Effect of Barely Visible Impact Damage on Thermoplastic Welded Structure

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2026
Seattle Washington

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Conference & Exhibition

Welcome Slide – Introduce Yourself

Professionally

7 years at Spirit AeroSystems

Materials Engineer (PhD, University of Nottingham)

Team lead thermoplastic composites

Areas of interest: AFP, VBO, trade studies

- **Technical Theatre**

IATSE electrician, rigger, carpenter, Lighting Designer

Technical Director for Wichita Community Theatre

Scouting

Eagle Scout, Vigil Honor Member

Scoutmaster, Lodge Adviser

Camp Alaska Program Director, District Training Team

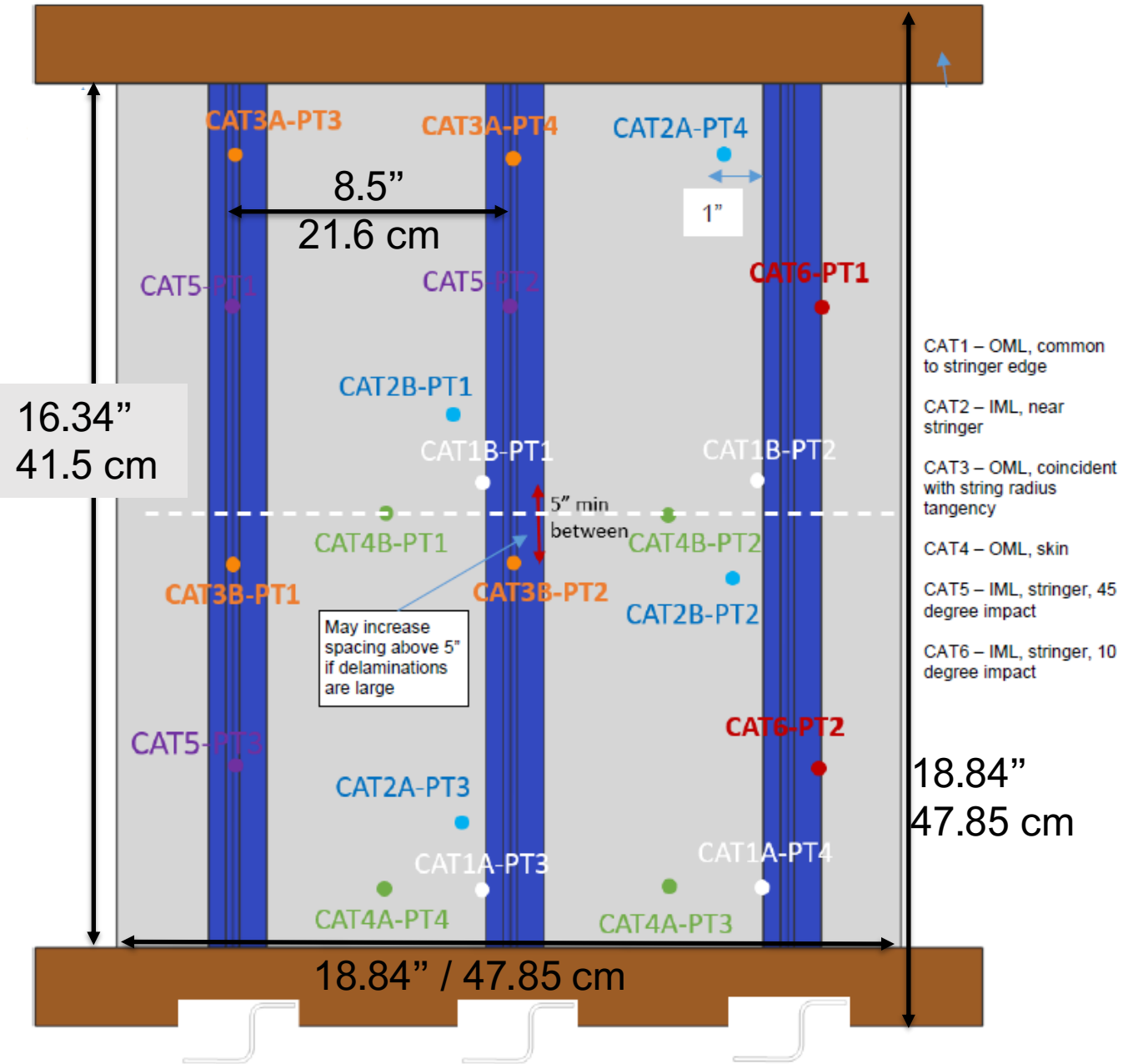


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Look Ahead

- Panel design
- Energy needed to create BVID
- Unique types of damage
- BVID+ CAI planning
- NDI
- Compression after Impact

Stiffened Panel Design

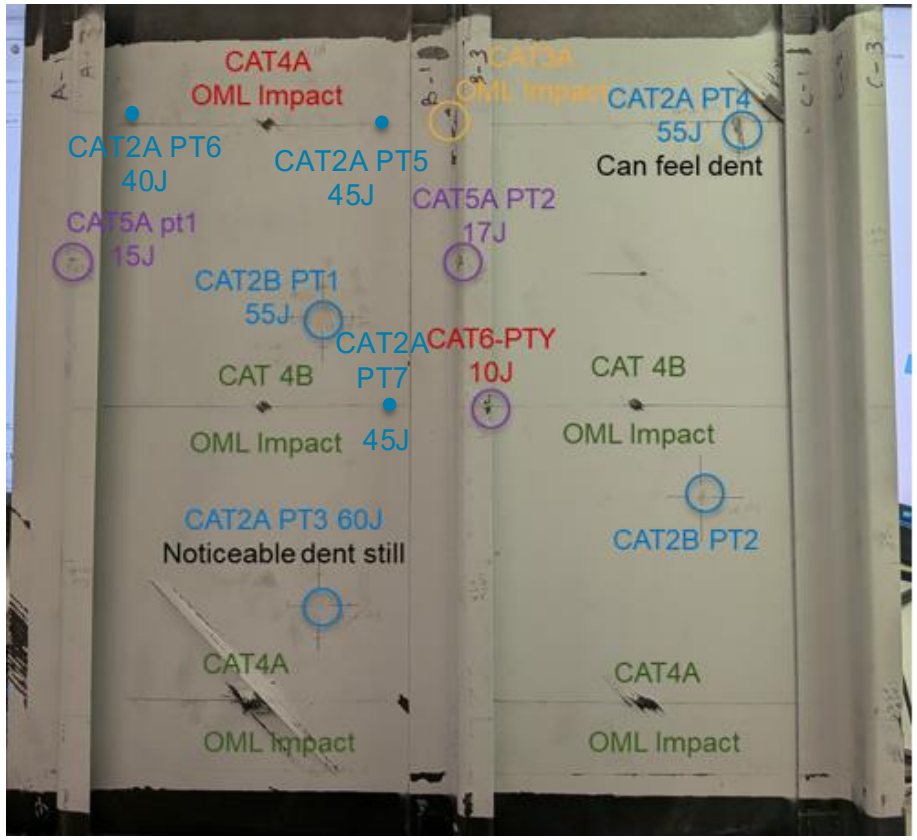


- 12 ply (0.066 in / 0.168 cm) skin and stringer
- Representative section in belly
- Zee shape for welding
- Things to study:
  - Stringer impact
  - Skin impact
  - Weld between skin & stringer
  - Influence of boundary conditions

- “CAT” is simply a naming convention within this project
- Instron Dynatup
  - 1” Hemispherical Indenter
  - Drop height used to set energy
  - Velocity of indenter measured
  - Mass of indenter: 14.92 lb or 13.74 lb
- Target dent depth: 0.01”

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Impact Energies



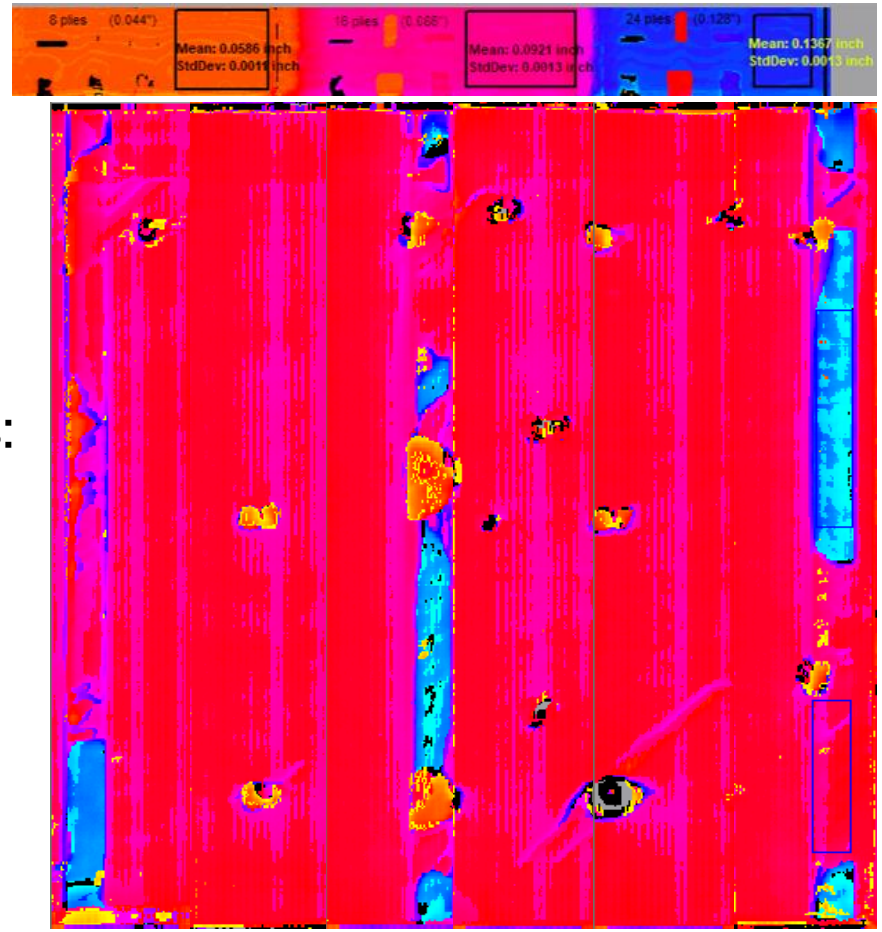
Mid-bay Impacts: ~55J

Near ‘Frame’ Impacts: ~55J

Near Stringer & Frame Impacts: 40J & 45J

Stringer Radius 45° Impacts: 15J-17J

Stringer Cap 10° Impact: 10J

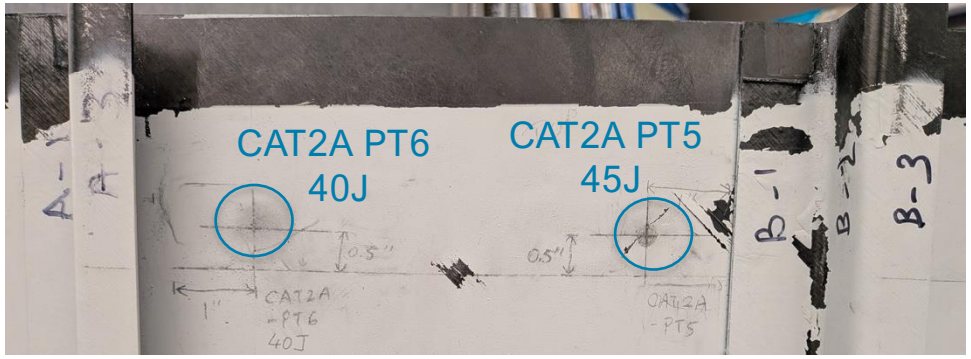


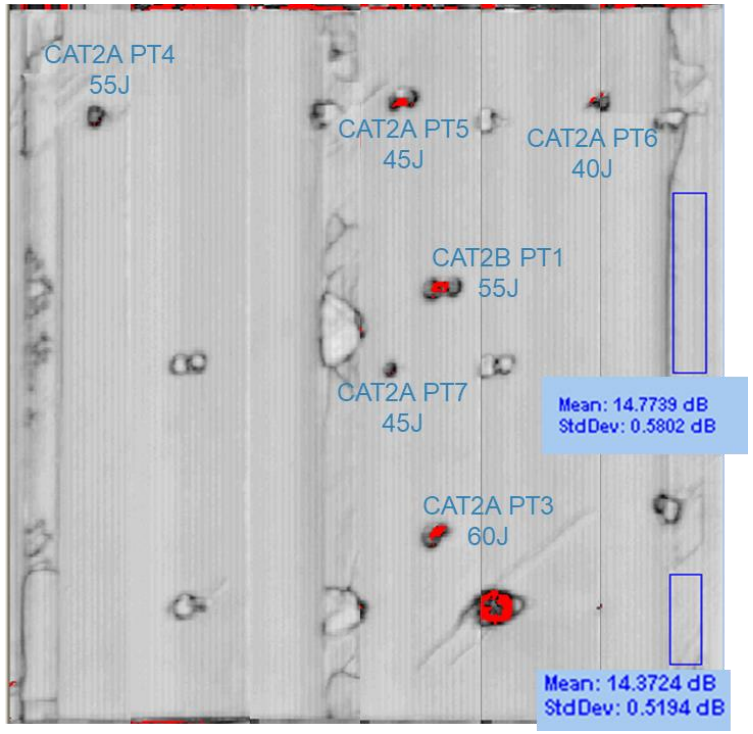
- NDI shows impacts did not create overlapping damage zones
- Time of flight data shows damage more clearly than amplitude data

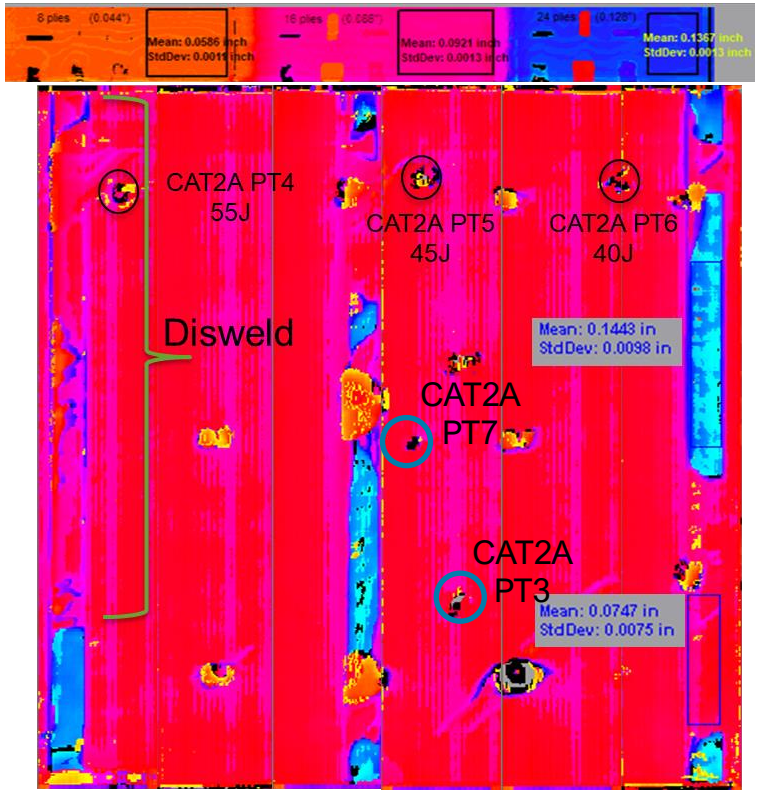
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Skin-Stringer Disweld Risk

Location Name	Impact Energy (J)	Dent Depth (inches)			
		Initial	24hr	48hr	2 weeks
CAT2A-PT3	60	0.0119	0.0106	0.0103	0.0117
CAT2A-PT4	55	0.007	0.0061	0.006	0.0069
CAT2A-PT5	45	0.0086	0.0085	0.0074	
CAT2A-PT6	40	0.0073	0.0072	0.0068	
CAT2A-PT7	45	0.0064	0.0057	0.0056	





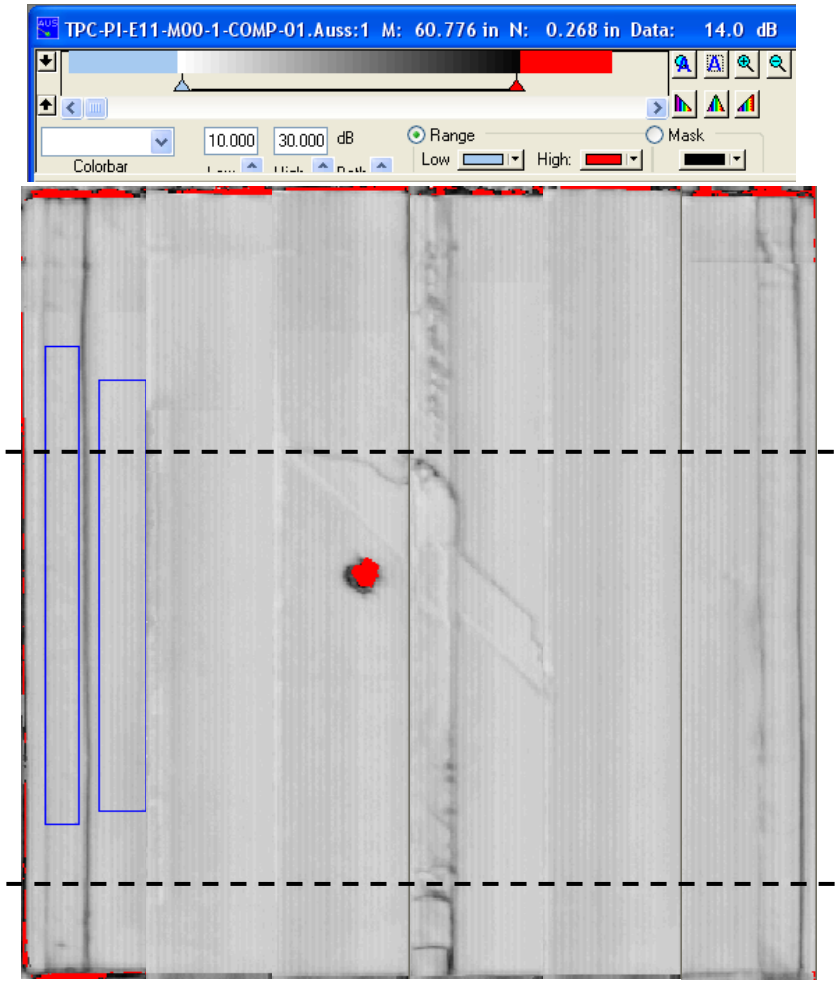


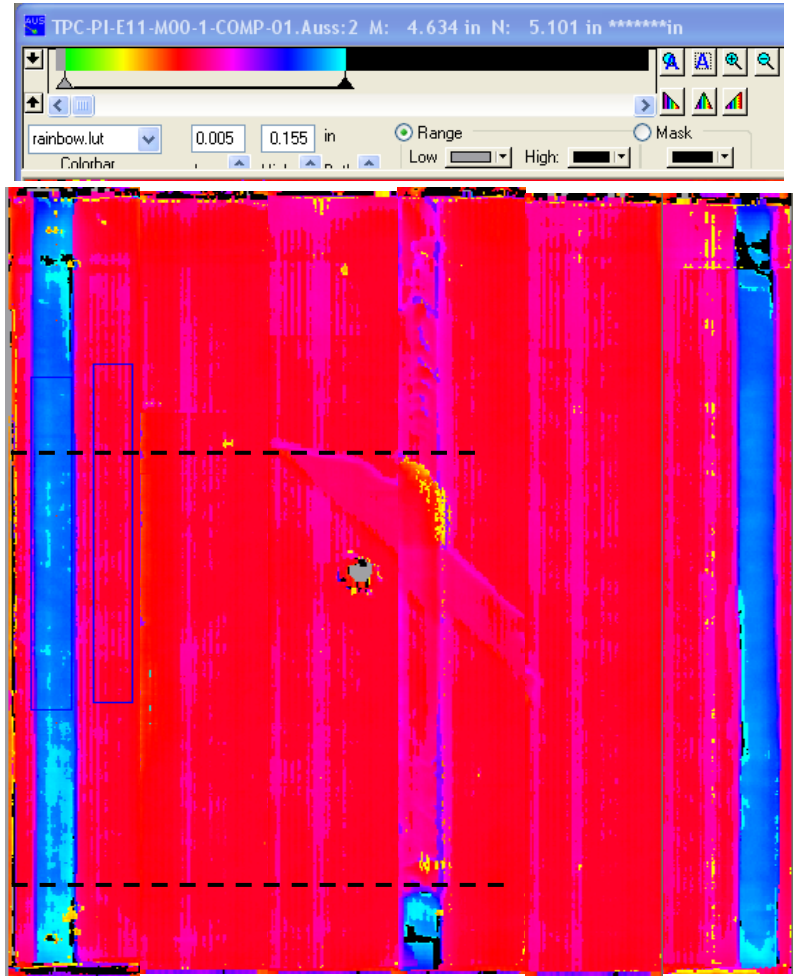
- CAT2 impact to the skin near the stringer flange may have caused stringer to disweld.
- Proximity to clamping frame likely to have exaggerated effect of PTs4-6
- CAT2 impact type caried forward to residual strength testing
  - Center stringer, mid-bay
  - 75J; maintain dent depth after relaxation, account for lower stiffness location

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BVID Residual Strength COMP-01



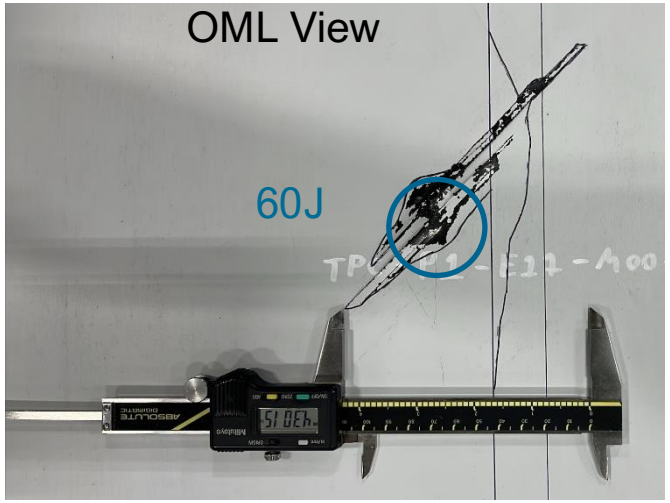




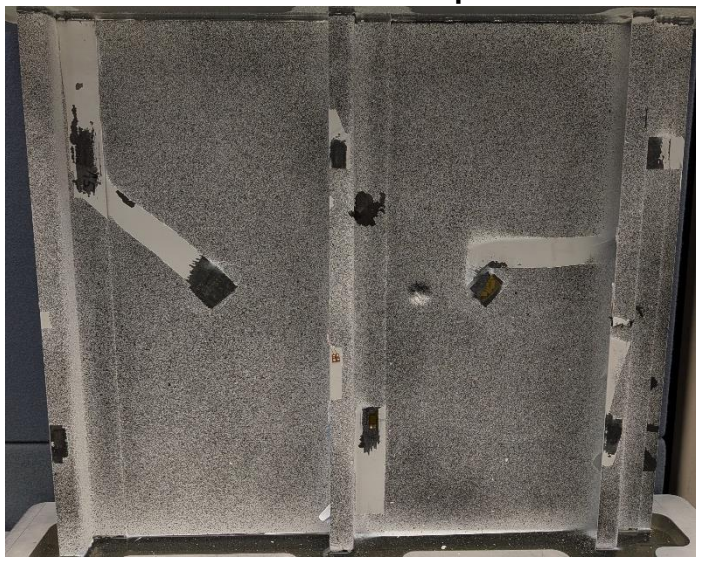
Substantial cracking in paint. Diswelded most of center stringer
More damage than intended

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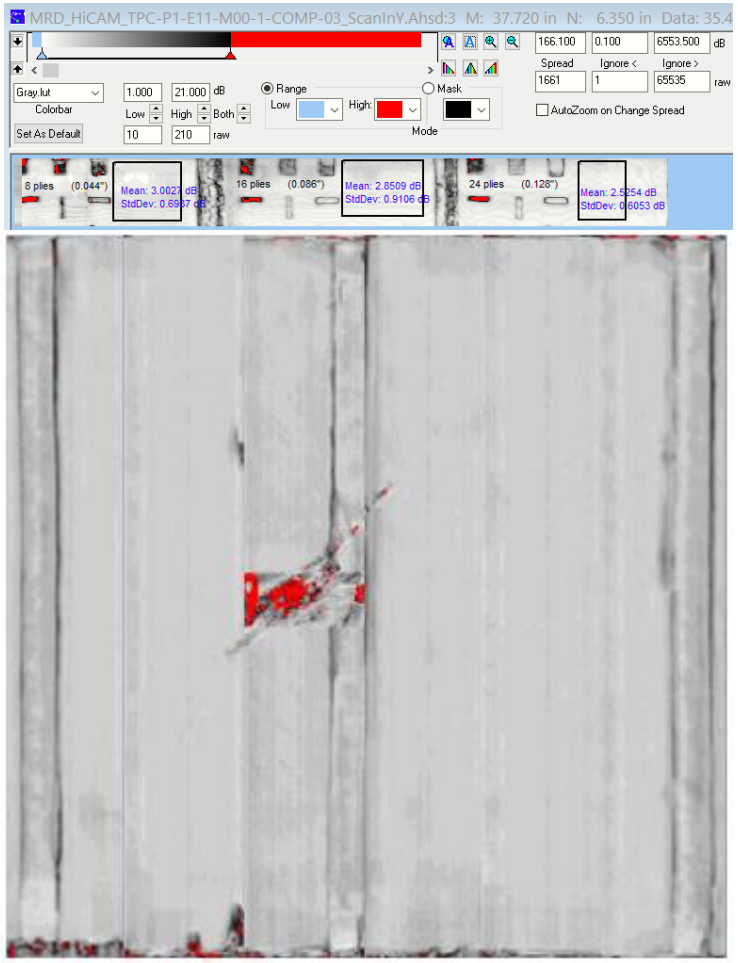
BVID Residual Strength COMP-03

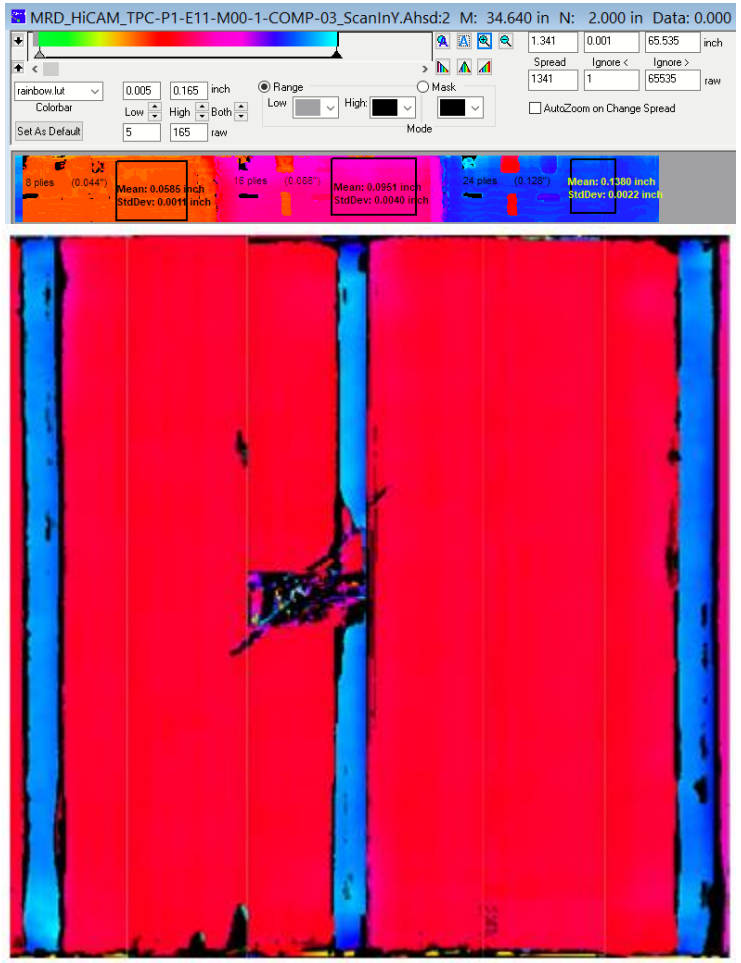


Dent size & shape



IML View

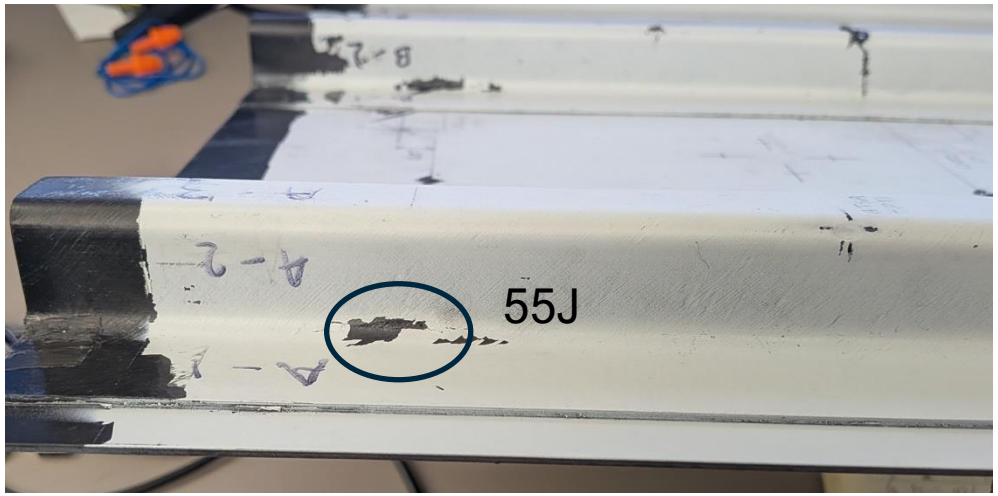




- 60J still produced visible impact damage
- Smaller length of disweld
- Fiber splitting confirmed with NDI

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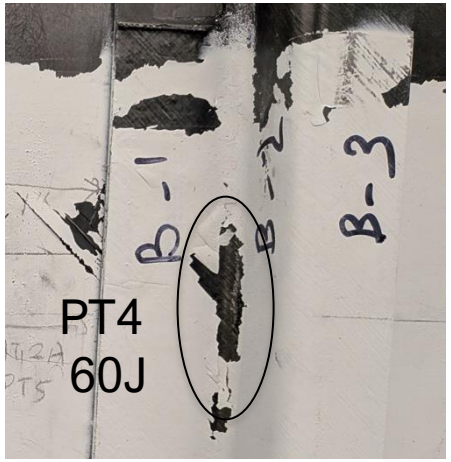
Stringer Damage Risk

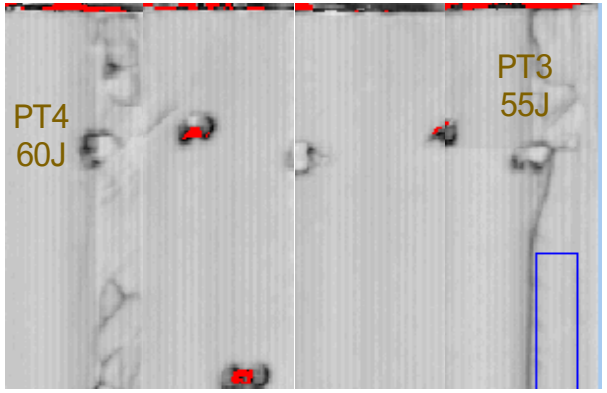


impact: OML coincident with stringer radius

		Dent Depth (inches)			
Location Name	Impact Energy (J)	Initial	24hr	48hr	2 weeks
PT3	55	0.008	0.0064	0.0064	0.0072
PT4	60	0.0096	0.0091	0.0081	0.0118



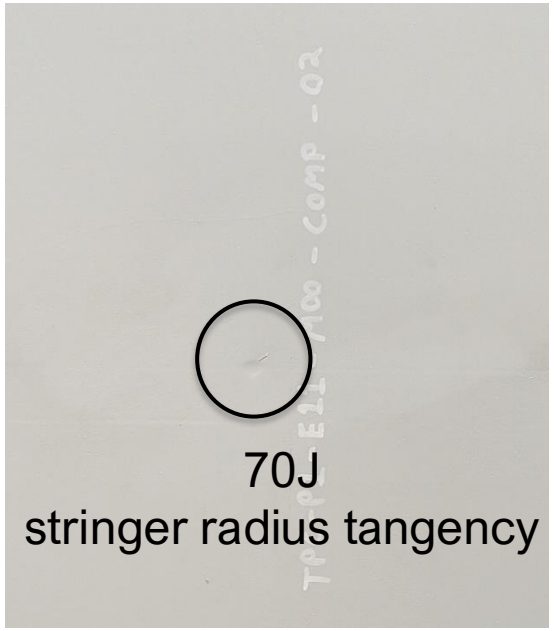


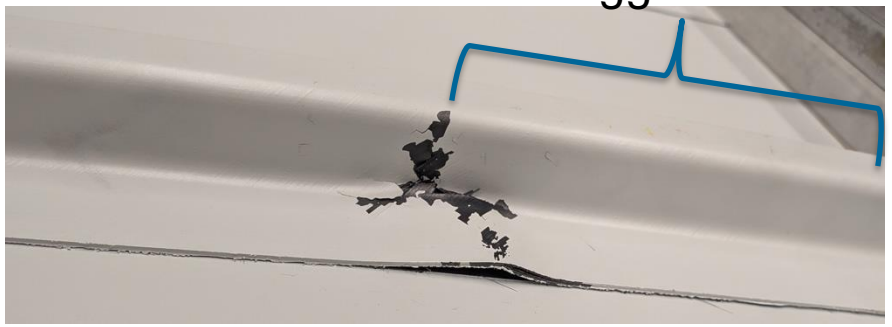


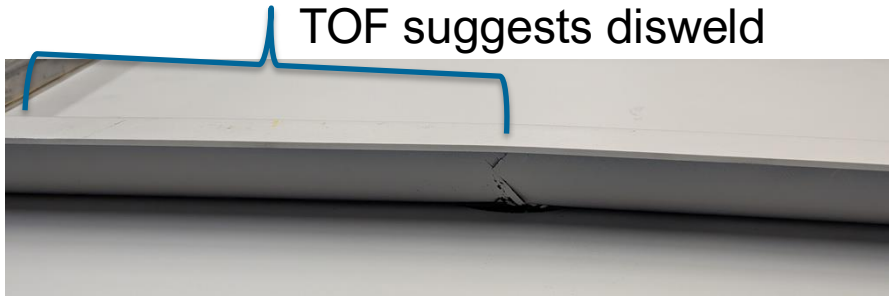
- OML impact caused possible fiber damage on the stringer
- NDI shows minimal damage than can be attributed impact
- Shallow dent depths
- Use COMP-02 to test if fiber cracking in stringer will occur on a new panel
  - Energy level increase proposed to get deeper dents

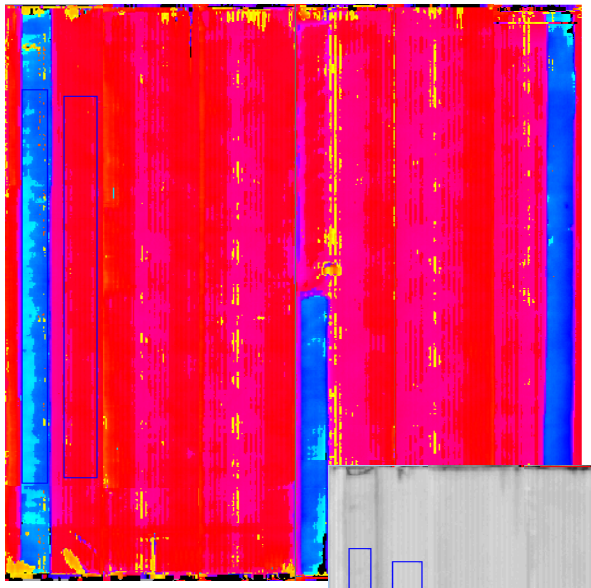
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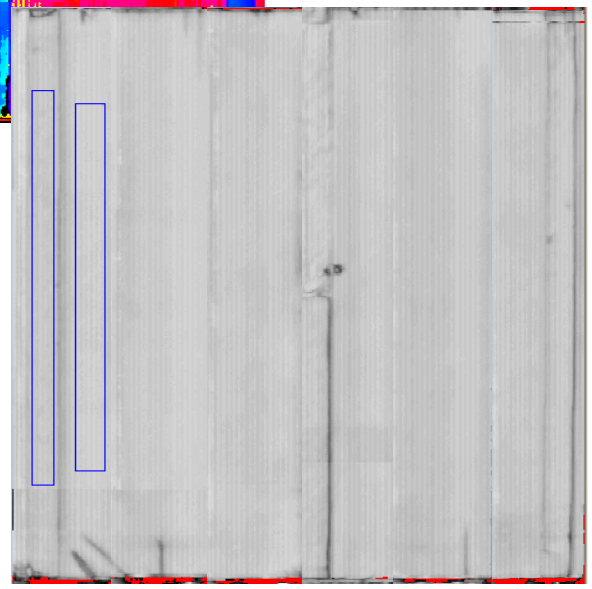
BVID Residual Strength COMP-02







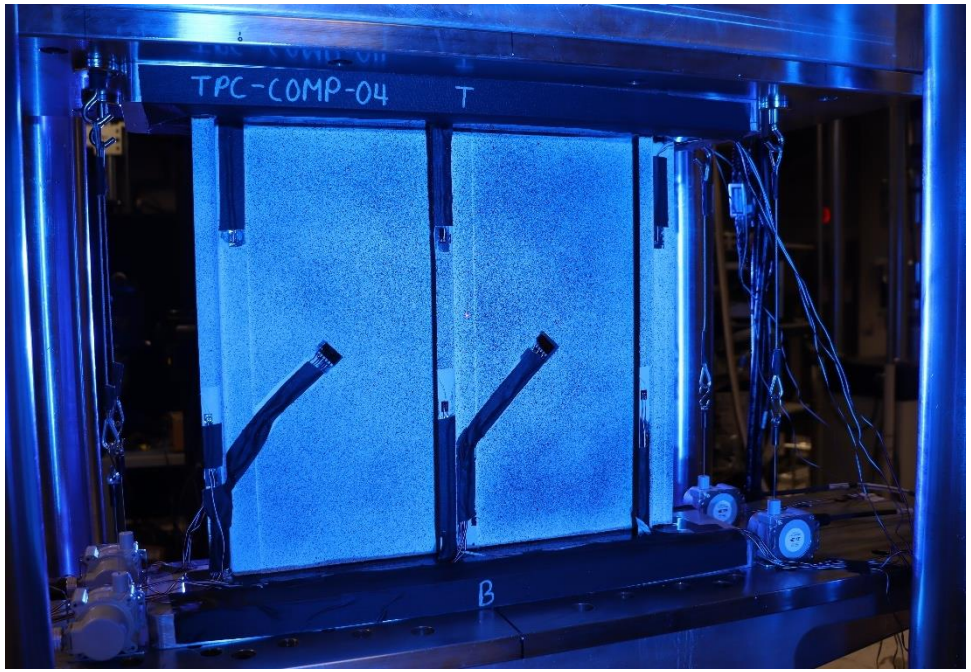




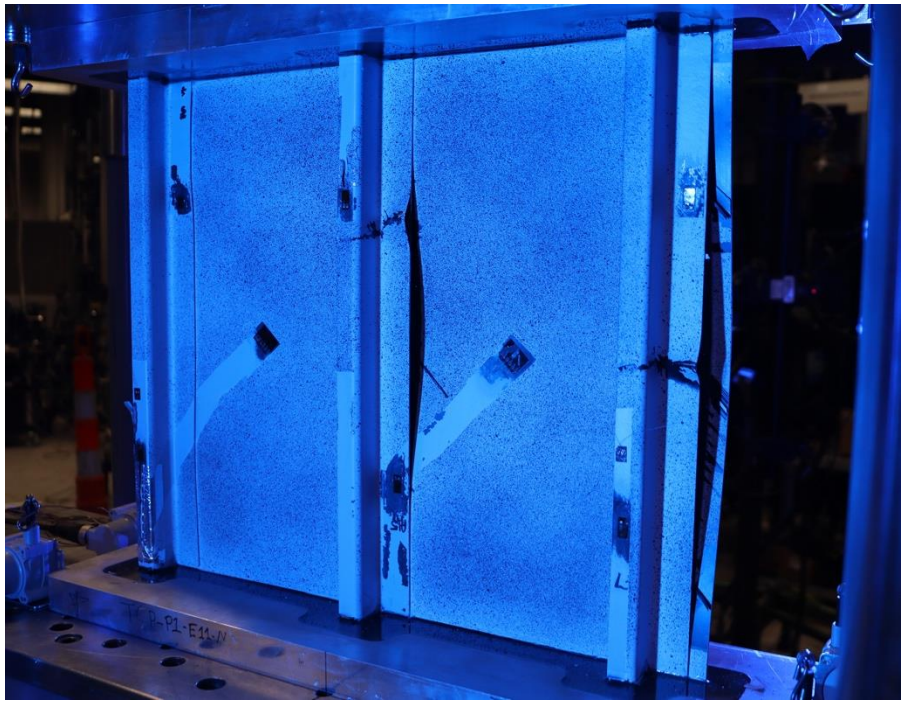
- Fiber cracking in flange and web of stringer
- NDI shows almost no damage on amplitude scan
- Time of flight (TOF) clearly shows half of stringer diswelded

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Residual Compression Strength Testing

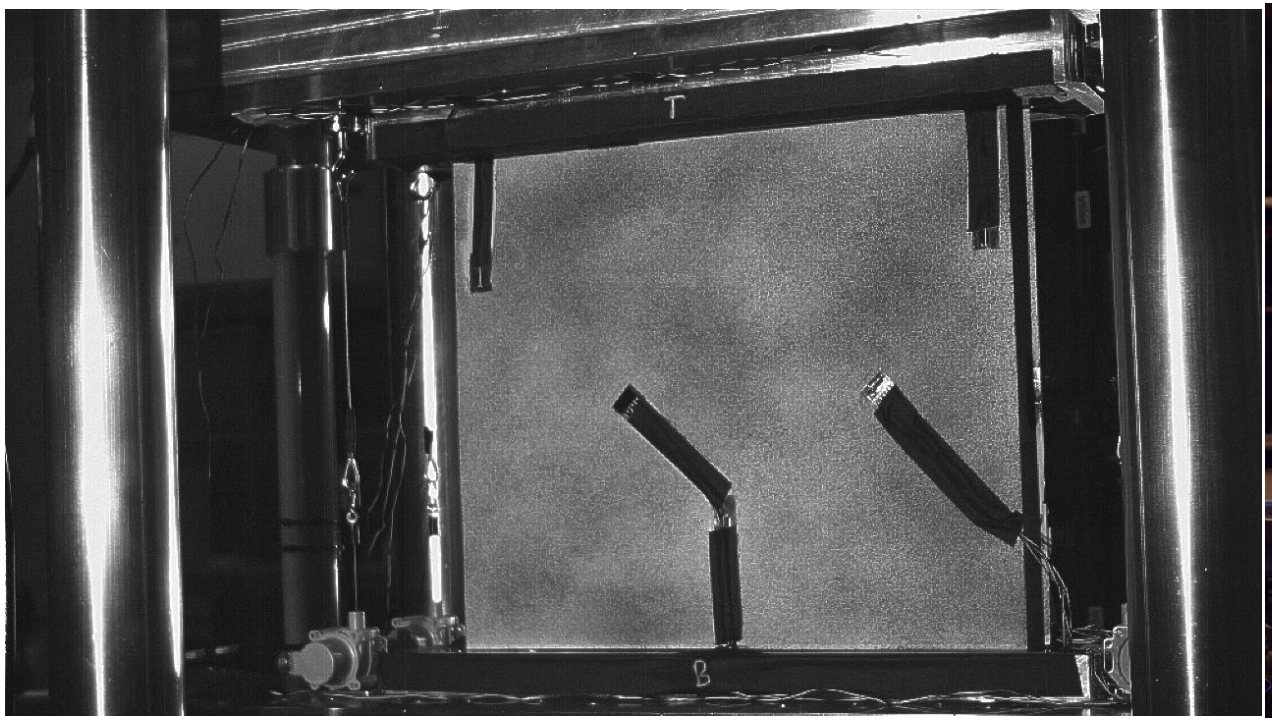


- 16 strain gauge locations
- High speed video
- 2 camera DIC
- High definition video
- Record load for 1st audible crack
- Record failure load

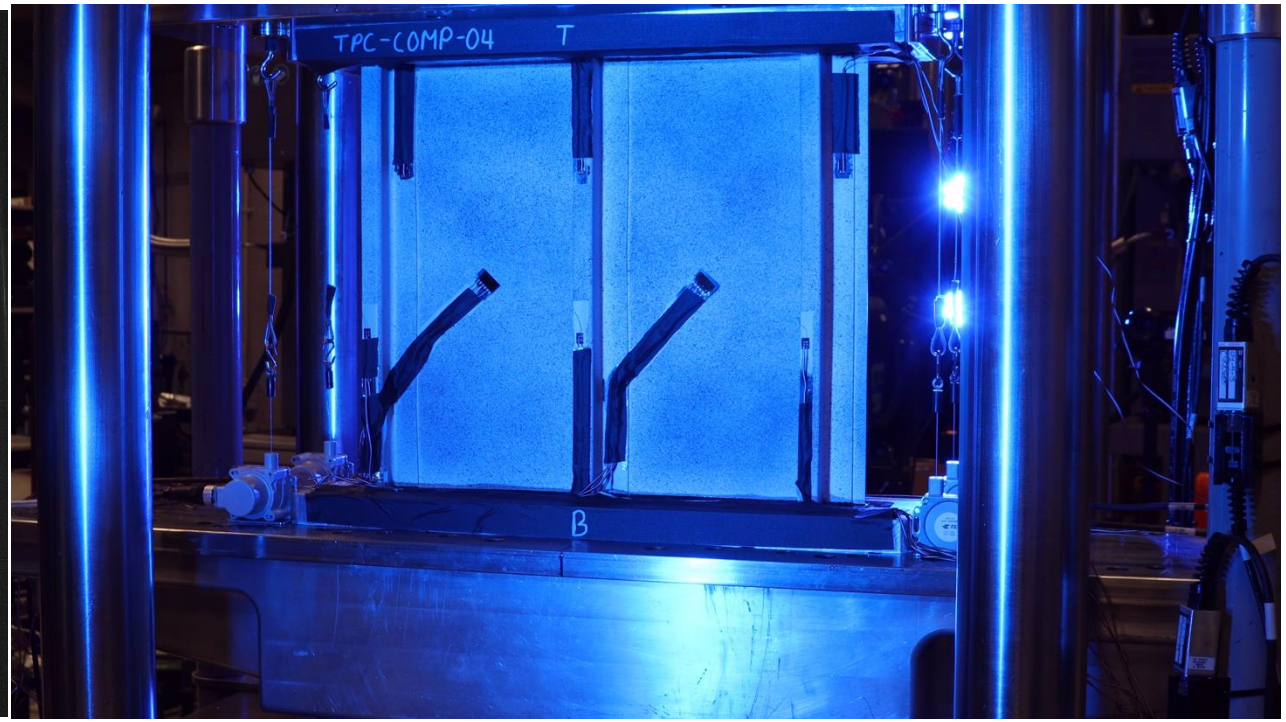


- Failure due to skin buckling followed by stringer crippling
- Pristine panel failure load 28,845 lbf

Video of Failure



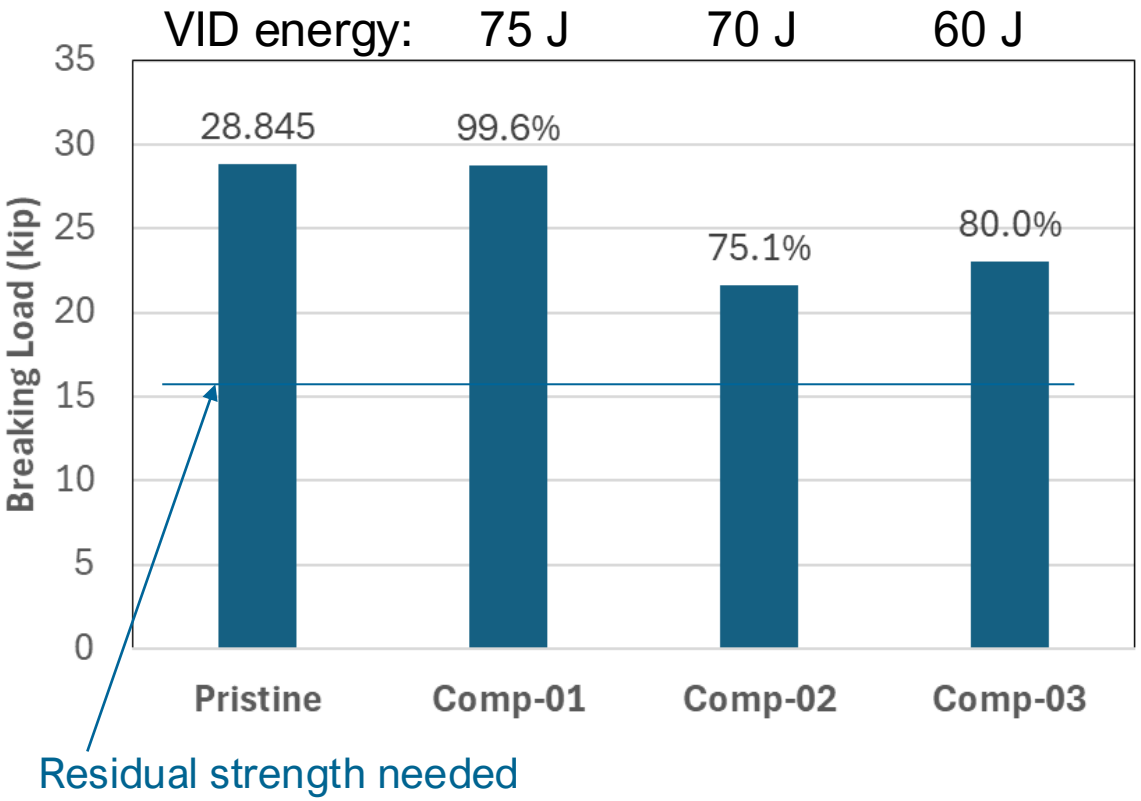
High Speed

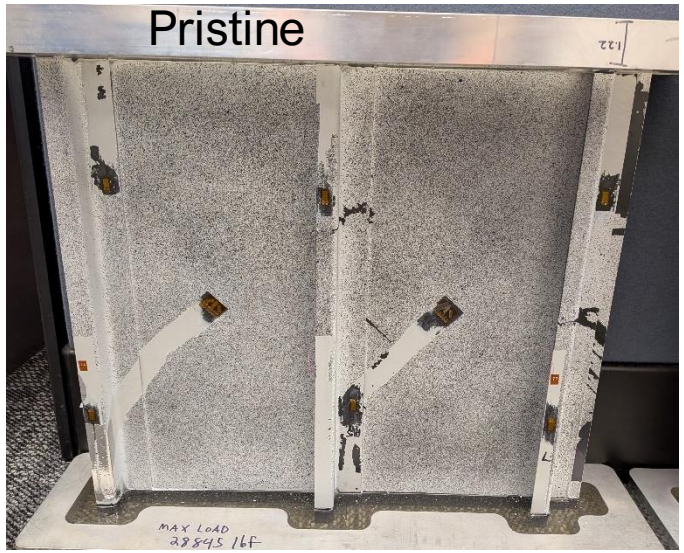


High Resolution

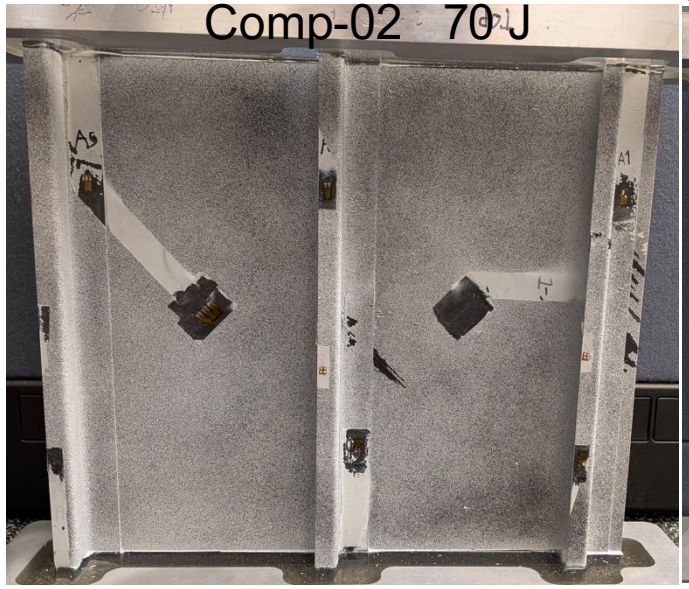
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Residual Strength











Damage tolerance requirements (from FARs) require damaged structure to support ultimate load.

- All panels meet residual strength requirements
- Damage level is beyond BVID
- Strength more dependent on how/where damage occurred rather than impact energy

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Residual Strength Analysis

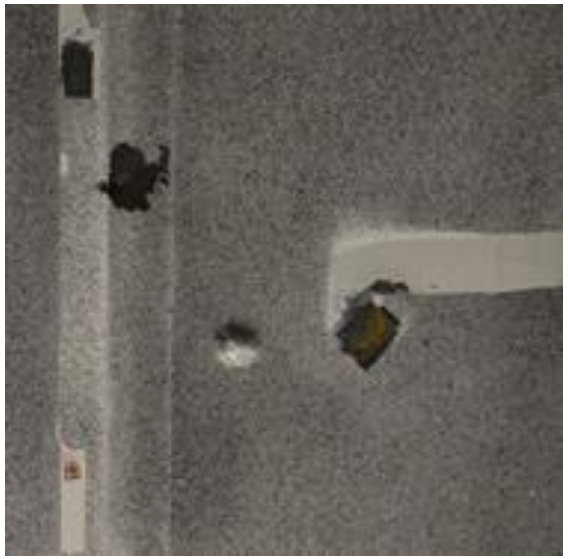
COMP-01

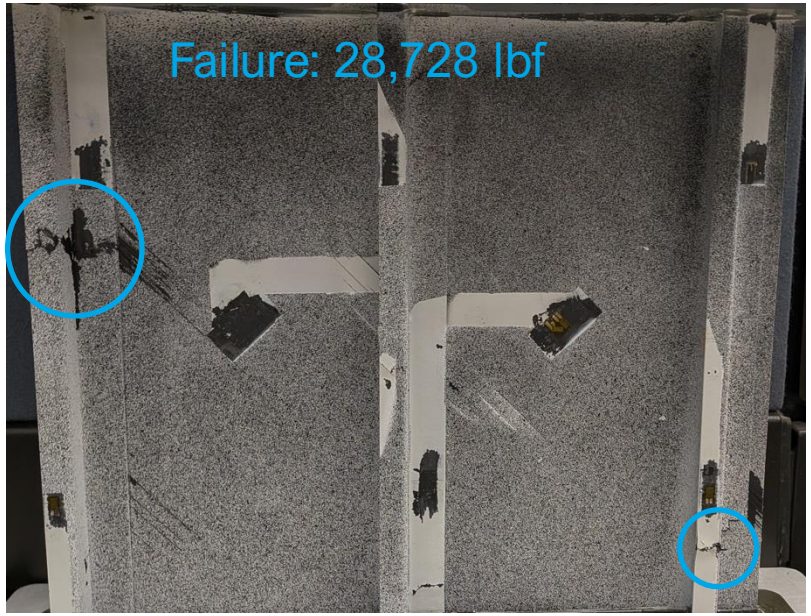


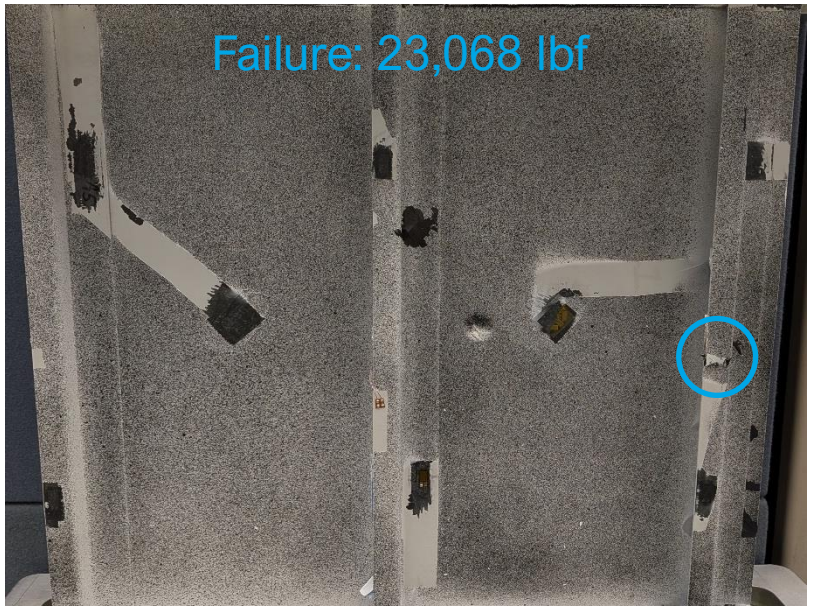
COMP-01
- Fiber splitting in skin
- Long disweld of stringer
- Stringers 1 & 3 cracked at failure

COMP-03
- Deep dent in skin
- Short disweld length
- Possible damage to stringer 2
- Only stringer 3 cracked at failure

COMP-03







Hypothesis

1. After skin buckles stringers as column elements still carry significant loads
2. After VID, stringers in COMP-01 undamaged. Load supported evenly
3. COMP-03 stringer 2 damaged, stringer 3 loaded more heavily
4. COMP-02 stringer 2 most heavily damaged

Therefore
Max load COMP-01 > COMP-03 > COMP-02

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- Michel Van Tooren & Andre DeJesus, Collins

For test plan development

Questions

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