



JAMS

FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES

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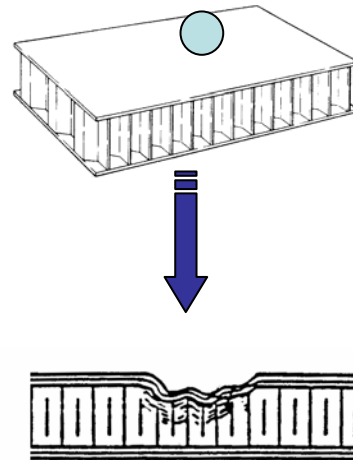
The Joint Advanced Materials and Structures Center of Excellence

FAA Sponsored Project Information

- Principal Investigators & Researchers
 - J.S. Tomblin
 - K.S. Raju, J. Dietiker, J.F. Acosta
 - J. Bakuckas
- FAA Technical Monitor
 - P. Shyprykevich
- Other FAA Personnel Involved
 - C. Davis
 - F. Leone
- Industry Participation
 - Adam Aircraft Co.(P. Harter, B. Allbritten)
 - Toray Composites (L. Cook)
 - NSE Composites (T. Walker)
 - Hostert Technical Services (R. Hostert)

Background

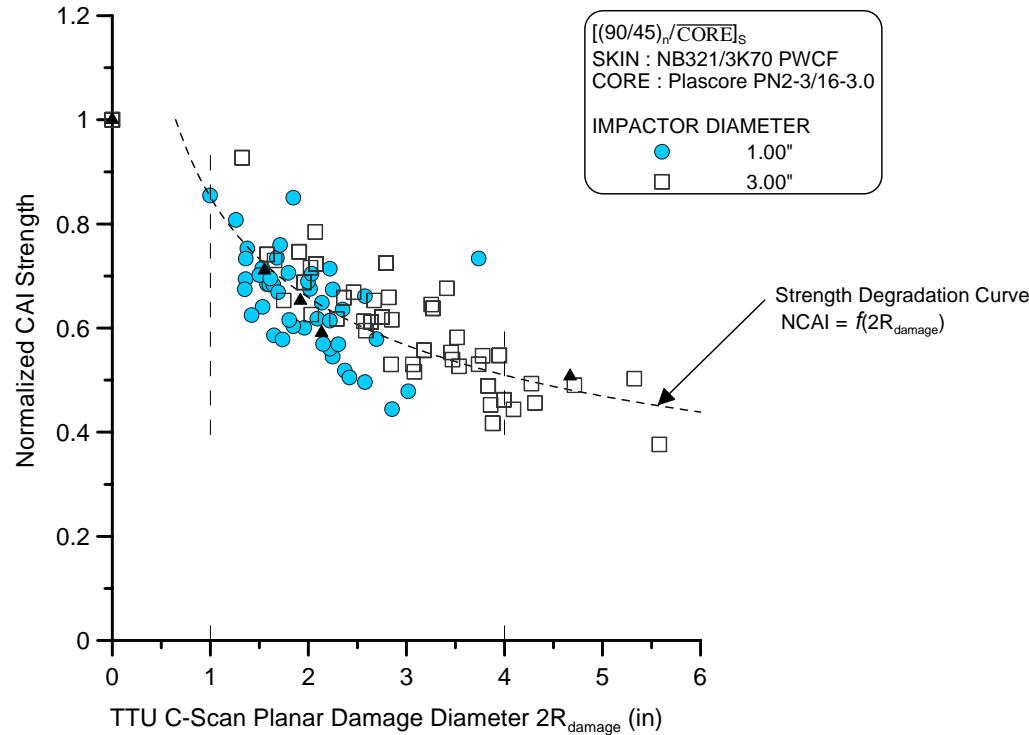
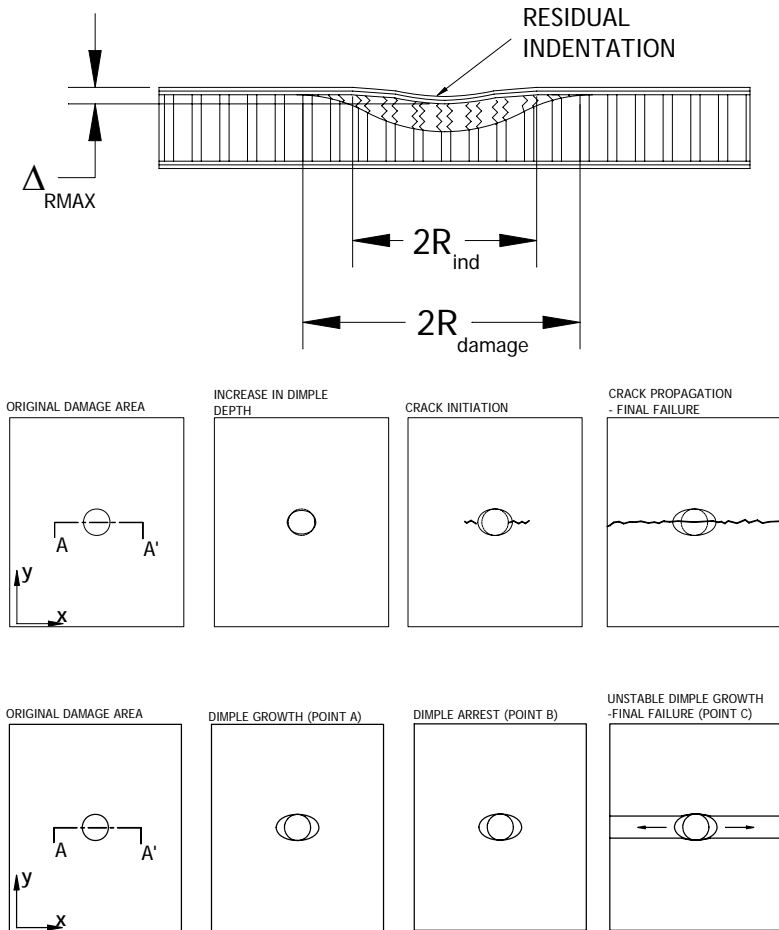
- Literature Review
- Experimental Investigation of Damage Resistance & Tolerance
- NDI Techniques, Curvature effects, Fatigue
- Design of experiments, CAI modeling
- Scaling effects
- Open-Hole Testing
- Independent Review



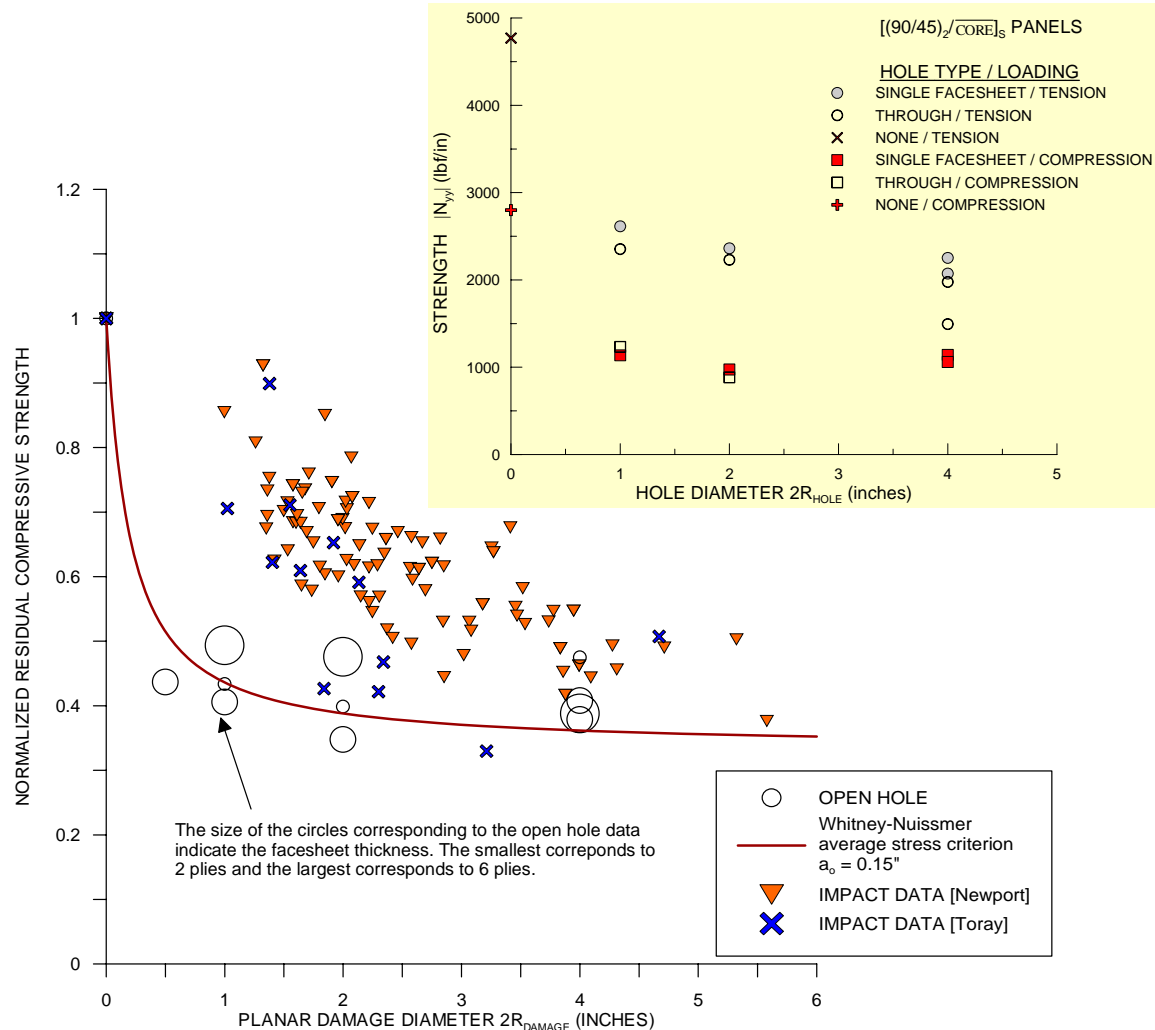
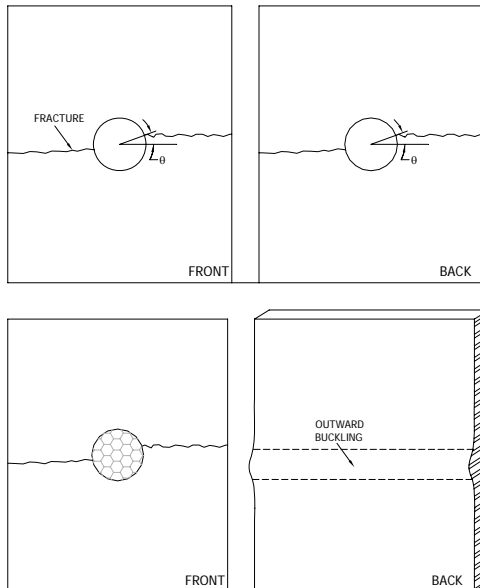
- REPORTS-
- DOT/FAA/AR-99/49, 1999
 - DOT/FAA/AR-00/44, 2001
 - DOT/FAA/AR-02/80, 2002
 - DOT/FAA/AR-02/121, 2003
 - DOT/FAA/AR-03/75, 2004
 - DOT/FAA/AR-0?/??, 2005



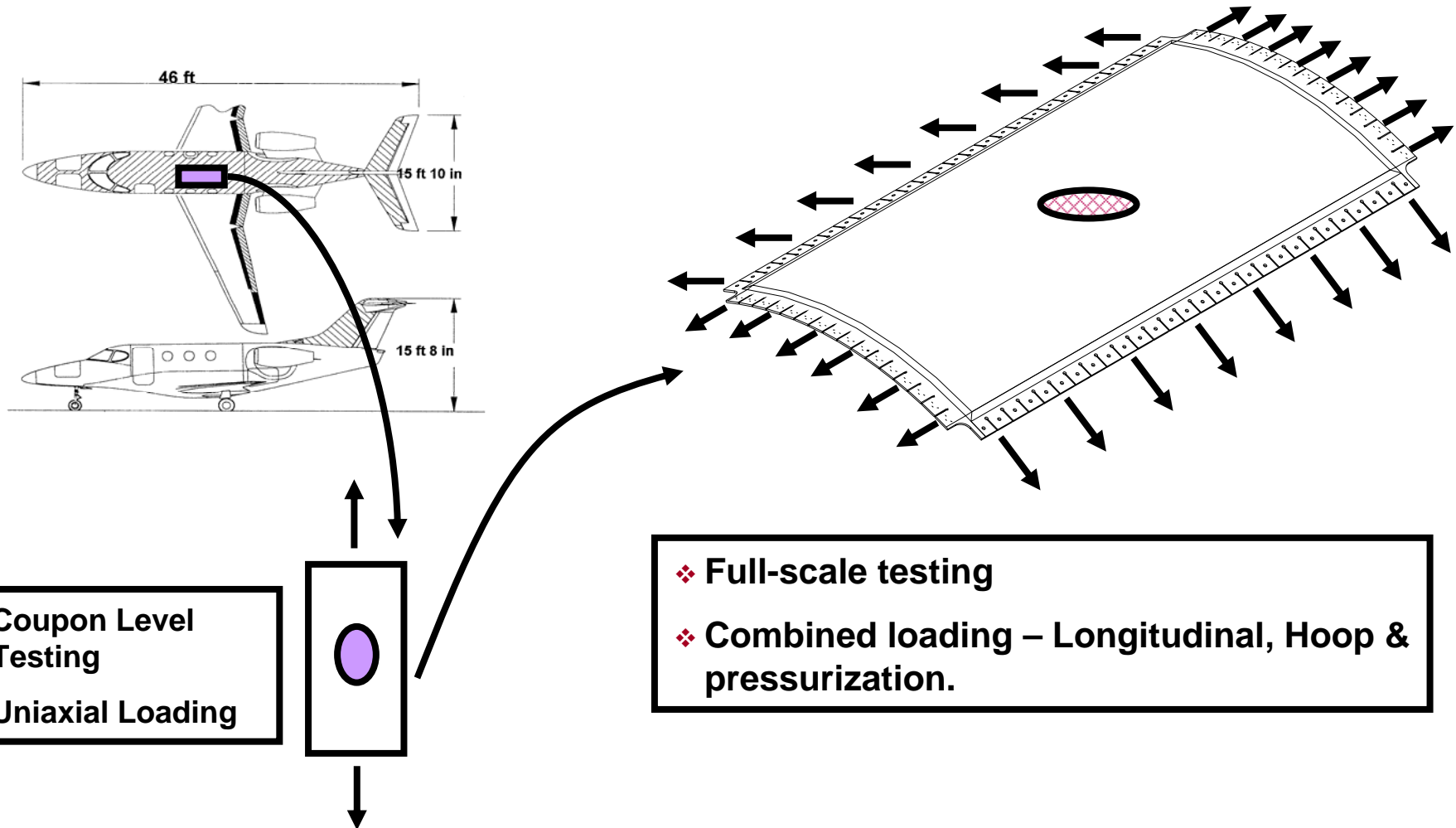
FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



- **Critical Damage States**
 - **IMPACT DAMAGE** – Load transfer through damage region
 - **OPEN HOLE** – No load transfer through damage region



FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES



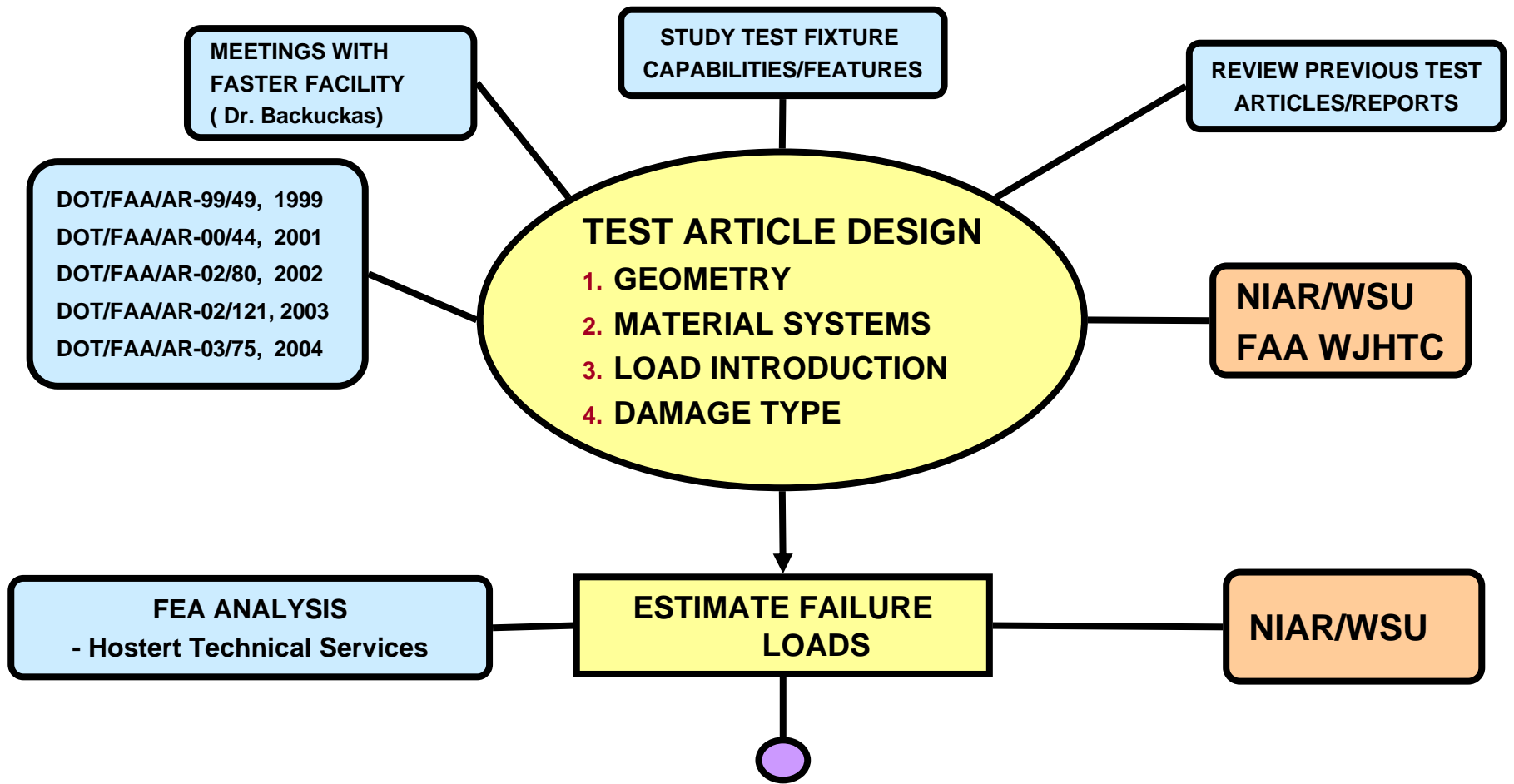
- ❖ Coupon Level Testing
- ❖ Uniaxial Loading

- ❖ Full-scale testing
- ❖ Combined loading – Longitudinal, Hoop & pressurization.

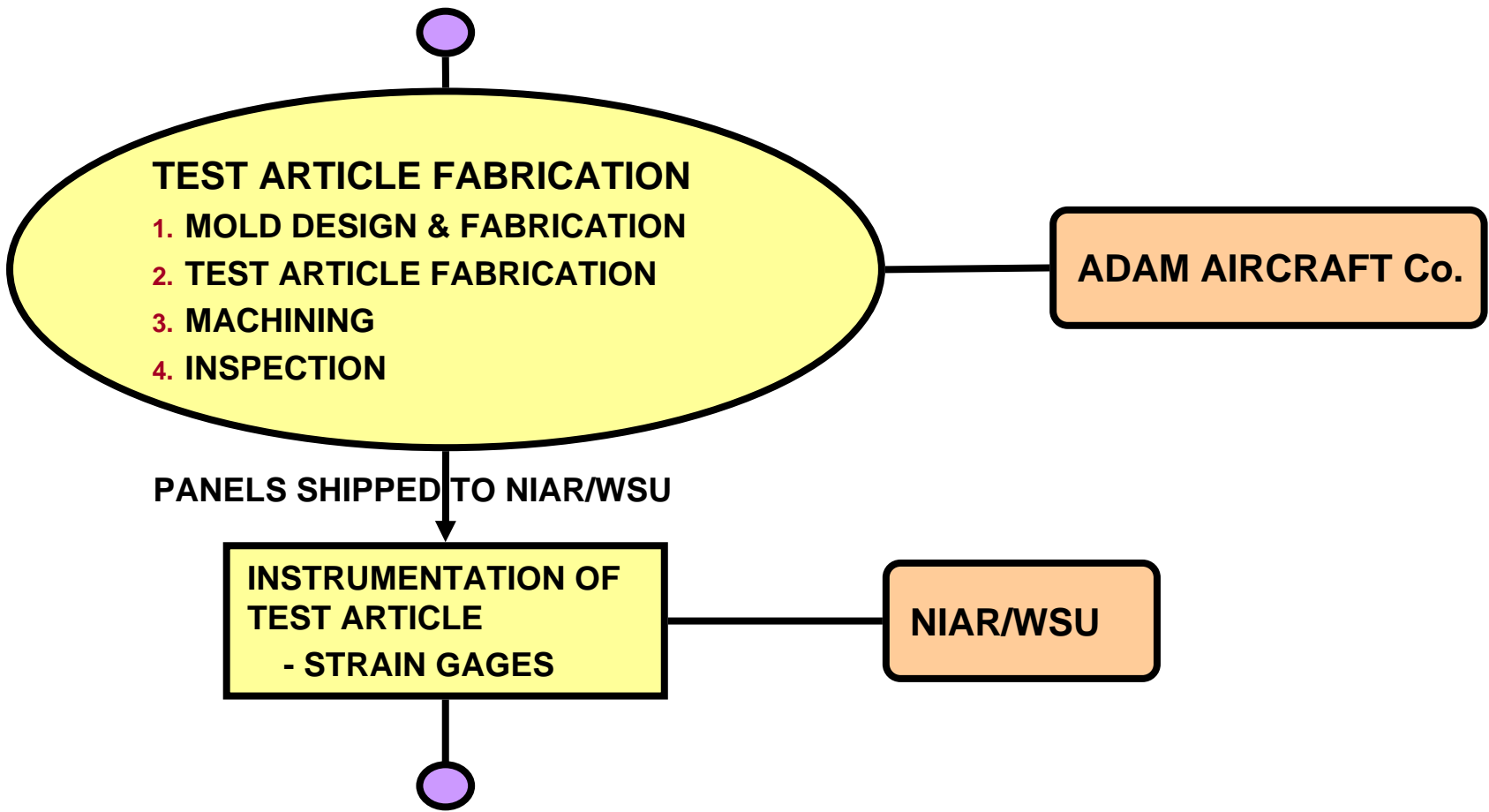
FULL-SCALE DAMAGE TOLERANCE OF COMPOSITE SANDWICH STRUCTURES

- Objectives
 - Design, fabrication & Testing of sandwich test article(s) under combined loading at WJHTC test facility
 - Material Systems & Sandwich Configuration
 - Geometry
 - Load-introduction
 - Attachments, etc.
 - Damage configurations – notches, holes, impact damage, etc..
 - Instrumentation
 - Loading Scenarios
 - Failure load predictions
 - Testing

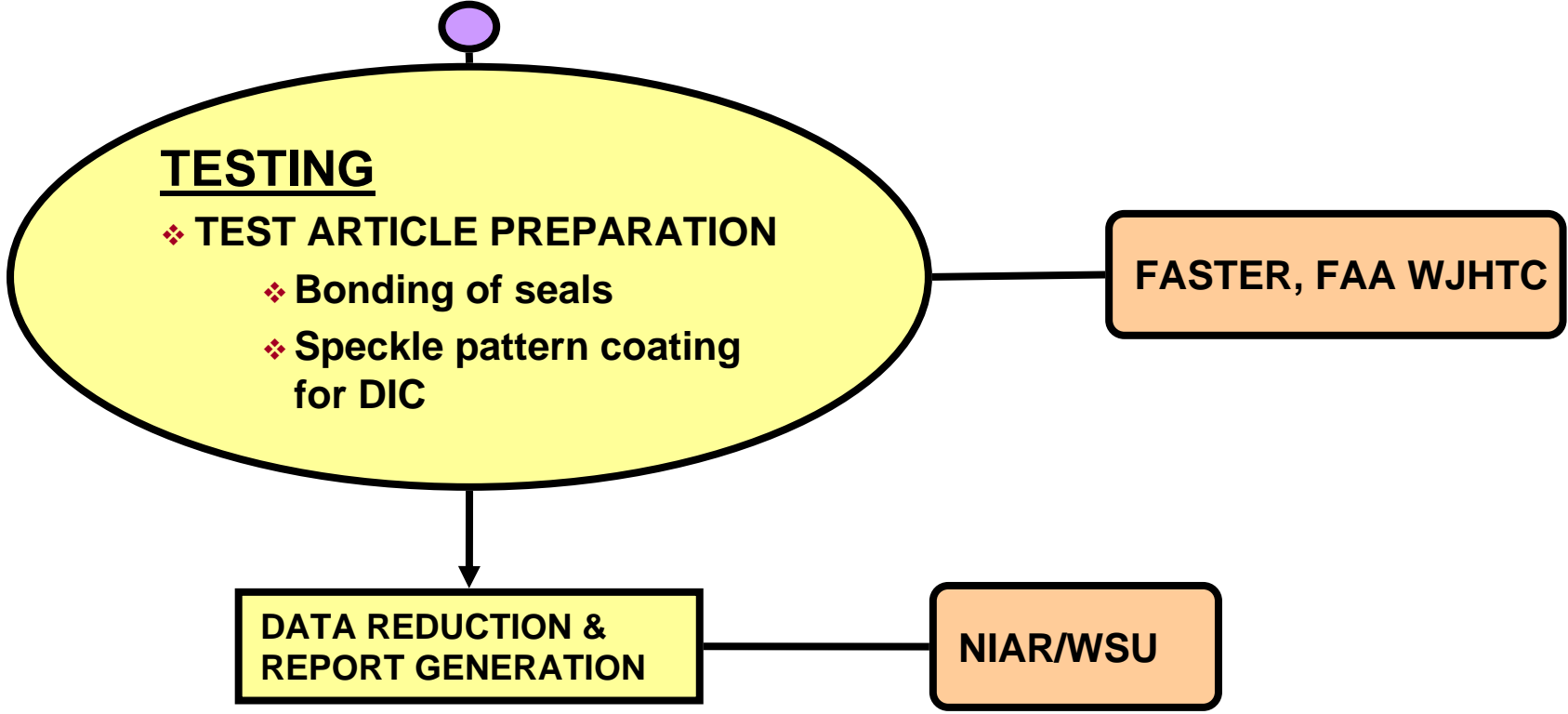
APPROACH

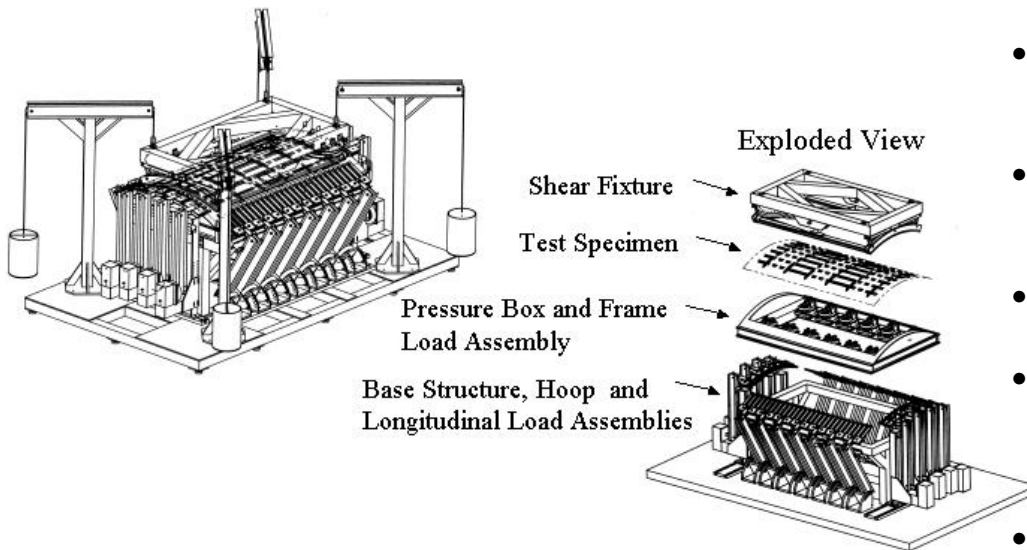


APPROACH



APPROACH



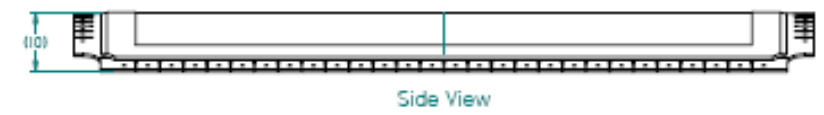
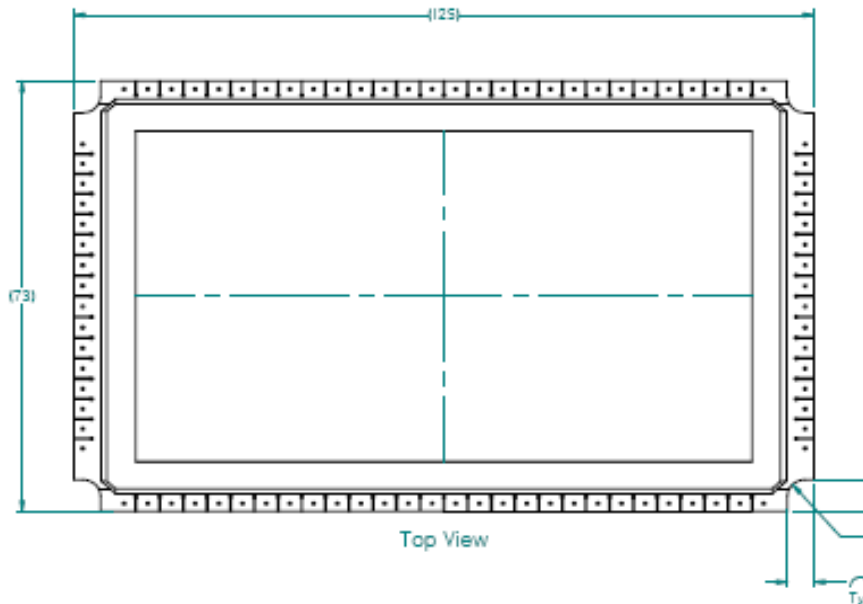


TEST FIXTURE SPECIFICATIONS^{Ref}

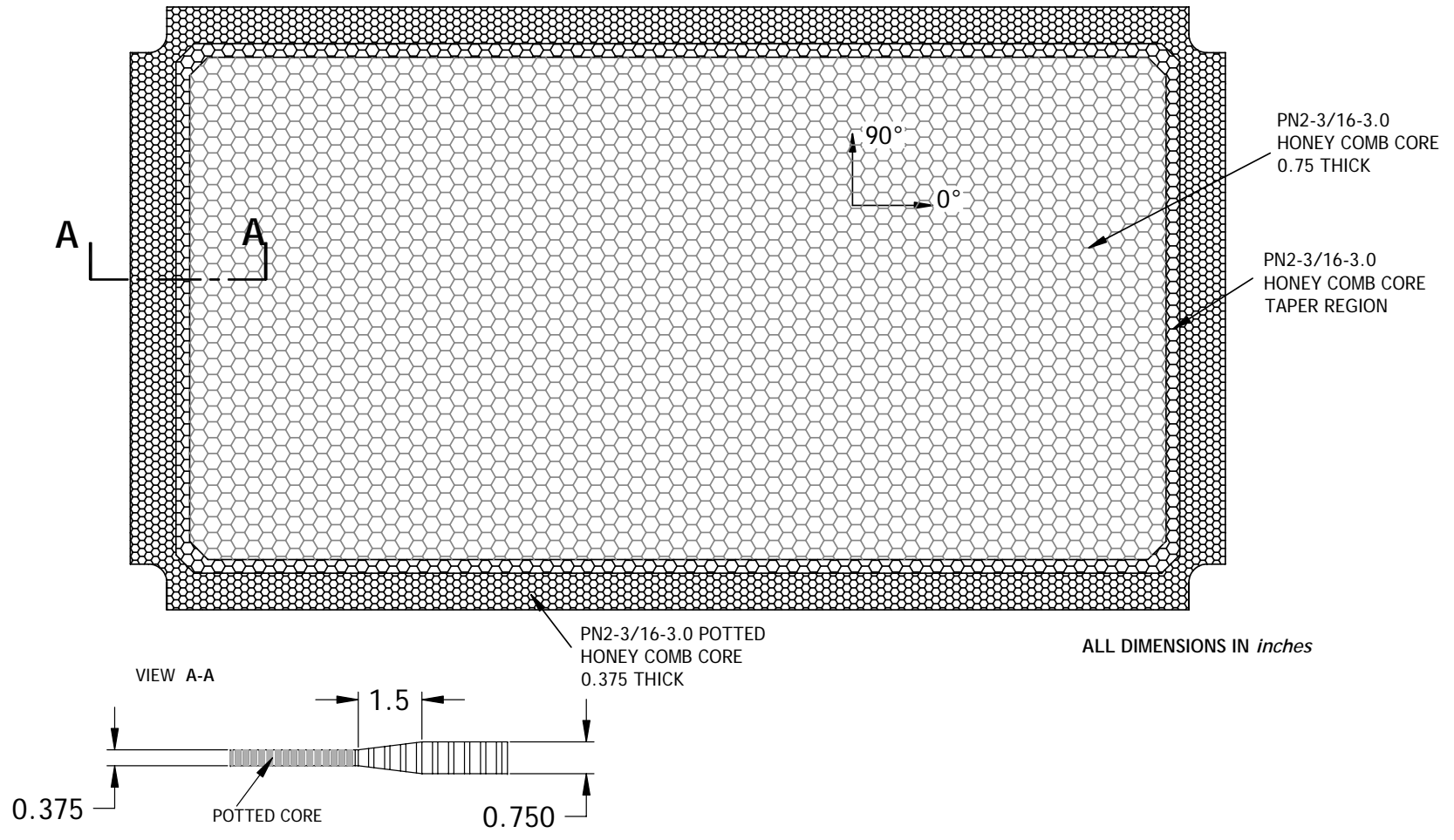
- **Longitudinal loading**
 - 1800 lbf/in
 - 16 load introduction points
- **Circumferential (Reactive) loading**
 - 1800 lbf/in
 - 28 load introduction points
- **Frame Loads**
 - 360 lbf/in
- **Pressurization loading**
 - 15 psi
 - Water / Air
- **SPECIMEN GEOMETRY**
 - Radius : 60 – 130 inches (**** 74 inches**)
 - Length : 120 inches
 - Width : 68 inches

Ref. John Bakuckas, "Full-Scale Testing and Analysis of Fuselage Structure containing Multiple Cracks," DOT/FAA/AR-01/46.

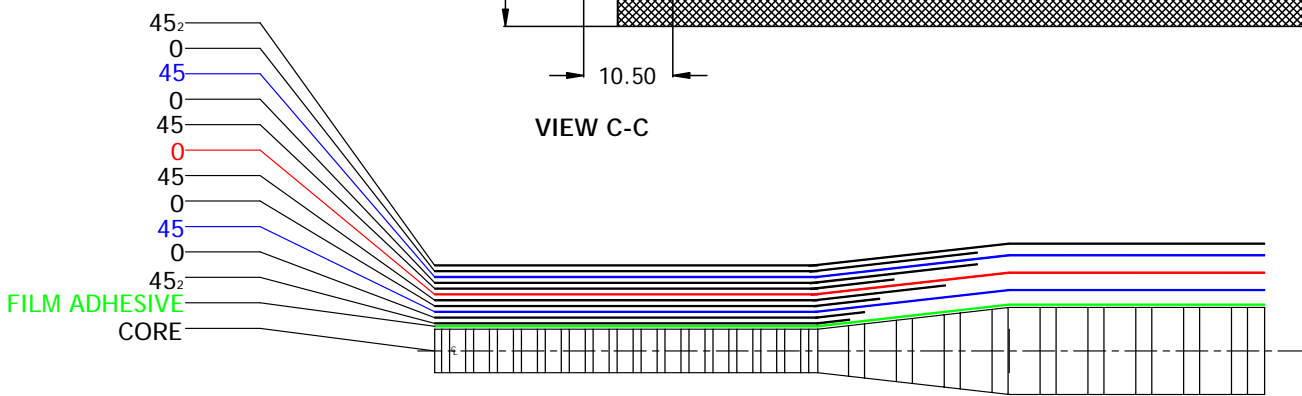
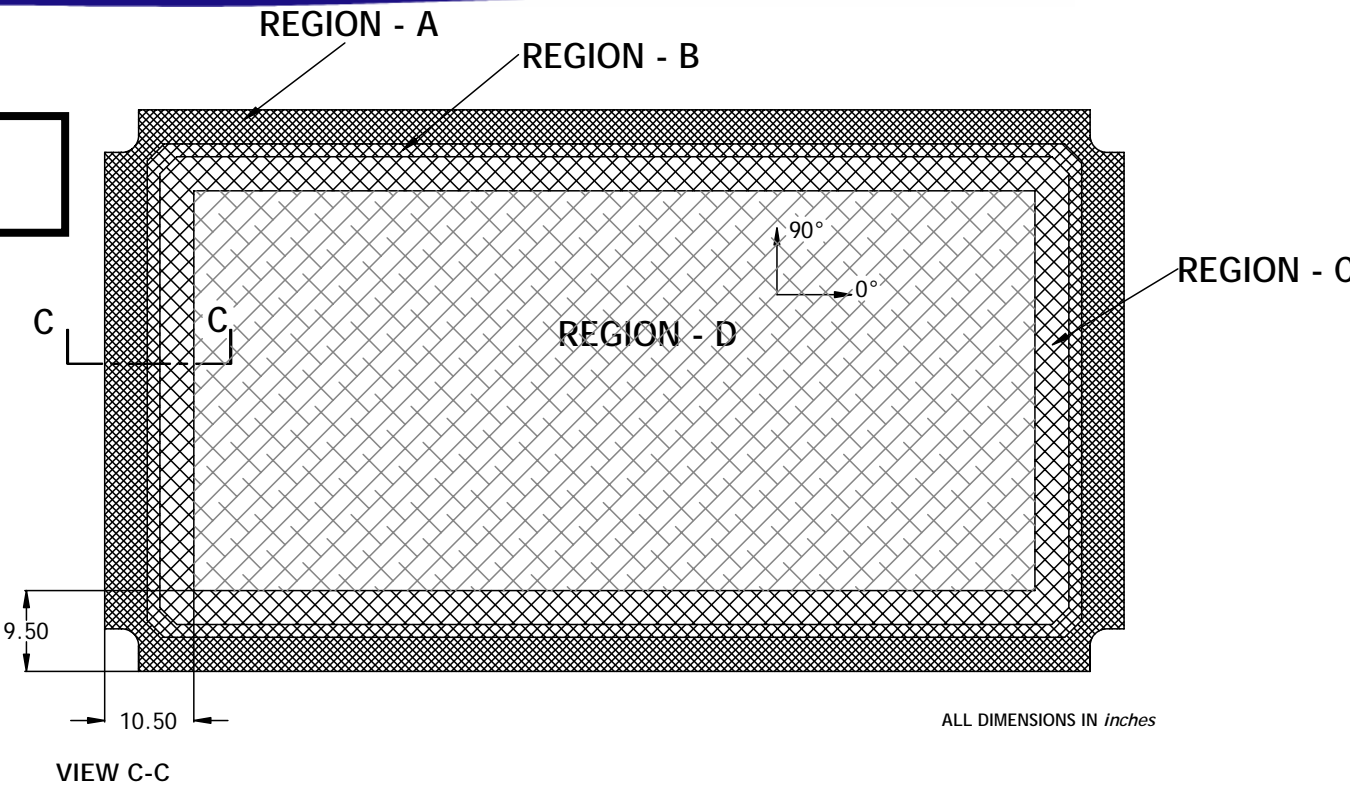
TEST ARTICLE GEOMETRY



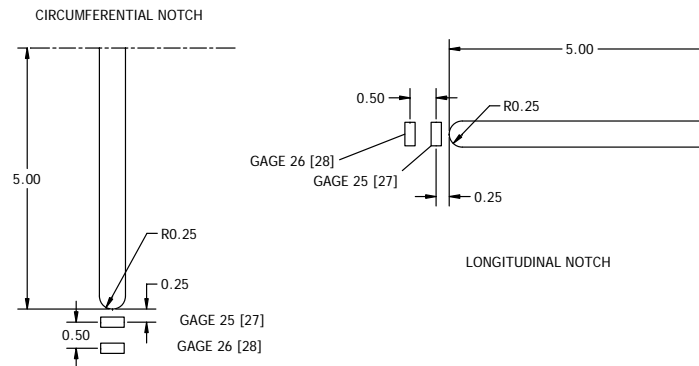
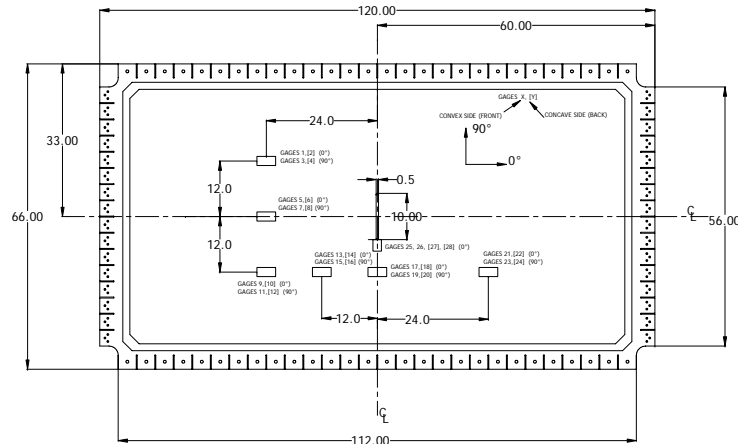
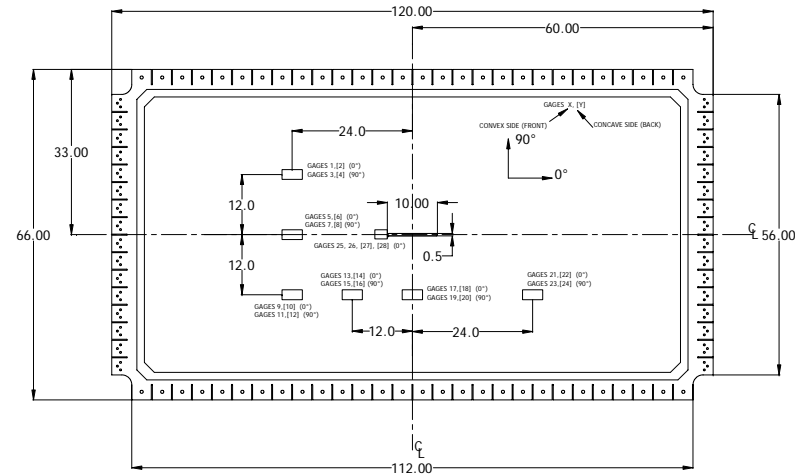
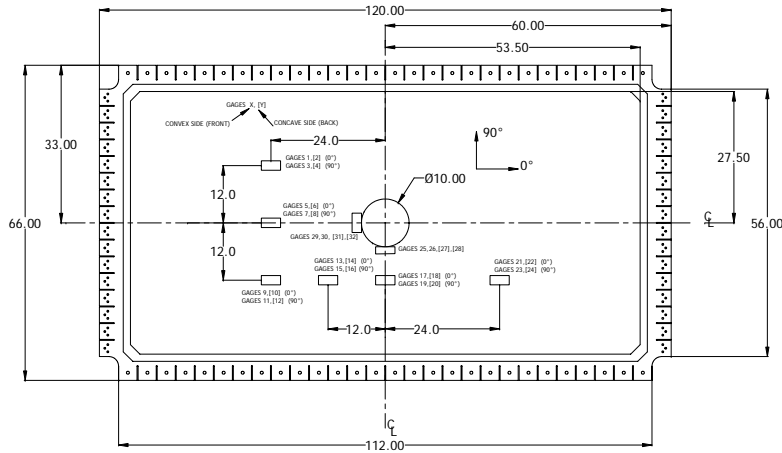
- Material Systems
 - Facesheet
 - TORAY COMPOSITES T700SC-12K-50C/#2510 PWCF
 - Core
 - Plascore Nomex PN2-3/16-3.0 honeycomb (0.75 in thick)
- Sandwich Configuration (test section)
 - [45/0/45/core/45/0/45]



**STACKING SEQUENCE
LAYOUT**



DAMAGE CONFIGURATIONS



TEST MATRIX

TEST CASE No.	DAMAGE TYPE	LOAD CASE No.	LOADING TYPE		
			Longitudinal loads	Pressurization loads	Longitudinal + Pressurization Loads
1.	None	1A	X		
		1B		X	
		1C			X
2.	10" diameter hole in top facesheet	2A	X		
		2B		X	
		2C			X
3.	10" Longitudinal Notch (a/b = 20)	3A			X
		3B		X	
4.	10" circumferential Notch (a/b = 20)	4A	X		
		4B			X

NOT LOADED TO FAILURE

Test Case No.	Damage Type	Load Case No.	Loading Type	Primary M.S.	Failure Mode	Secondary M.S.	Failure Mode	Maximum Deflection (in)	Panel Capability	
									Longitudinal Load (lb/in)	Pressure Load (psi)
1 (With Tab)	None	1A	Longitudinal	0.871	ϵ_{11}^T Fiber Strain	1.060	Core Shear	0.354	1871	-
		1B	Pressure	0.880	Core Shear	1.687	ϵ_{11}^T Fiber Strain	0.309	-	25.4
1 (Without Tab)	None	1A	Longitudinal	1.220	Principal Stress Wrinkling	2.132	Core Shear	0.335	2220	-
		1B	Pressure	2.364	ϵ_{22}^T Fiber Strain	3.060	Core Shear	0.275	-	45.4
2	10" Diameter Hole	1A	Longitudinal	0.700	Compression Wrinkling	1.236	ϵ_{11}^T Fiber Strain	0.342	1700	-
		1B	Pressure	0.187	ϵ_{22}^T Fiber Strain	0.380	Core Shear	0.463	-	16.0
3	10" Longitudinal Notch	3A	Pressure	-0.541	ϵ_{22}^T Fiber Strain	-0.284	ϵ_{11}^T Fiber Strain	0.418	-	6.2
4	10" Circumferential Notch	4A	Longitudinal	0.066	ϵ_{11}^T Fiber Strain	0.786	ϵ_{22}^T Fiber Strain	0.339	1066	-



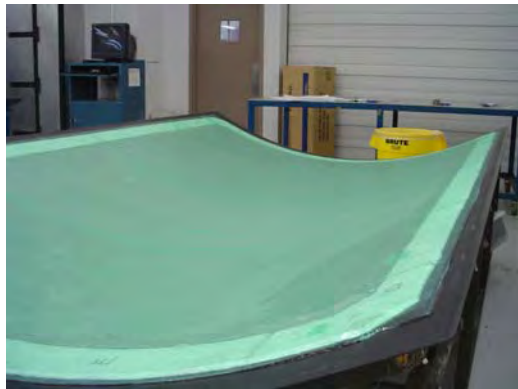
TOOLING FABRICATION



COMPLETED TOOLING

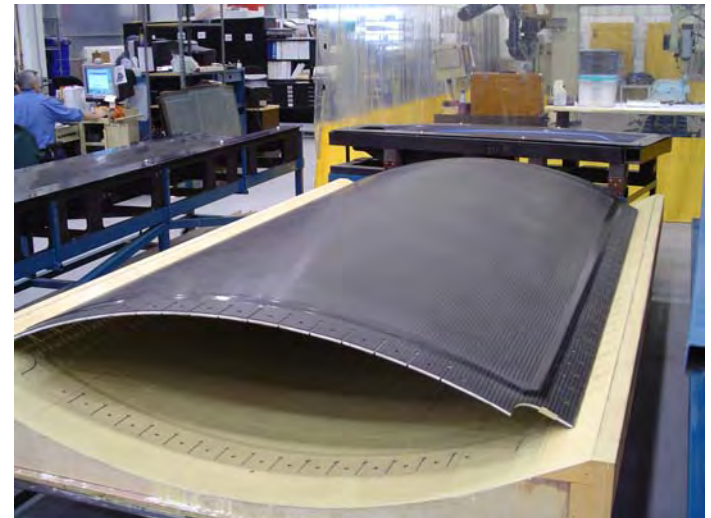
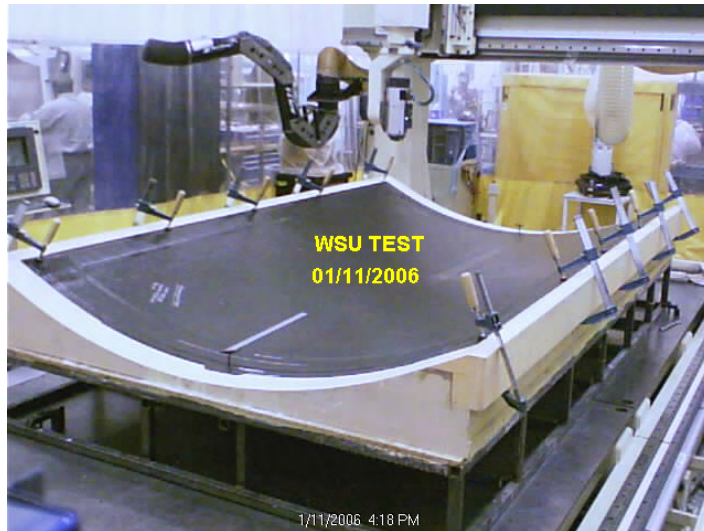


FABRICATION OF TEST ARTICLES



LAYUP

MACHINING



TEST ARTICLE FABRICATION STATUS

- First Test panel delivered to NIAR/WSU – Jan 2006
 - Panel without hole/notch
 - Test article bonded with strain gages at NIAR/WSU
 - Test article shipped to FAA WJHTC – 2nd week of Feb 2006
- Fabrication of test panels with hole and notches under progress (06/01/2006)
 - Panel with circumferential notch – layup under progress
 - Shipped to WSU 7/10
 - Panel with longitudinal notch – machining completed
 - Shipped to WSU 7/10
 - Panel with hole – layup under progress
 - Manufacturing defects (wrinkles)

TESTING : STATUS/SCHEDULE

- Pressure seals acquired by NIAR /WSU - Dec 2005 - Jan 2006
 - Pressure seal shipped to FAA WJHTC - 3rd week of February 2006
- July 10, 2006 - Receive panels (notched) from Adam Aircraft Co.,
 - Strain gaging (~ 2 weeks)
- July 30, 2006- Ship panels(notched) and pressure seals to FAA WJHTC
- July 20, 2006- Receive panel (open hole) from Adam Aircraft Co.,
 - Strain gaging (~ 2 weeks)
- August 10, 2006- Ship panels(open-hole) and pressure seals to FAA WJHTC
- August 15, 2006 - First panel installed
 - August 15 - September 30, 2006 - testing of panels

A Look Forward

- Future needs
 - Longitudinal compression loading capability in the fixture
 - Inclusion of shear loading
 - Fatigue
 - Structural details – cut-outs, adhesive joints, etc.
 - Other damage types – Impact damage, Lightning strike, off-axis notches, etc.