Test and Analysis of Fuselage Structure to Assess Emerging Metallic Structures Technologies

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ICAF, June 26-29, 2023, Delft

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Outline

- Background and Project Overview
- Fixture, Panel and Test Phases
- Panel 1-3 Test Results
- Summary and Future Work

Assessment of Emerging Technologies Advanced Metallic Fuselage Structure

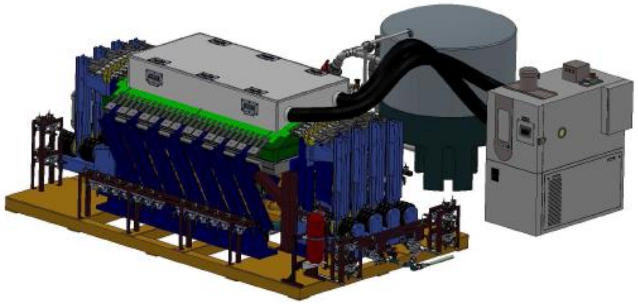
- **Background**: Significant advancements made in emerging metallic structures technology (EMST) aimed at improved performance and reduced cost compared to composites
- **Purpose**: Assess fatigue and structural integrity of EMST for fuselage applications
- **Approach**: Partner with industry to conduct full-scale test and analysis of using the FAA's FASTER and SML lab
- **Outcome**: Gather data which will be used to ensure safe implementation of EMST

Partners

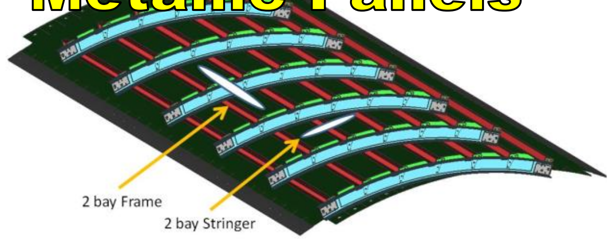
ARCONIC

EMBRAER

FASTER Fixture



Testing Advanced Metallic Panels



Project Objectives

- Assess EMST in collaboration with industry leveraging unique FAA structural testing capabilities
- Provide a better understanding of advanced technologies and help ensure their safe implementation in aircraft products
- Identify unique damage mechanisms, damage-tolerance behavior and MSD scenarios associated with EMST
- Explore applicable inspection methods including integrated Structural Health Monitoring (SHM)
- Verify analytical methods and generate data to support certification, and continued airworthiness of EMST

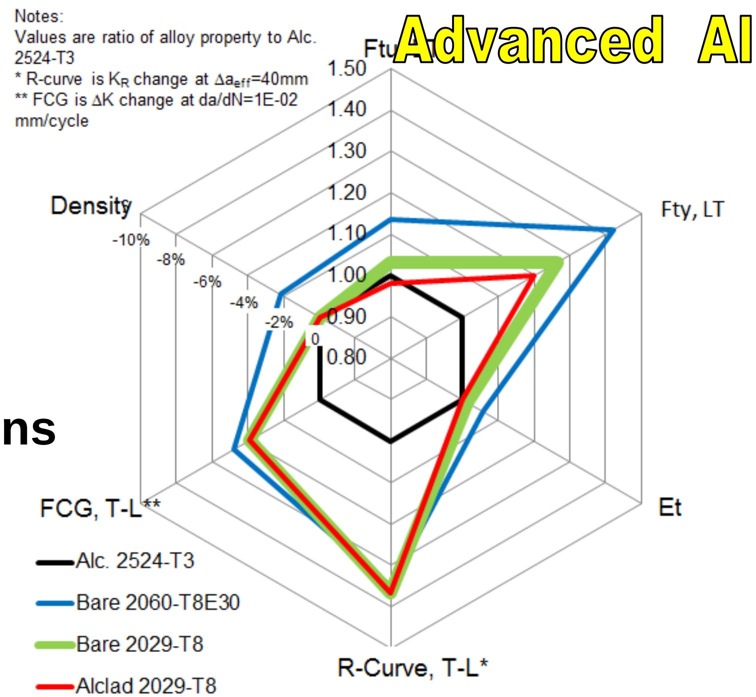
Technologies Considered

- Advanced Alloys:
  - 2524-T3 (Baseline)
  - 2060-T8 Al-Li
  - 2029-T3 Clad

  Skin

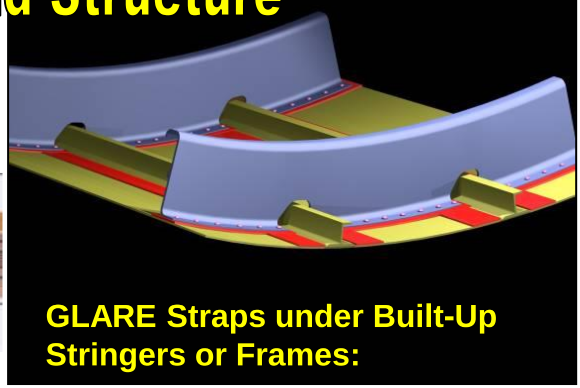
  - 7075-T62 (Baseline)
  - 7150-T77511(Baseline)
  - 2055-T8 Al-Li
  - 2099-T83 Al-Li

  Extrusions



- Hybrid Construction and Fiber Metal Laminates
  - GLARE Reinforcement Straps
  - Improve damage containment

FML Hybrid Structure



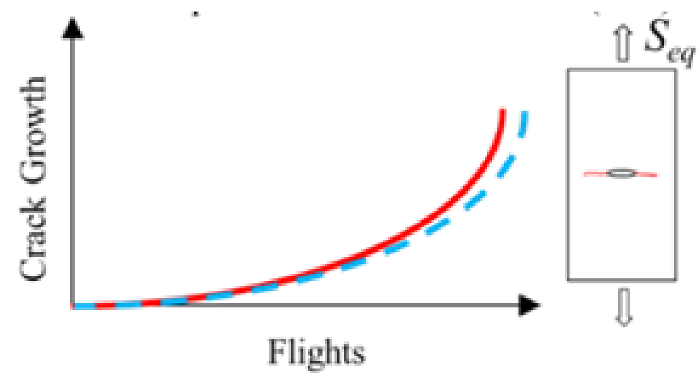
FASTER Fuselage Panel Test Matrix

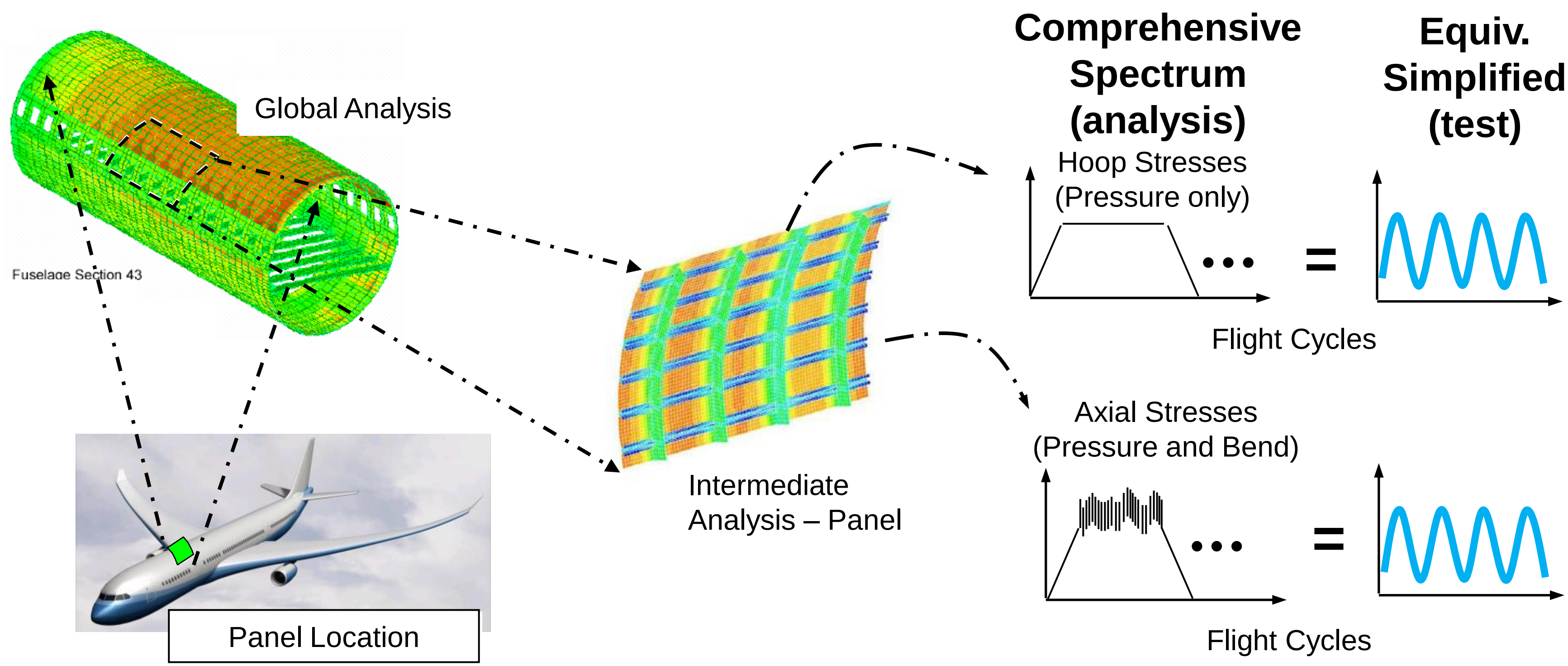
Focus: Fatigue crack growth and residual strength

		1	2	3	4	5
		Baseline	Advanced Density Reduction	Advanced Materials	FML Reinforced	FML Reinforced (Optimized for Weight)
Component	Skin	2524-T3 sheet	2060-T8E30 Al-Li sheet	2029-T3 sheet	2524-T3 sheet	2524-T3 sheet
	Stringer	7150-T77511 extrusions, riveted	2055-T84 Al-Li extrusions, riveted	2055-T84 Al-Li extrusions, riveted	7150-T77511 extrusions, with FML straps	7150-T77511 extrusions, with FML straps
	Frame	7075-T62 - shear tied, extruded, riveted	2099-T83 Al-Li integral extrusions, riveted	2099-T83 Al-Li integral extrusions, riveted	7075-T62 - shear tied, extruded with FML straps	7075-T62 - shear tied, extruded with FML straps
Schedule	Start	Oct-17	Jan - 19	July - 21	Sep - 23	Jan - 25
	Finish	Dec-18	July -21	Aug - 23	Dec – 24	Dec - 25

Target Location and Loads

- Crown of fuselage forward of wing:
  - Cabin pressurization (Hoop and Axial)
  - Flight Loads : Gusts and Maneuver (Axial)
  - Landing Load (Axial)
- Flight loads represented by 50% Mini-TWIST spectrum





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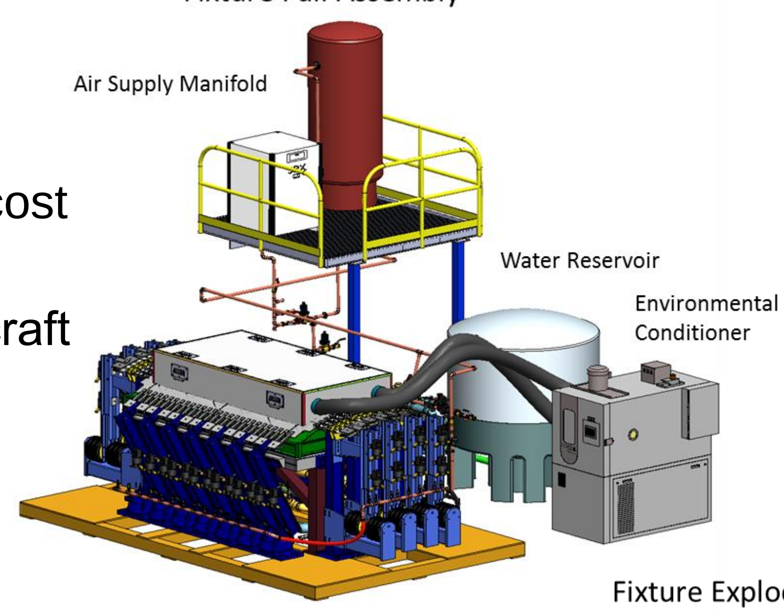
Full-Scale Aircraft Structural Test Evaluation and Research (FASTER)

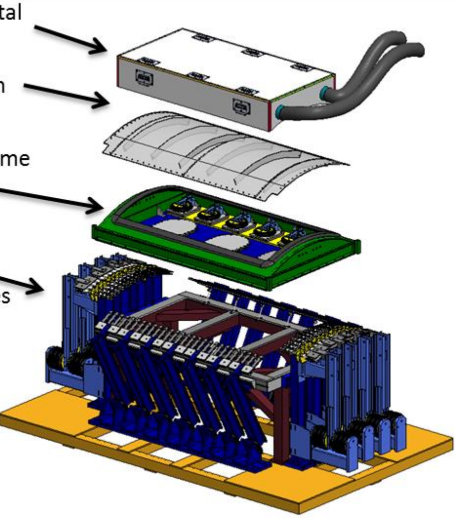
- History and Background:
  - Established: Dec. 1998 through cost share partnership with Boeing
  - Purpose: Support the FAA's Aircraft Safety Mission



- Applies Major Modes of Loading to Fuselage Panels:
  - Pressure
  - Hoop
  - Axial
  - Temperature
  - Humidity

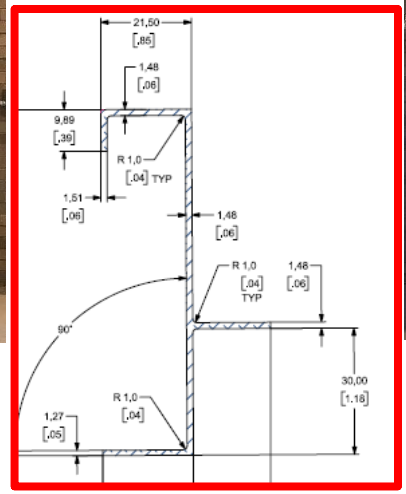
Mechanical (Pressure, Hoop, Axial)

Environment (Temperature, Humidity)



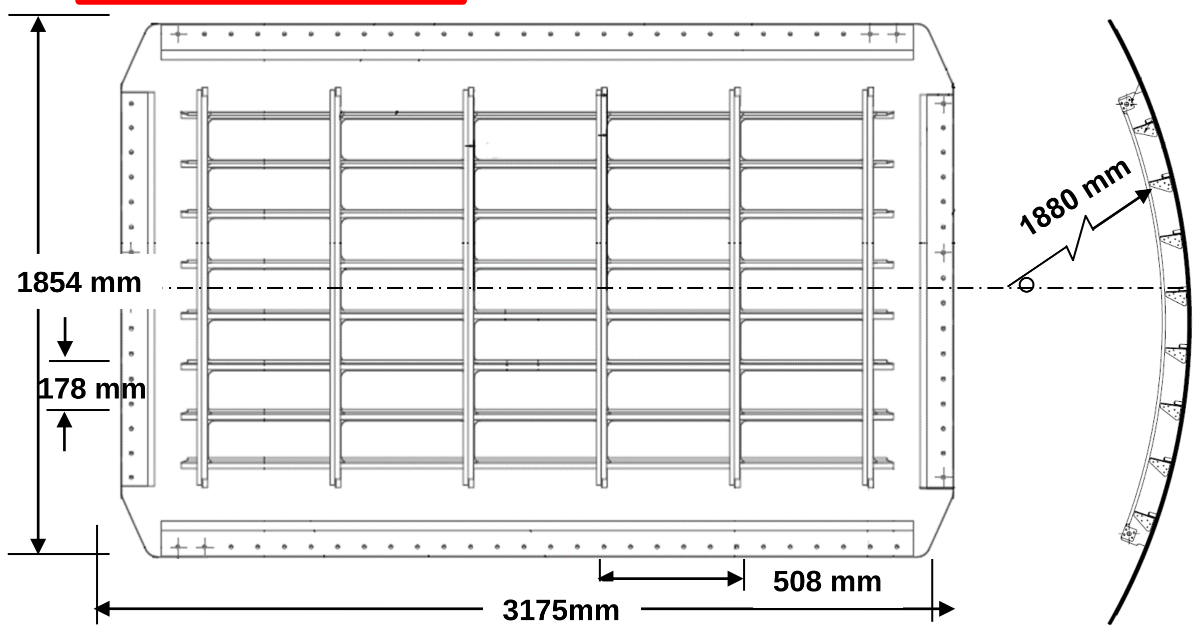
Panel Dimensions

Internal View



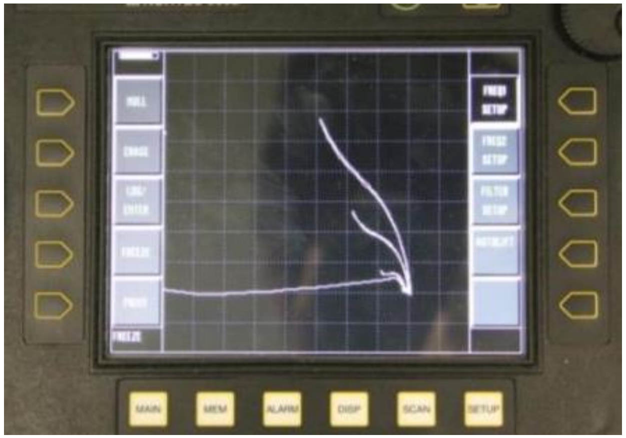
External View

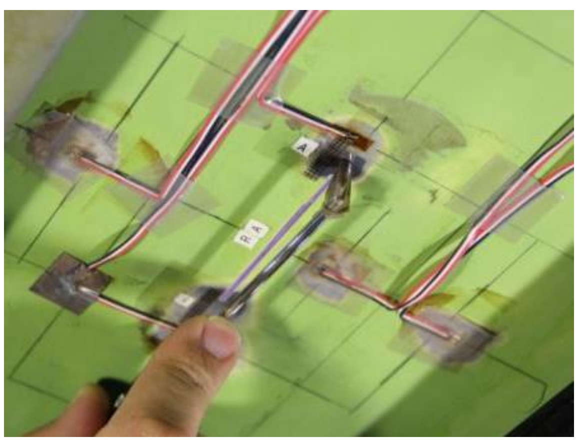
Panel Length	3175 mm
Panel Width	1854 mm
Panel Radius	1880 mm
No. of Frames	6
No. of Stringers	8
Frame Spacing	508 mm
Stringer Spacing	178 mm
Skin Pocket Thickness	1.xx mm
Skin Pad Thickness	1.65 mm



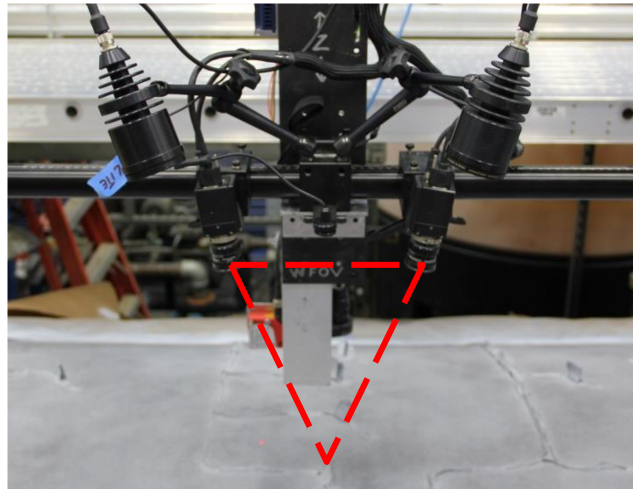
Monitoring Methods

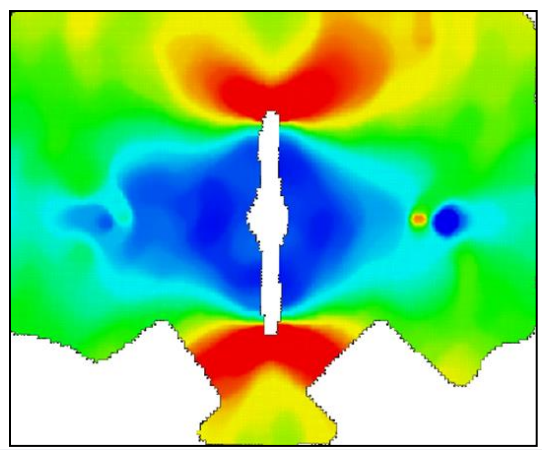
Eddy Current



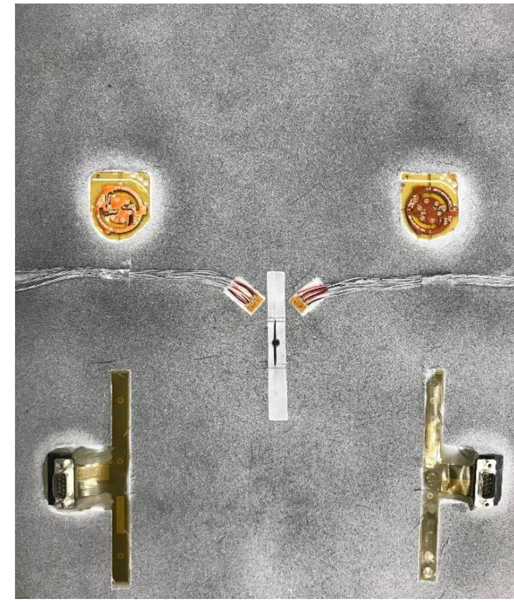


Digital Image Correlation





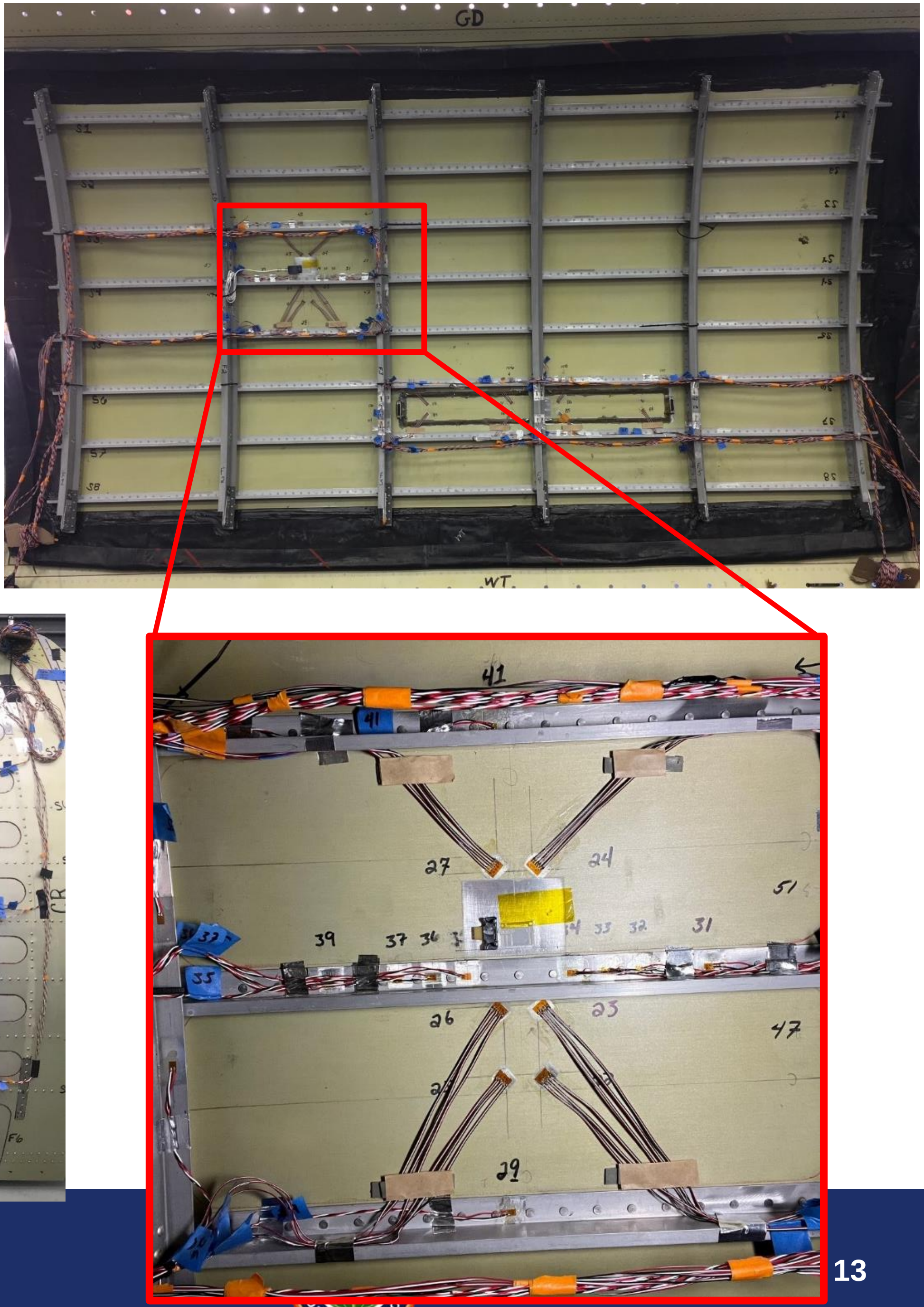
Structural Health Monitoring

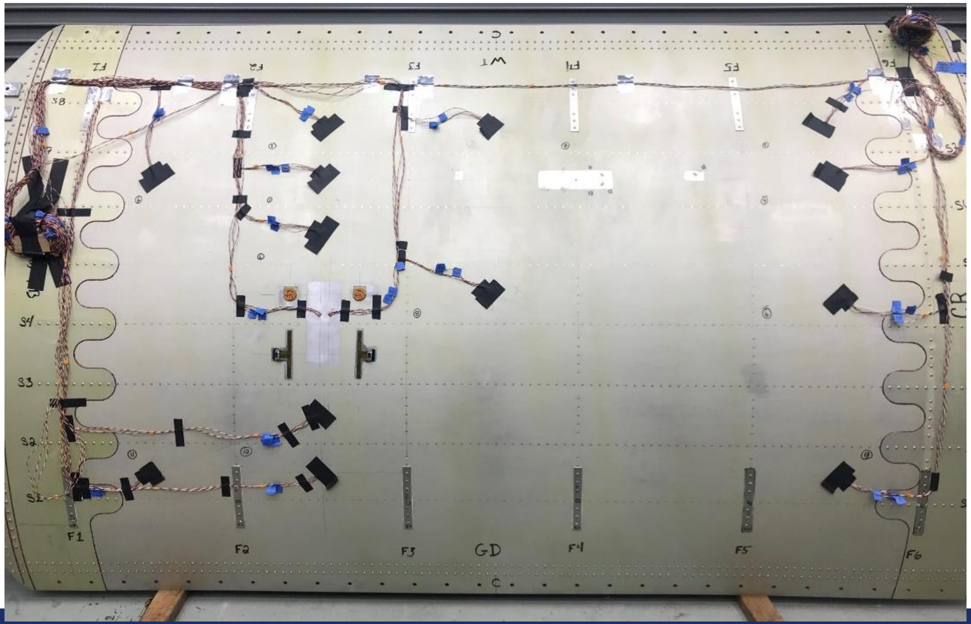


Strain Gage Map

142 channels of strain gages

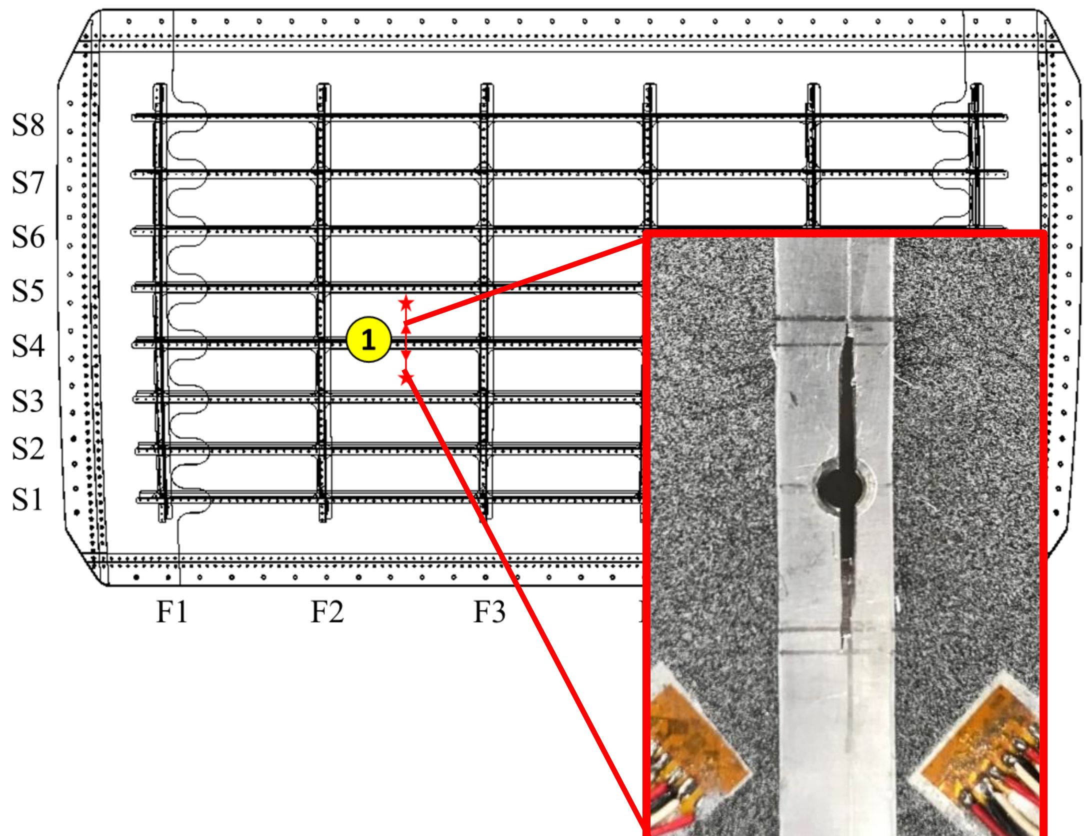
- Skin: 18 external rosettes, 16 internal rosettes
- Stringer: 20 uniaxial gages
- Frame: 20 uniaxial gages





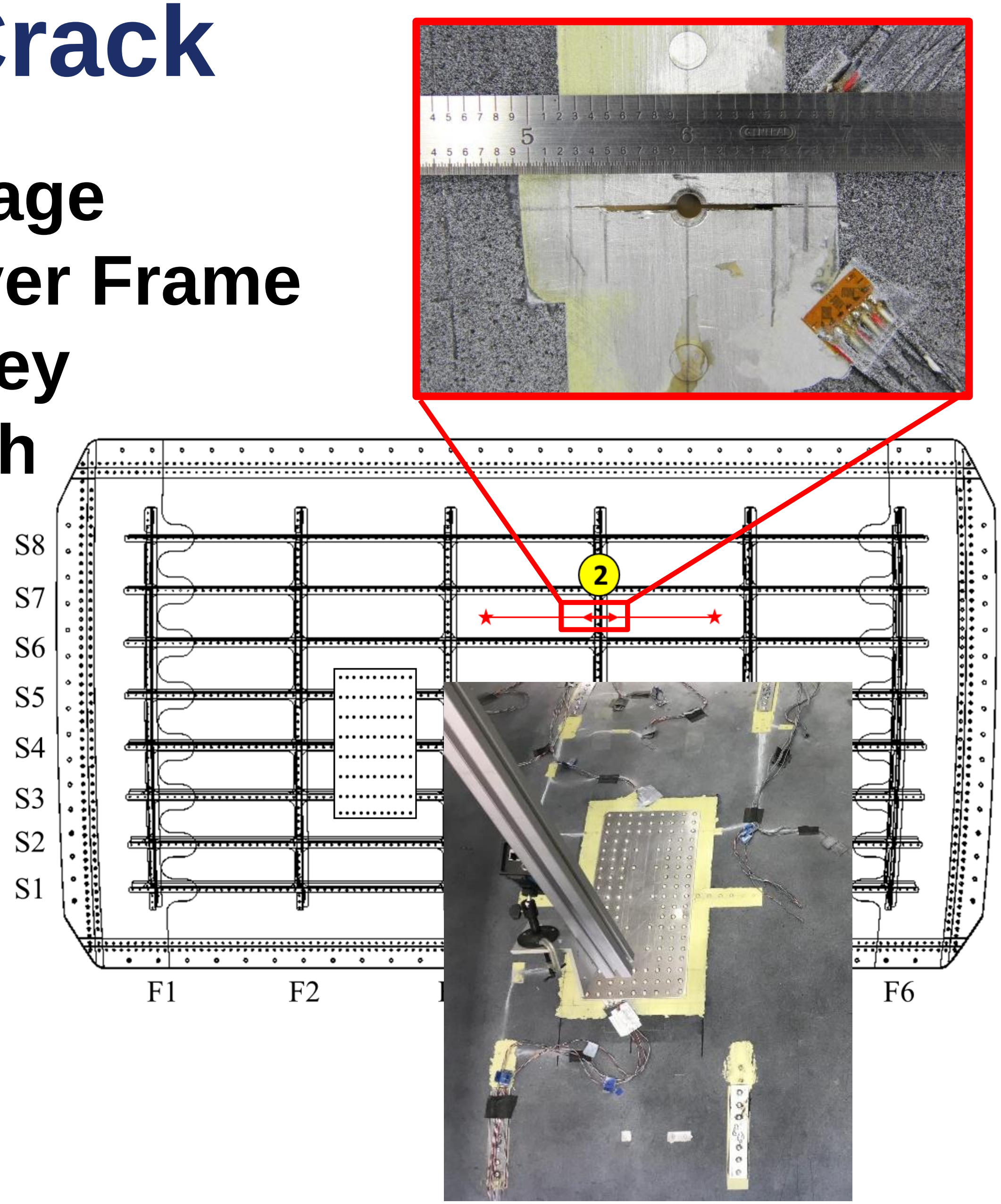
Test Procedure, Phase 1 – Circumferential Crack

- Insert Crack and Sever Stringer
- Baseline Strain Survey
- Fatigue Crack Growth
  - Strain Survey
  - Visual
  - Eddy Current
  - DIC – ARAMIS
  - SHM – Acellent & Metis
- Limit Load Test
  - Visual
  - DIC – ARAMIS



Test Procedure, Phase 2 – Longitudinal Crack

- **Repair Phase 1 Damage**
- **Insert Crack and Sever Frame**
- **Baseline Strain Survey**
- **Fatigue Crack Growth**
  - **Strain Survey**
  - **Visual**
  - **Eddy Current**
  - **DIC – ARAMIS**
  - **SHM – Acellent & Metis**
- **Residual Strength**
  - **Visual**
  - **DIC - ARAMIS**



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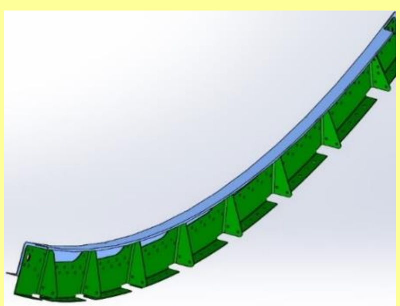
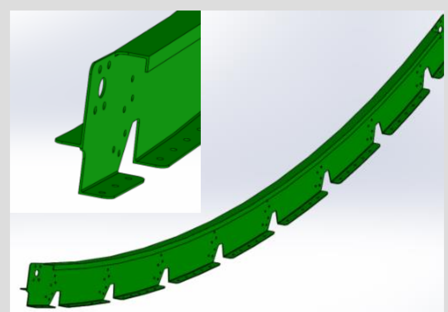
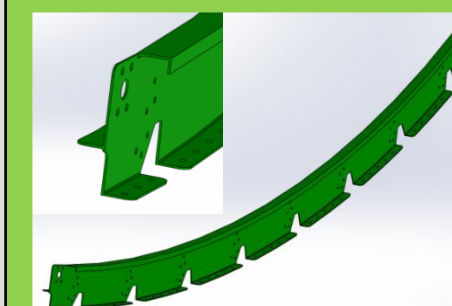
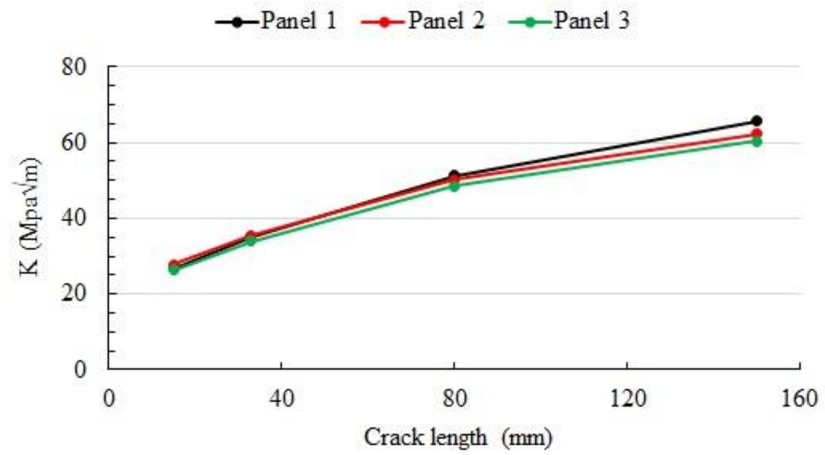
Panel 1 vs. Panel 2 vs. Panel 3

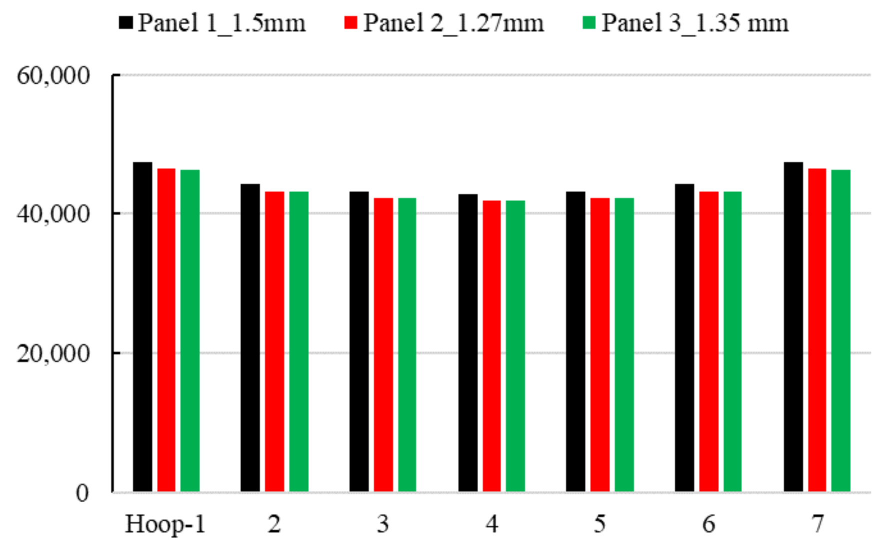
		Panel 1 Baseline	Panel 2 Advanced Density Reduction	Panel 3 High strength, corrosion-resistant
Component	Skin	2524-T3 sheet, 1.5mm	2060 - T8E30 Al-Li, 1.27mm	2029 – T3, 1.35mm
	Stringer	7150-T77511 extrusions, riveted	2055 -T84 Al-Li extrusions, riveted	2055 -T84 Al-Li extrusions, riveted
	Frame	7075-T62 – floating frame, shear tied, extruded, riveted 	2099 - T83 Al-Li integral frame and shear tie extrusions, riveted 	2099 - T83 Al-Li integral frame and shear tie extrusions, riveted 

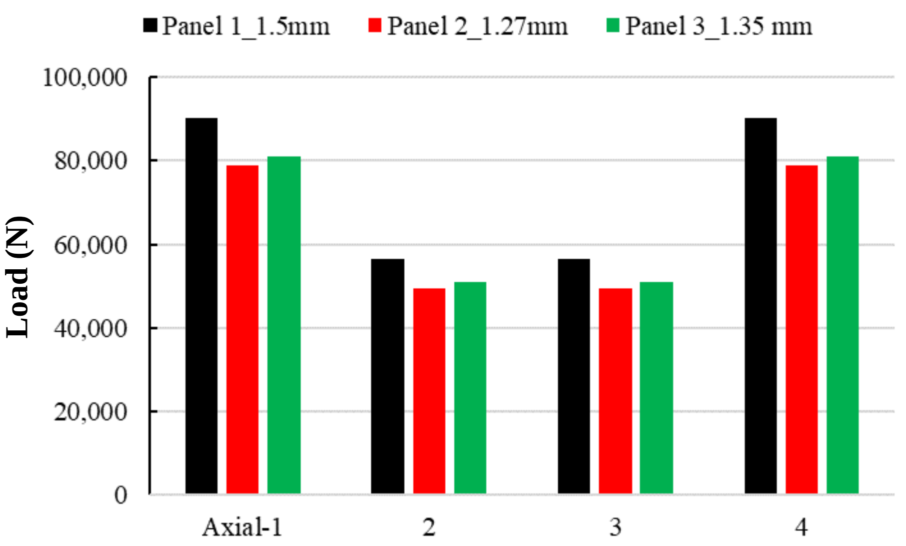
Challenges for Comparison

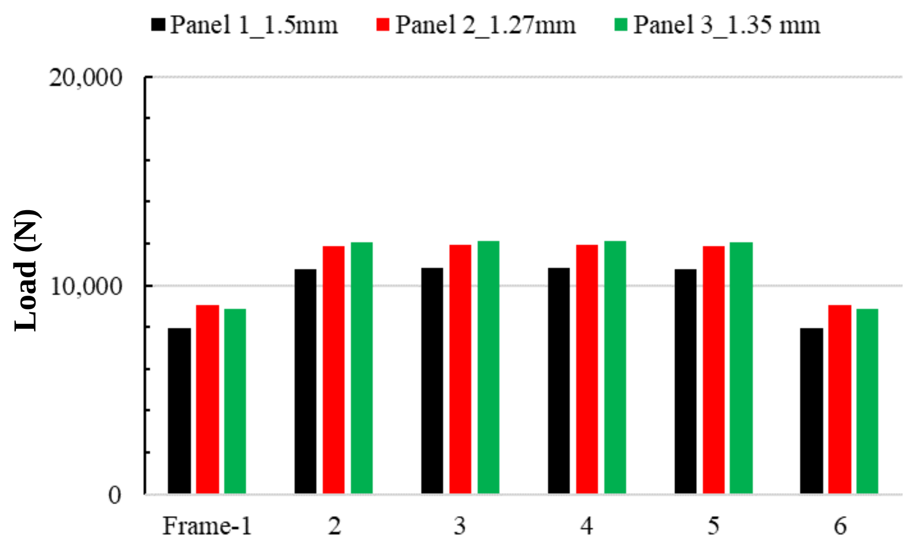
- Differences in panel skin dimensions inherent in manufacturing tolerances:
  - Panel skin thickness different between panels approx. 15%
  - Consequently, strains are different under the same applied load
  - Poses challenges for demonstrating performance difference between Panel 1~ 3
- Developed consistent approach to determine applied loads while accounting for varying thickness by keeping the same crack drive forces (stress-intensity factors) between panels
  - Stress intensity factors were determined by Finite Element Method using multiple 3D elements through thickness

Determination of applied loads by matching stress intensity factor



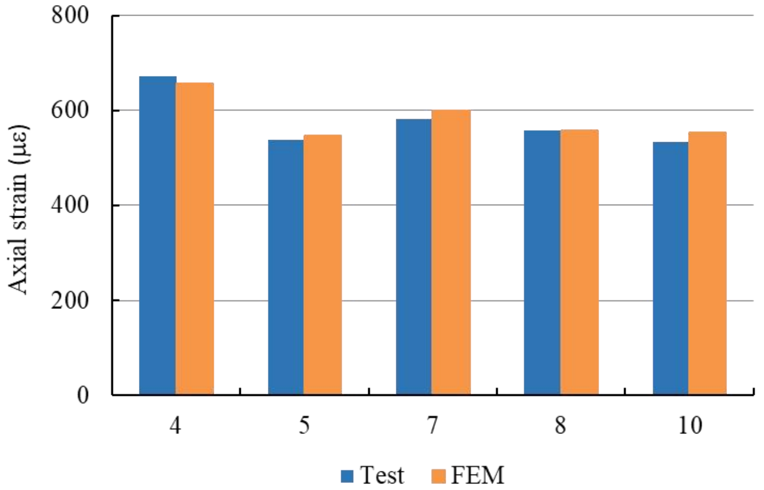


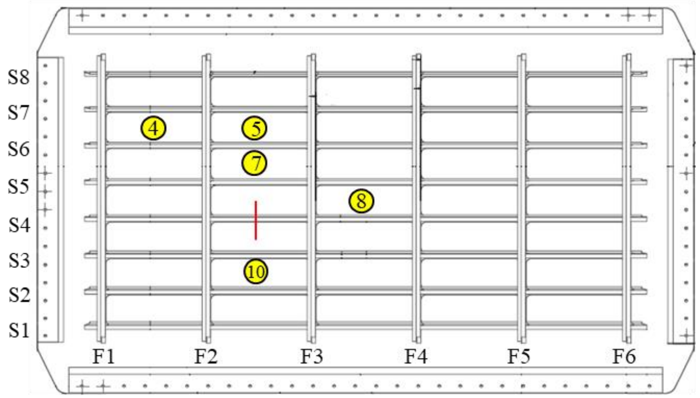


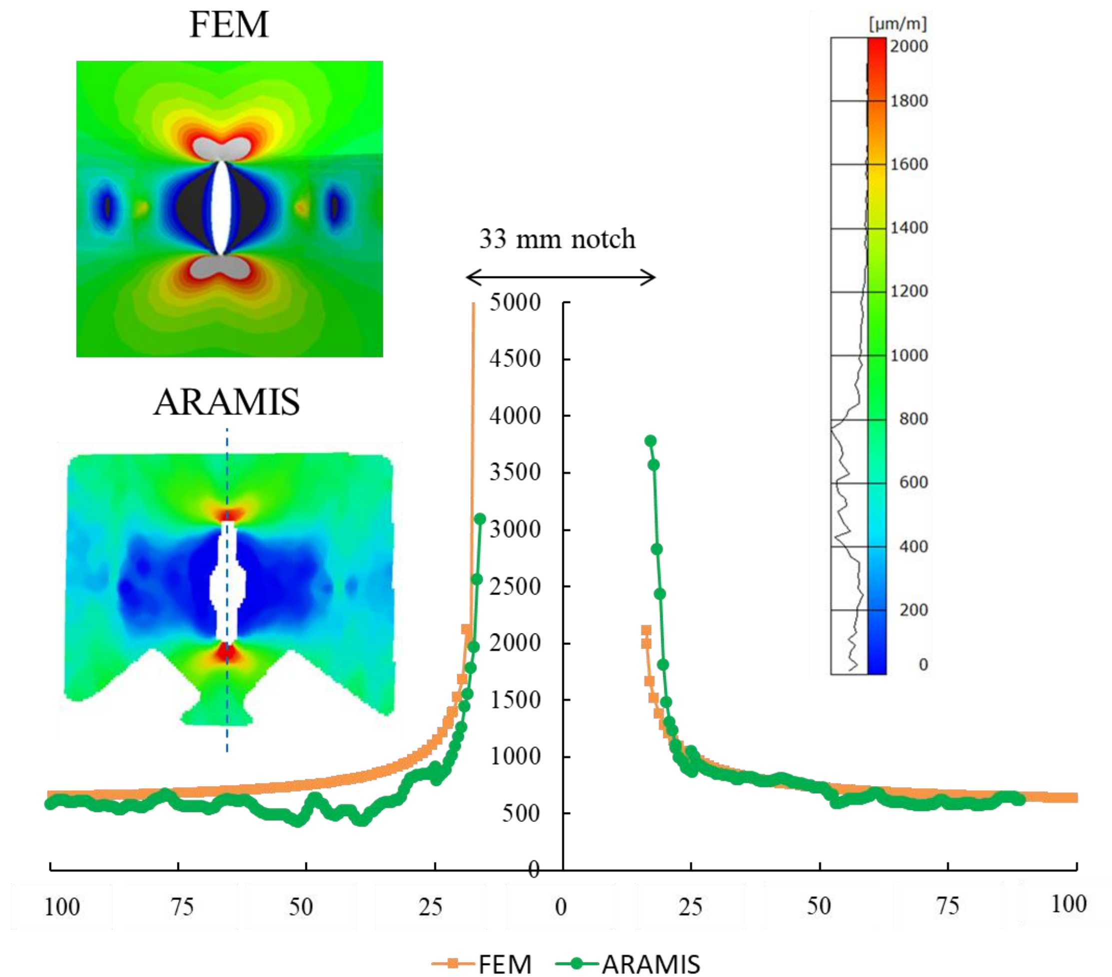


Phase 1 Baseline Strain Survey - Test and Analysis

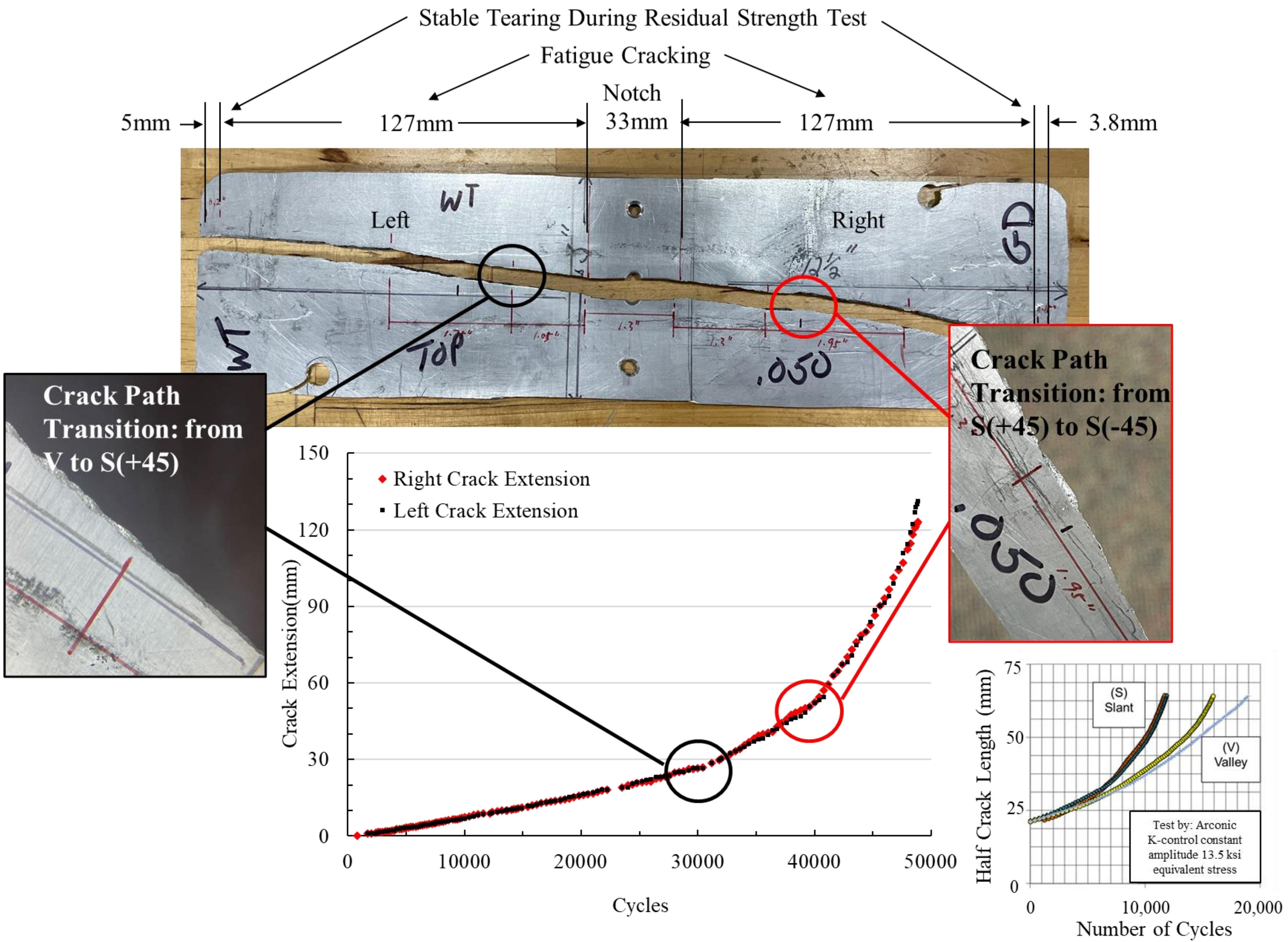
Panel 2 Phase 1



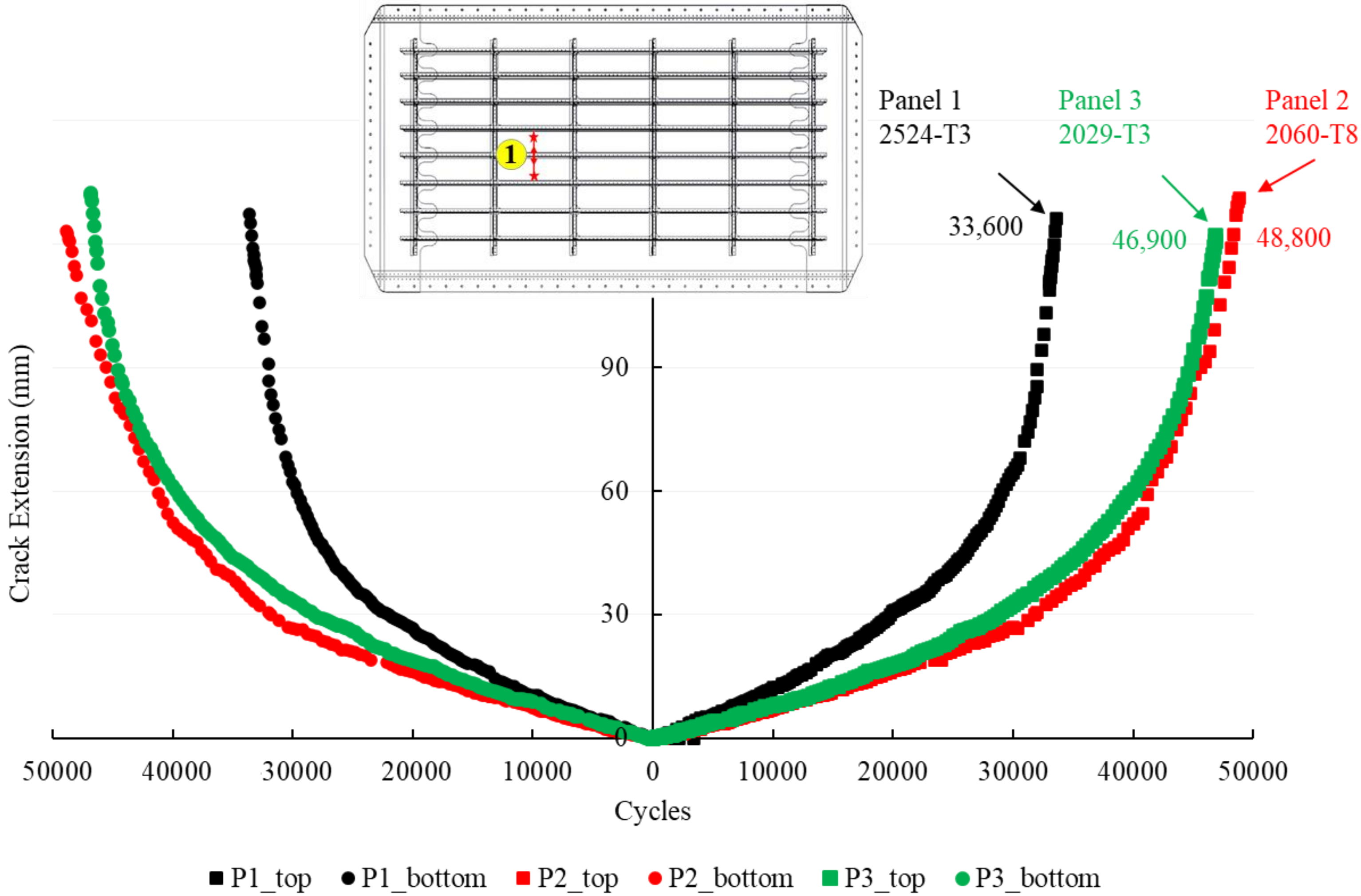




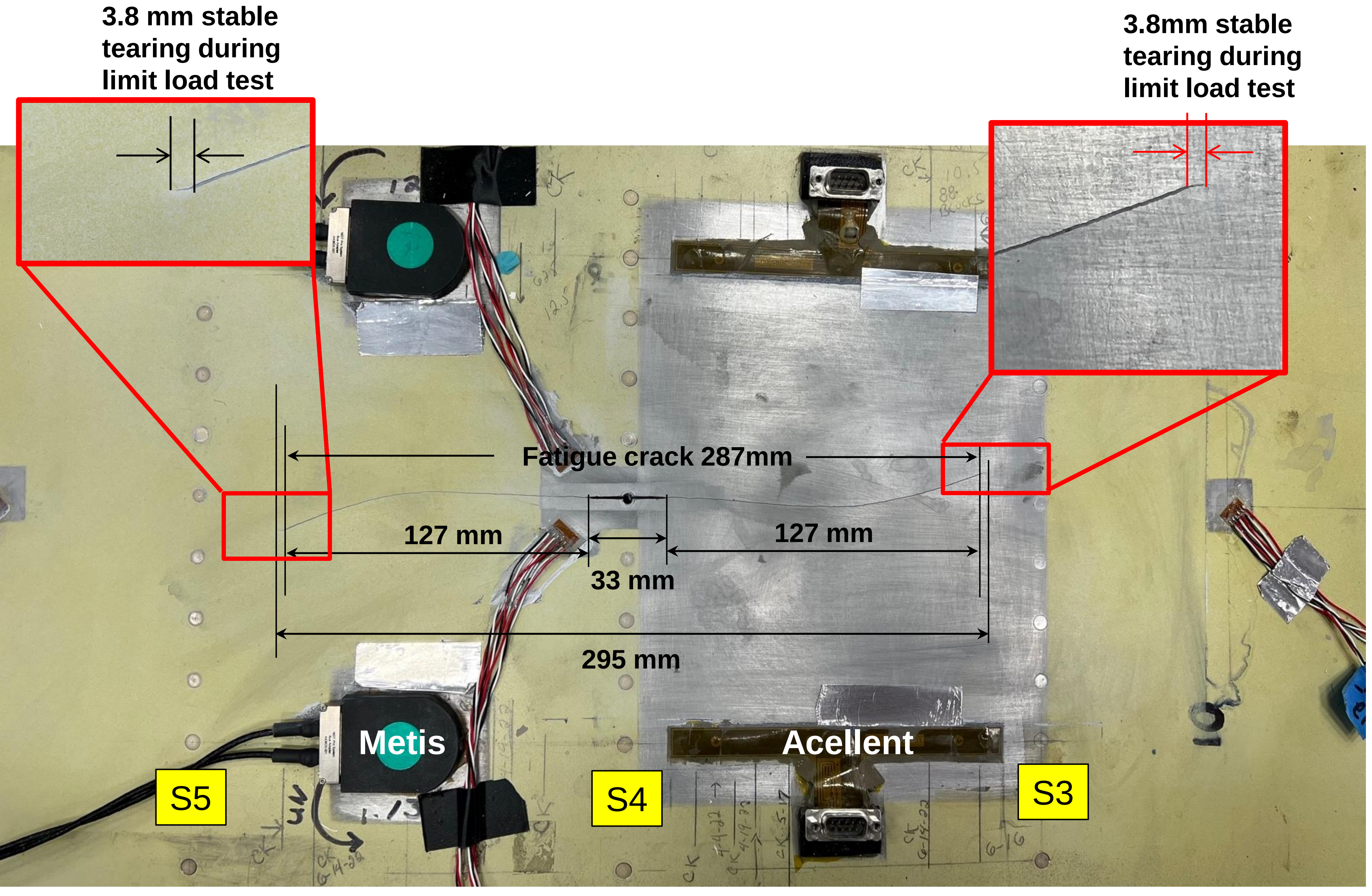
Crack Path Morphology – Panel 2



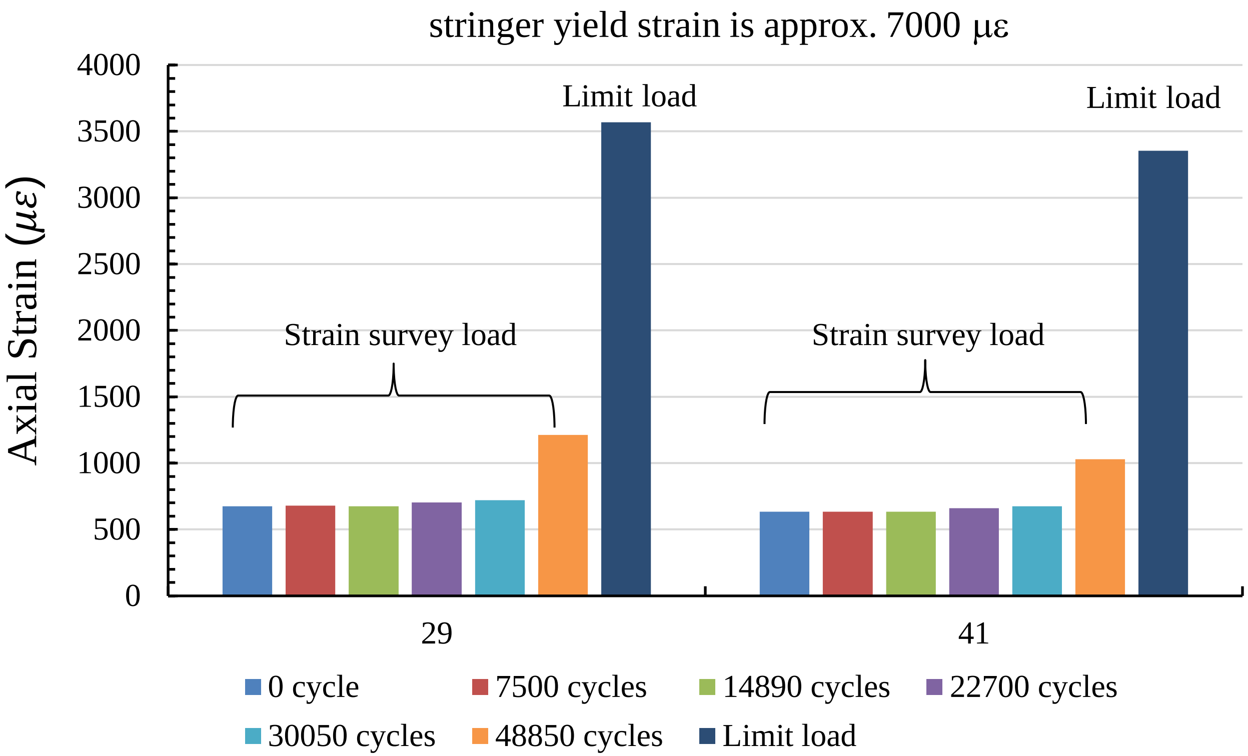
Phase 1 Circumferential Crack Growth Comparison

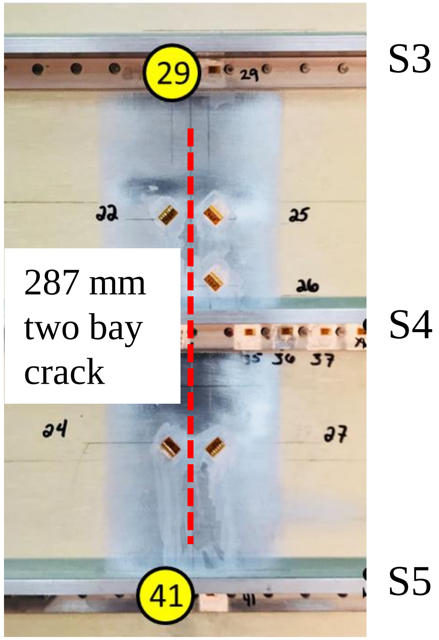


Phase 1 Limit Load Test – Panel 3

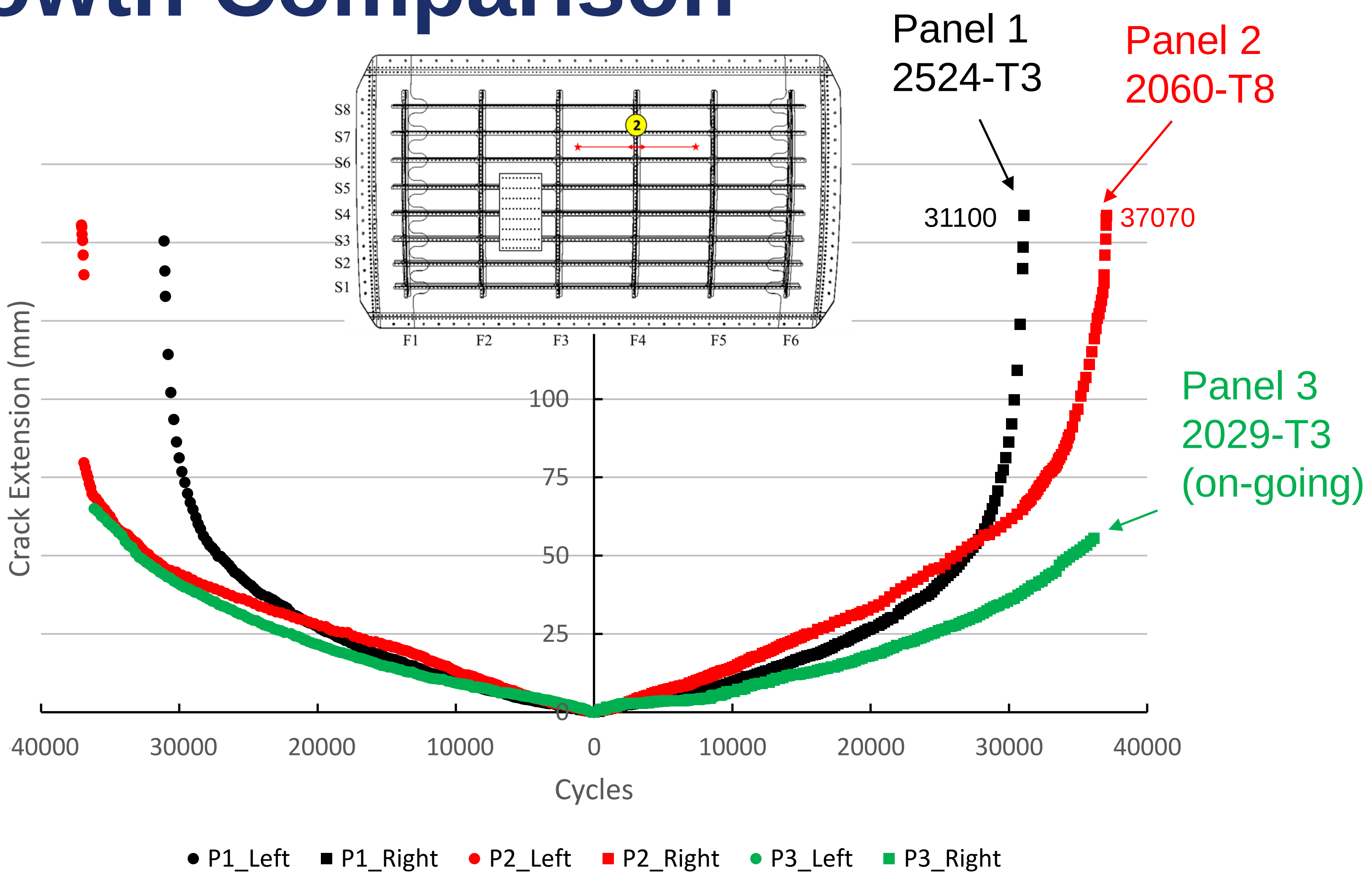


Phase 1 Limit Load Test – Panel 3 Stringer Strains



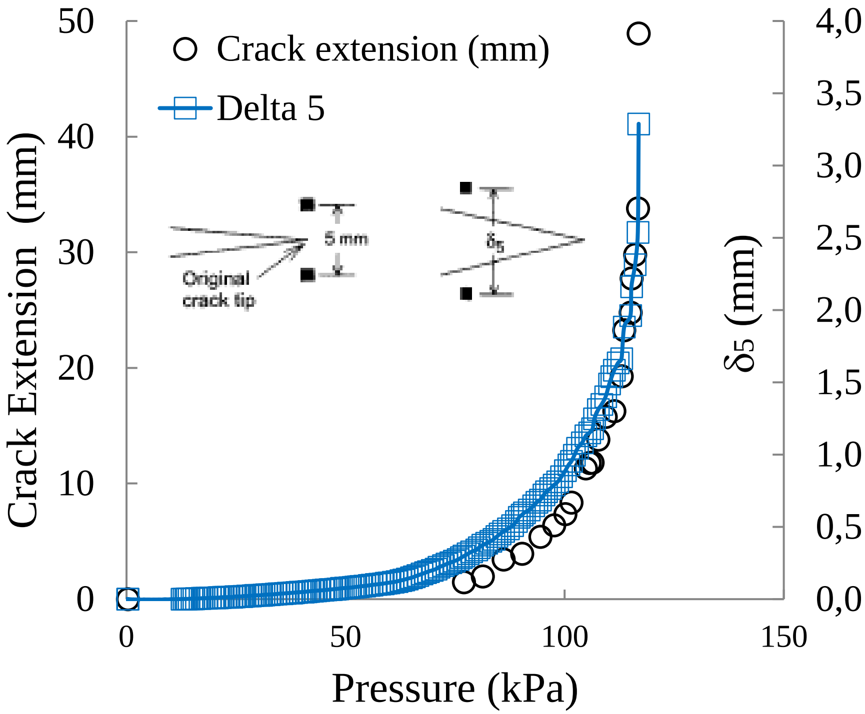


Phase 2 Longitudinal Crack Growth Comparison

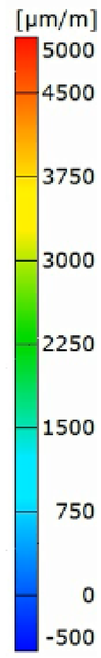


Phase 2 Residual Strength - Panel 1

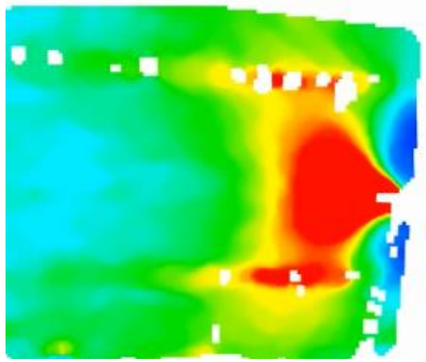
Crack Extension and δ_5 Measurements



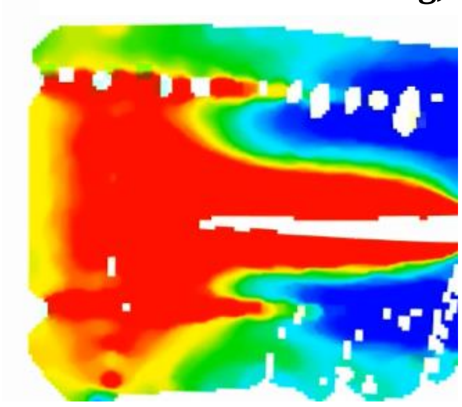
Hoop Strain



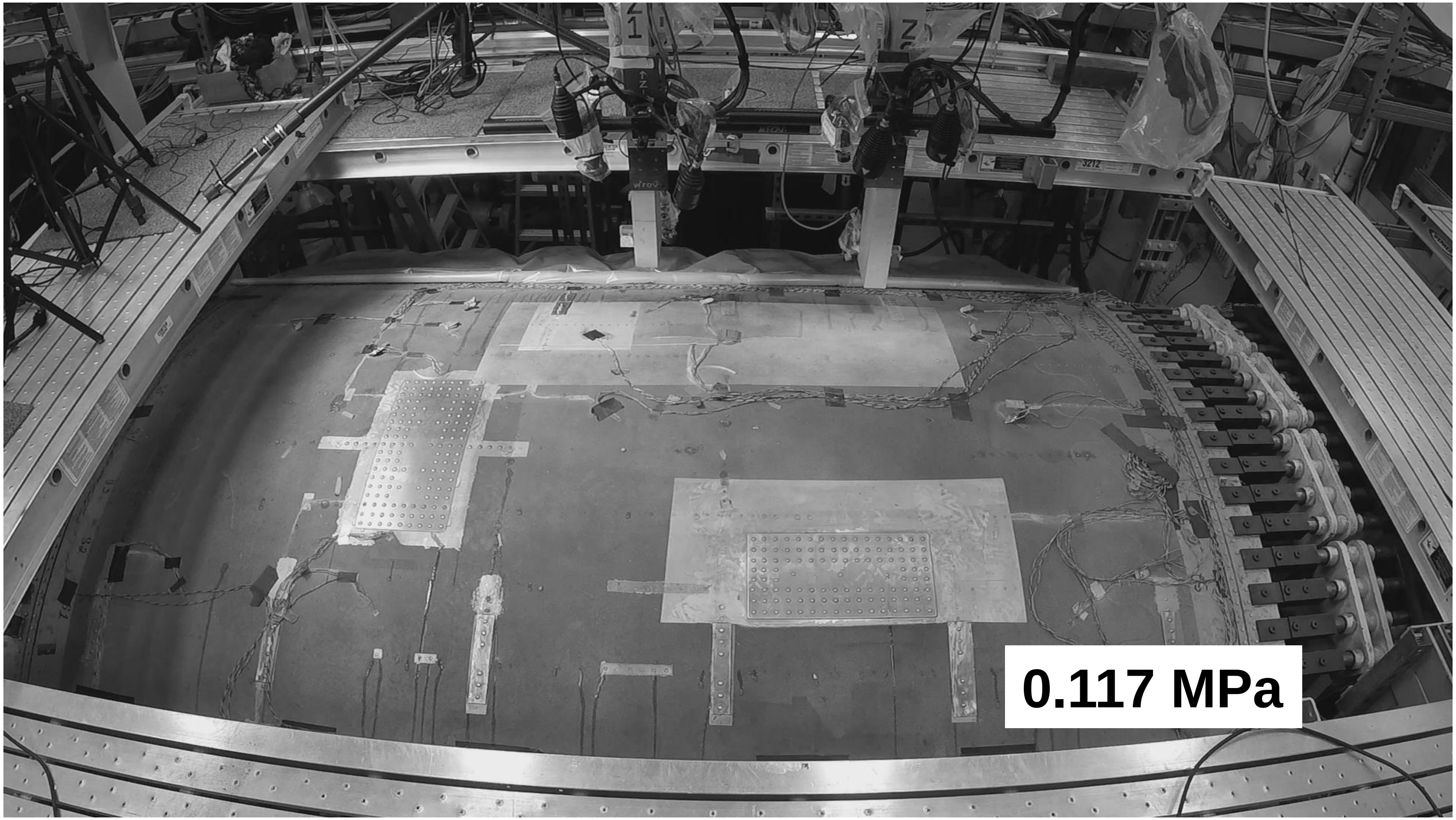
Maximum Load, 117 kPa



Unstable Tearing, 113 kPa



Phase 2 Residual Strength - Panel 1



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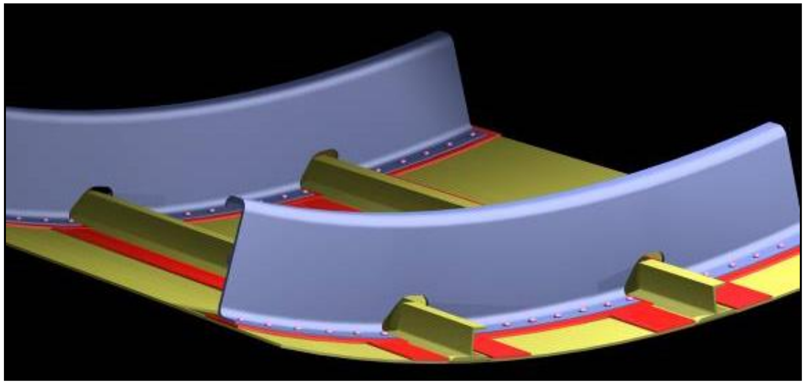
Summary

- Proactive government-industry partnership to understand potential fatigue and structural integrity issues associate emerging metallic structures technology (EMST)
- Obtain data to assess the damage tolerance of fuselage panels utilizing EMST through full-scale test and analysis
- Target Technologies:
  - Advanced alloys including next generation aluminum-lithium and clad aluminum
  - Hybrid structure including use of selective reinforcement with fiber-metal laminates
- Fuselage Panels 1 – 3: Advanced Alloys
  - Differences in panel skin dimensions inherent in manufacturing tolerances. Poses challenges for demonstrating performance difference between panels
  - Developed consistent approach to determine applied loads while accounting for varying thickness by keeping the same stress-intensity factors between panels
  - Demonstrated improvements in fatigue crack growth performance using EMST (advanced alloys) compared to baseline materials
  - Leveraged resources to assess SHM capability to detect and track skin cracks

Future Work

- Complete comparison of Phase 2 Longitudinal Crack Scenario for Panels 1 – 3.
- Fuselage Panels 4 and 5: FML reinforcement
  - Complete design concept and fabricate metallic fuselage panels reinforced with FML under substructure to demonstrate improved damage containment capabilities



FML reinforcement

Questions?

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