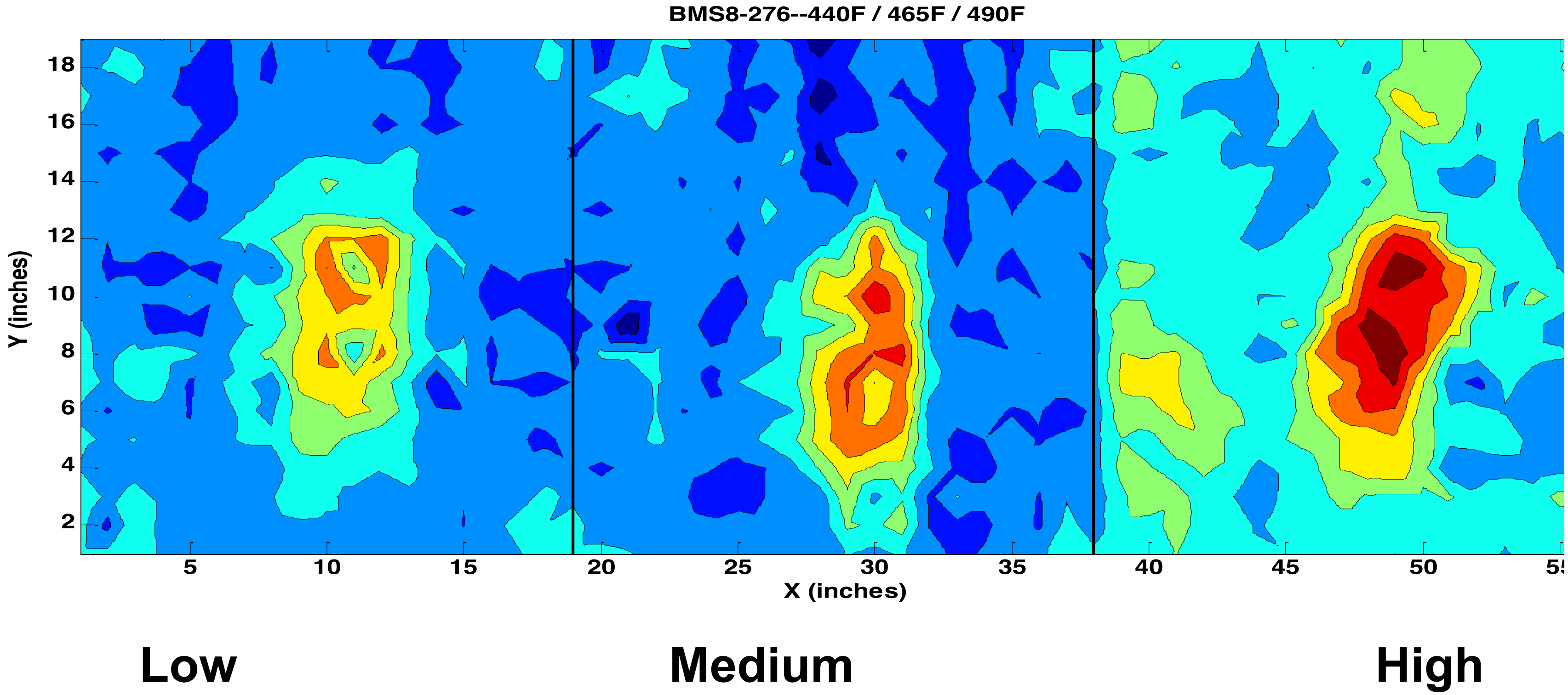
CECAM

JAMS
JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Year 1 and 2: Map of Localized Damage

- FTIR Surface Map of thermal damage



Year 3: Experimental Plan Overview

- Train personnel and confirm calibration curve on reference samples
- Advanced NDE characterization of panels (Sandia)
- Surface map thermal damage (all panels)
- 1st set of panels-Mechanical testing (SBS, Tg, ??)
- 2nd set of panels-Scarf repair guided by FTIR
  - Map damage ply by ply during scarfing – FTIR
  - Contact Angle & fluorescence measurements
  - Bonded Repair followed by NDE
  - Mechanical testing of repaired panel

CECAM center of excellence for composites and advanced materials

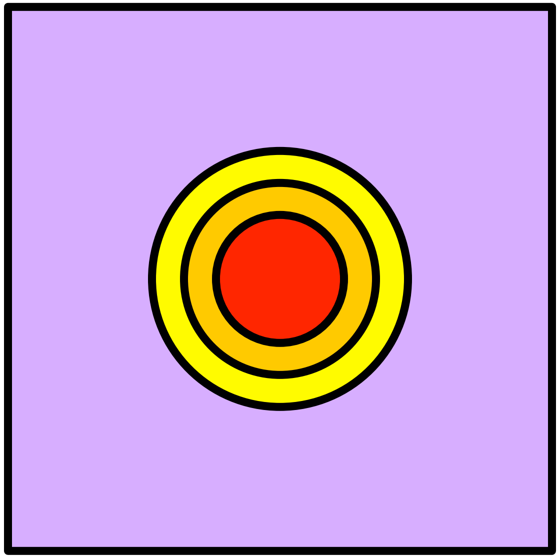
JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Year 3: Experimental Plan- Questions

- What are appropriate tests for localized damage?
  - SBS but in a gradient of damage?
  - Miniature tests
  - Tg (DMA vs DSC)
- Scarfing- thermal damage vs. 0.5” spacing/ply
- Testing the scarf repair panels (12”x12”)
  - Repair geometry to be designed based on FTIR
  - Tensile?
  - Flexure?
  - Flatwise tension?

Thermal Damage Panel Geometry



What are appropriate tests?

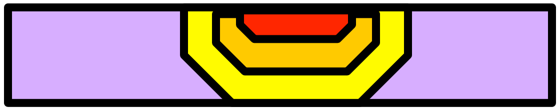
What are appropriate specimens?

Guided by NDE results?

-Matrix dominated properties

-Minimize damage gradient

-Small sample size



Summary

- FTIR effective in detecting thermal damage
  - ExoScan now part of Boeing 787 SRM
- Work remains to be done
  - 3D mapping of thermal damage
  - Correlation with other techniques
    - Advanced NDE
    - Tg
    - Contact Angle
    - Fluorescence

Looking Forward

- Benefit to Aviation
  - Improved damage detection in composites.
  - Greater confidence in repairs
- Future needs
  - Application to other composite systems
  - Other applications of handheld FTIR
    - Chemical damage
    - Surface prep for bonding
  - Wide area damage detection methods

Acknowledgements

- FAA, JAMS, AMTAS
- Boeing Company
  - Paul Vahey, Paul Shelly
- Agilent (A2 Technologies)
- Sandia National Lab
  - Dennis Roach
- UW MSE

Thank you

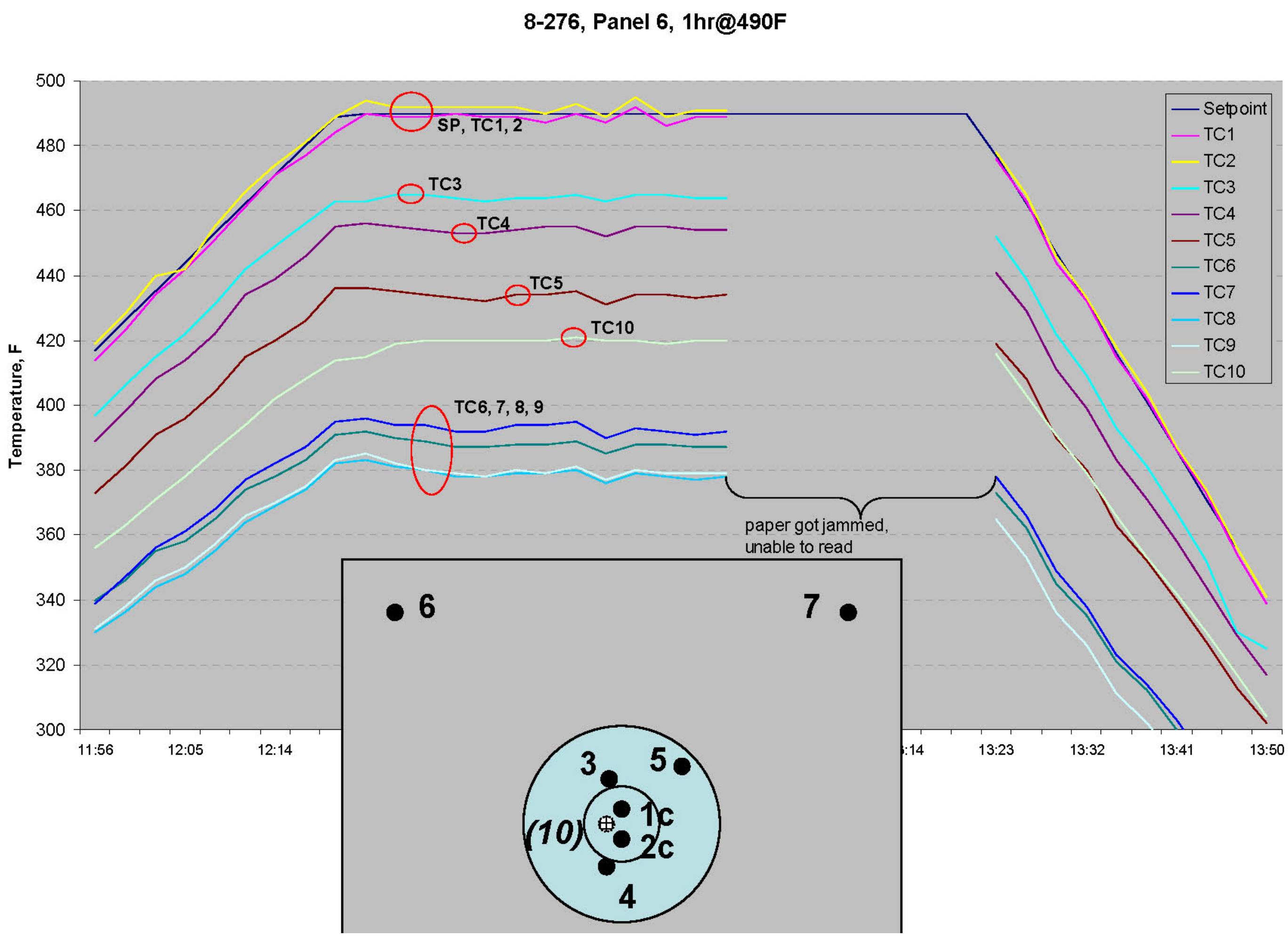
Questions and comments welcome

CECAM
center of excellence for composites and advanced materials

JAMS
JOINT ADVANCED MATERIALS & STRUCTURES
CENTER OF EXCELLENCE

A Center of Excellence
AMTAS
Advanced Materials in Transport Aircraft Structures

Example Thermal Exposure Data



CECAM

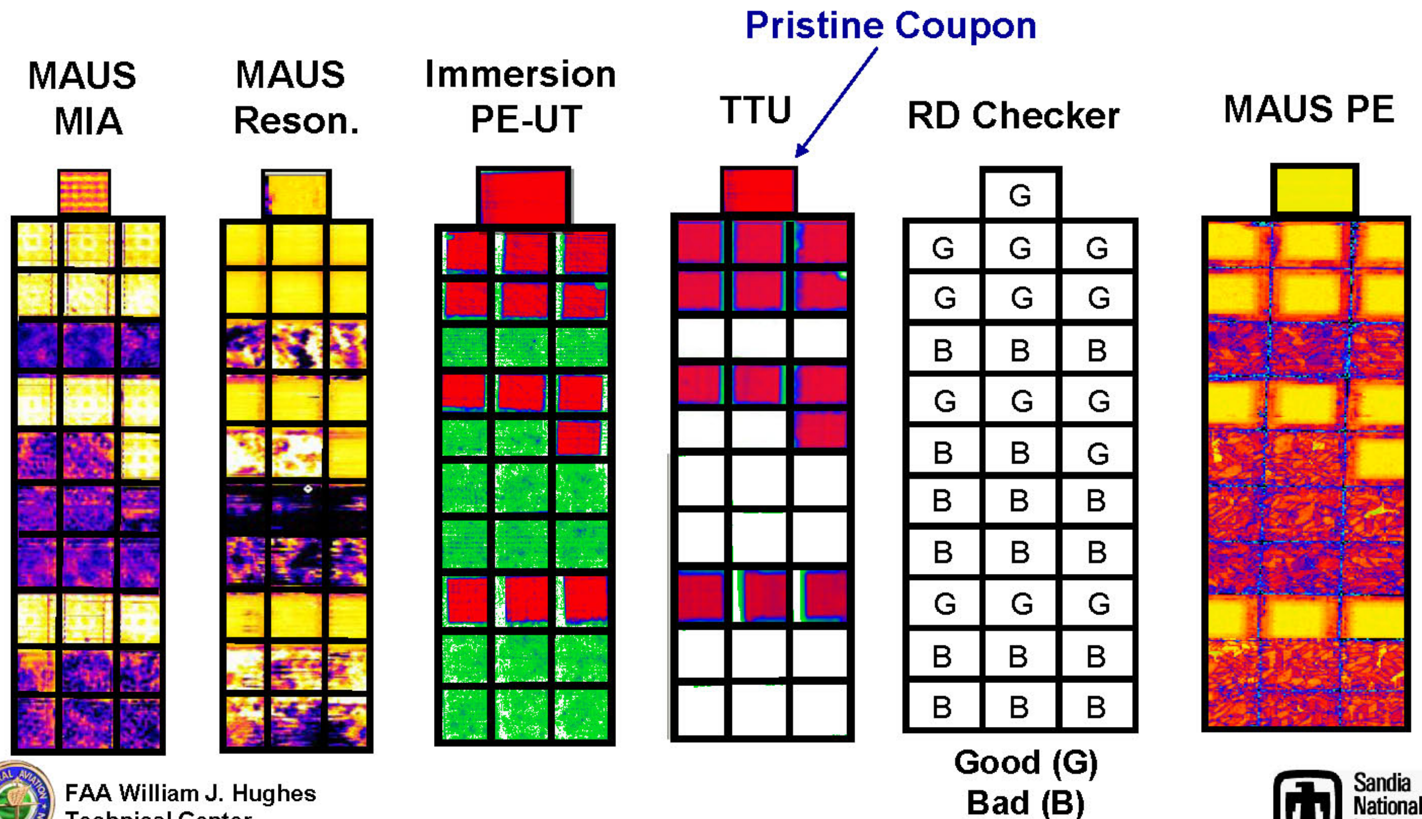
JAMS Joint Advanced Materials & Structures Center of Excellence

AMTAS A Center of Excellence Advanced Materials in Transport Aircraft Structures

Composite Heat Damage – Comparison of Several NDI Methods

(BMS8-276 Uniaxial)

Temp. & Time Exposure Varied in All 30 Coupons



FAA William J. Hughes Technical Center

Sandia National Laboratories