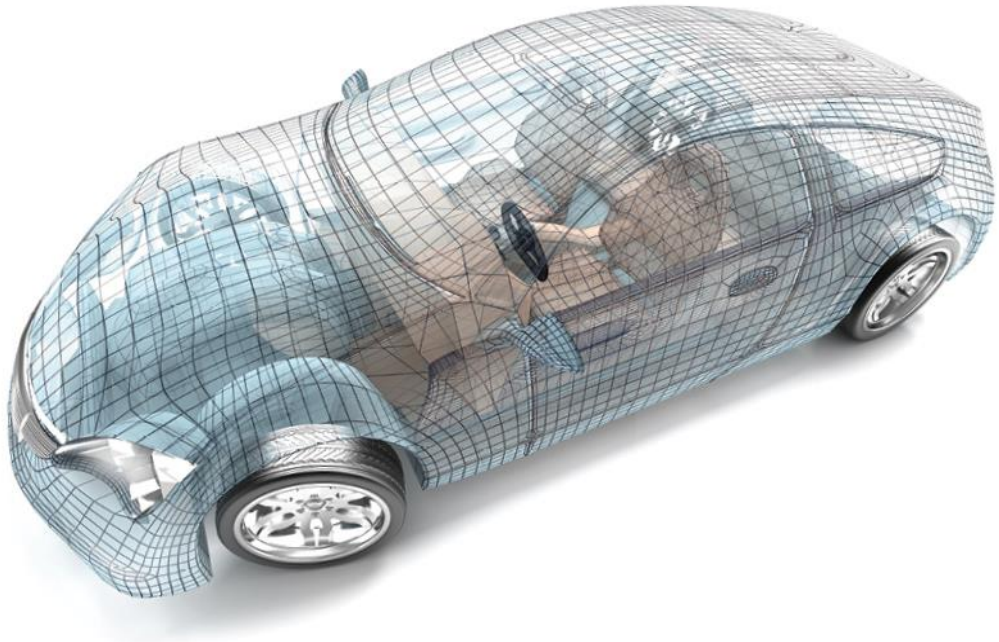
TCC 2020

THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT

APRIL 29 – MAY 1, 2020



Automated Fiber Placement - A Panel Discussion Modeling and Simulation

Presented By: Roberto Lopez-Anido

Professor

Advanced Structures and Composites Center, University of Maine

Why Simulate?

Virtual Prototyping

- Allows trial of ideas while minimizing cost of manufacturing
- Allows for design optimization

Model Iteration

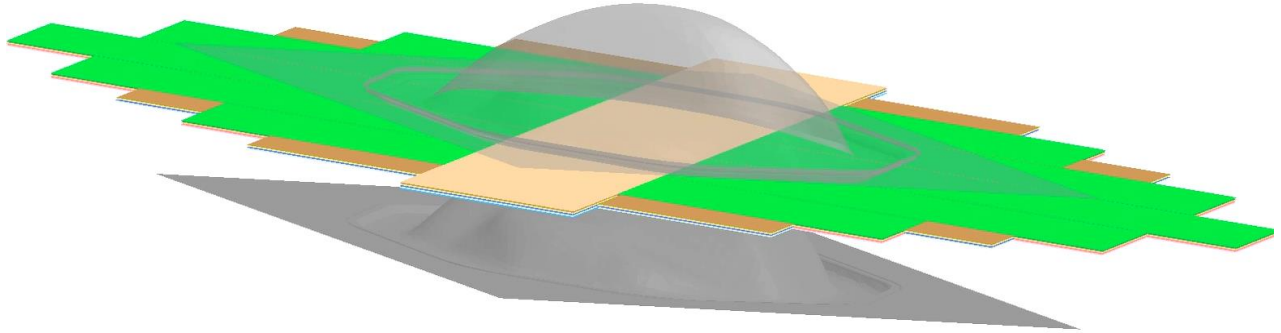
- Allows for optimization of the tooling without repeatedly remanufacturing
- Allows for optimizing process parameters quickly

Defect Prediction

- Wrinkling and Tearing can be detrimental to part performance
- Complex forming behavior makes these difficult to predict without computer models

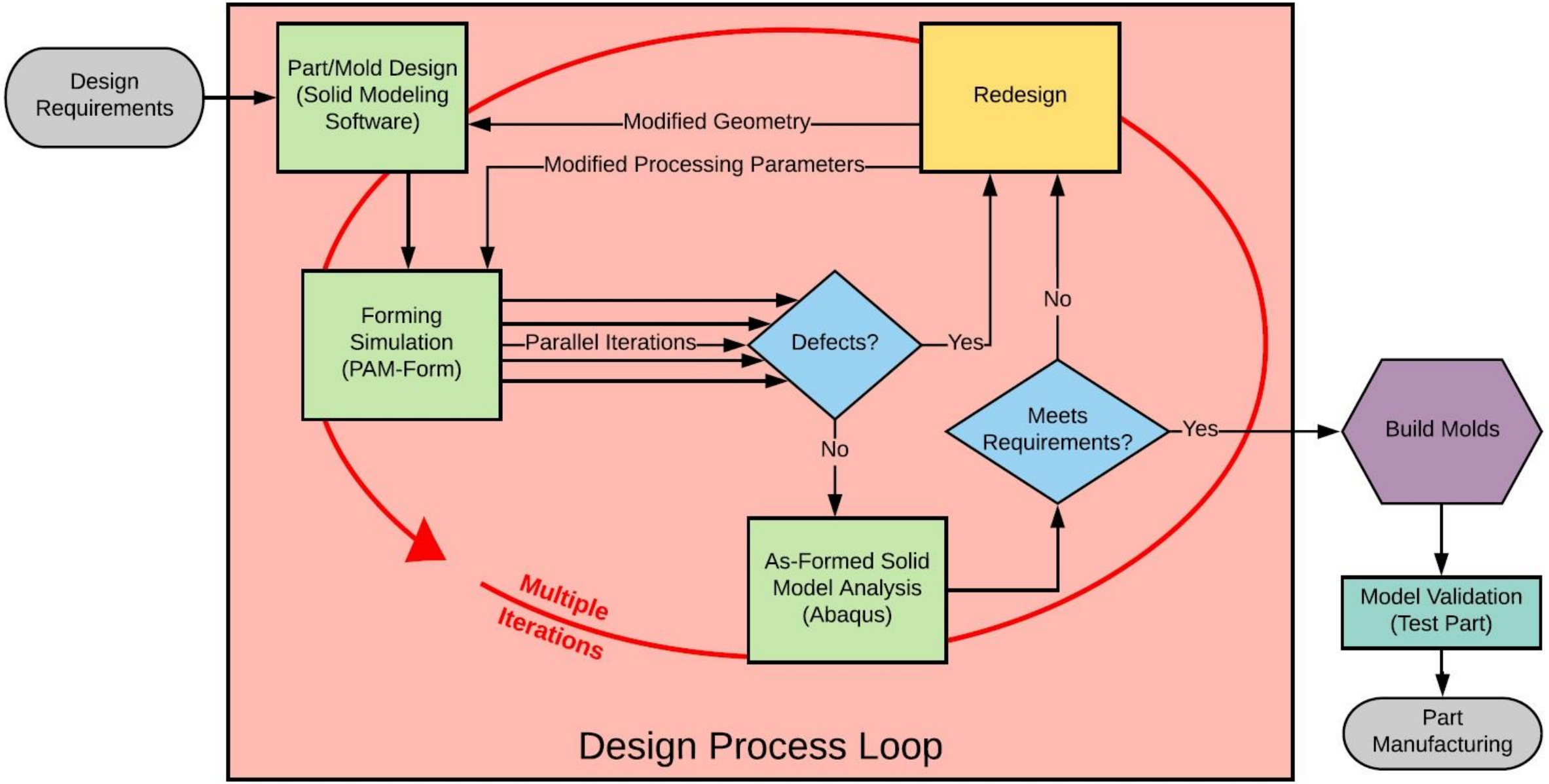
Automated Tape Layup Cell

Differential cover

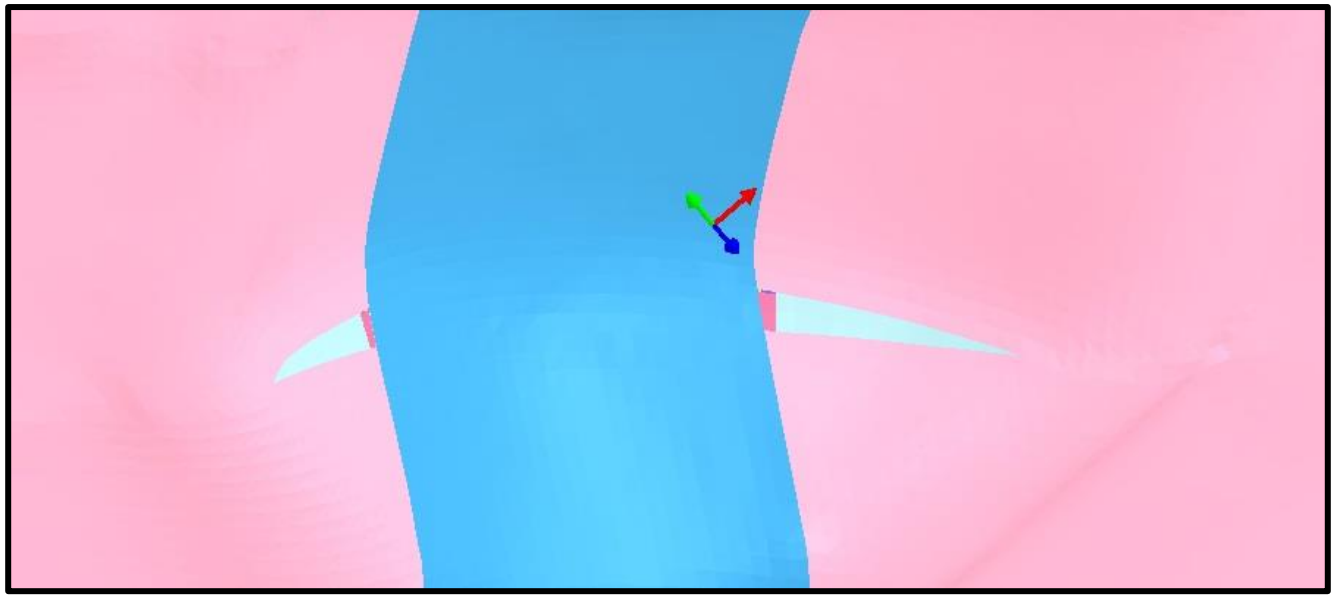


Forming Simulations

Continuous Fiber Reinforced Thermoplastics: Part Design Process

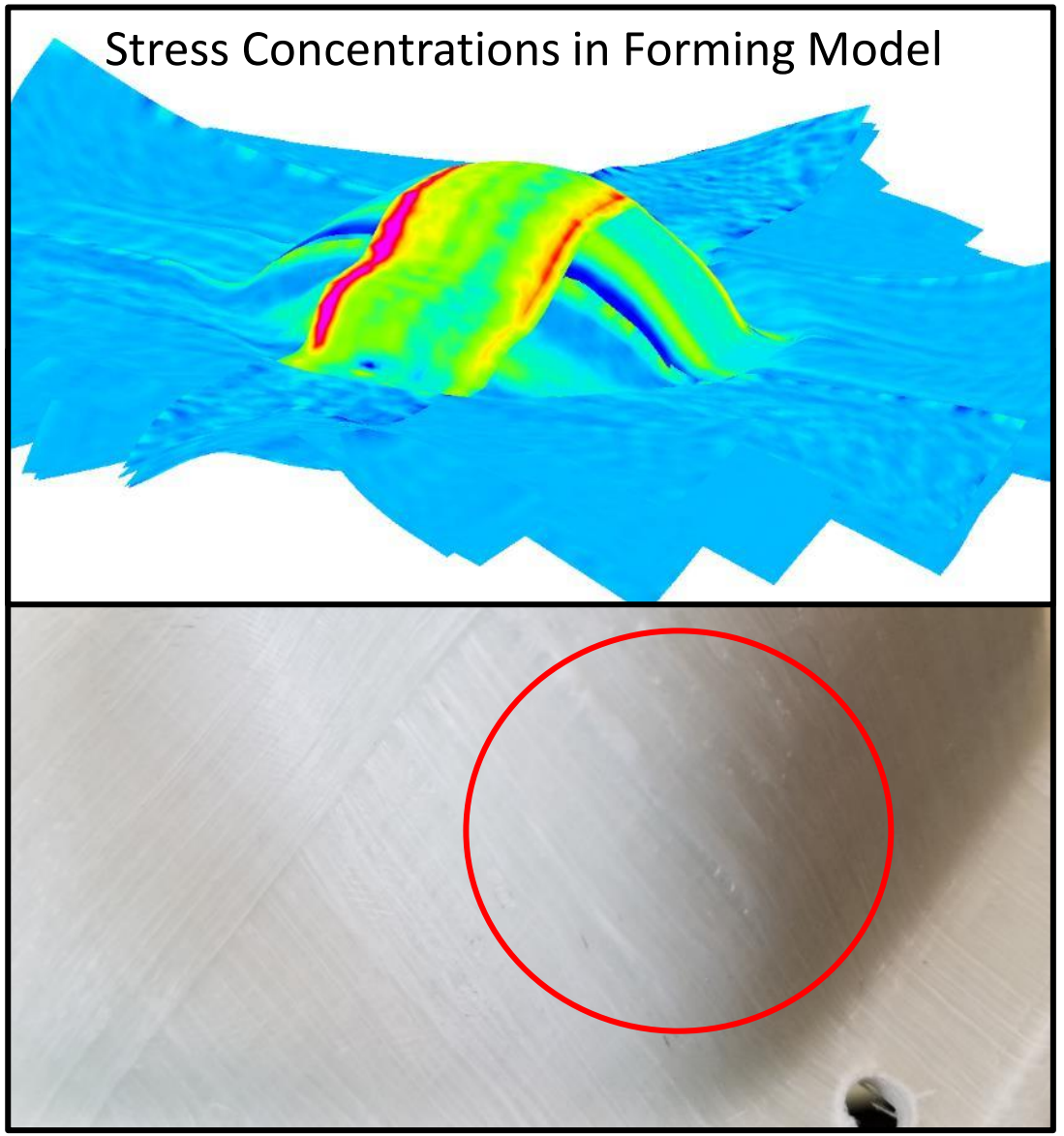


Forming Simulation



Tape Separation

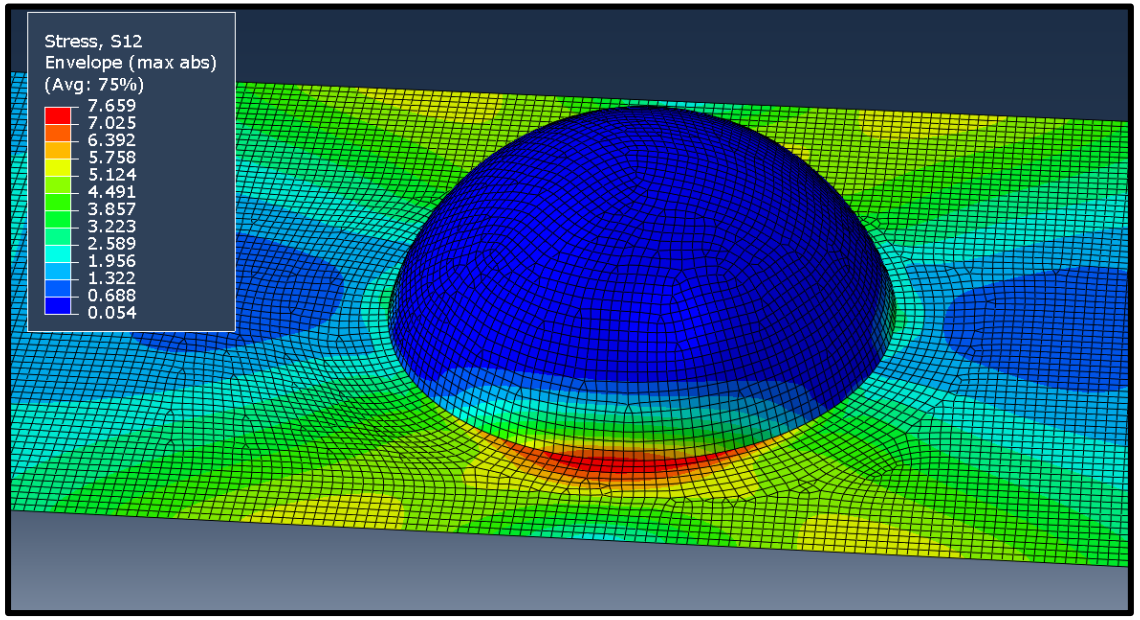
Correlation between the models and the formed part behavior.



Corresponding Splitting in Formed Part

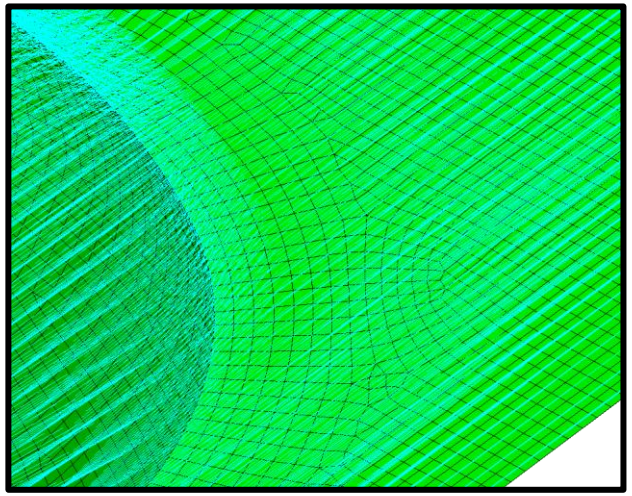
Modeling: Structural Analysis

Multi-Layer PAM-Form Mesh → Single-Layer Abaqus Mesh

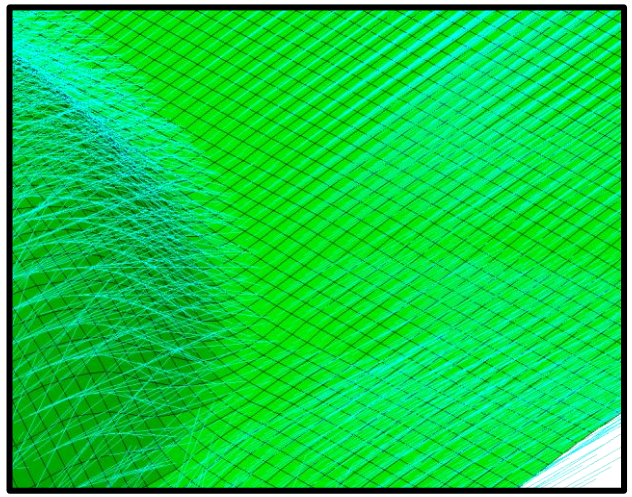


Shear stress envelope showing the concentration region

Fiber Migration $[0/90]_2$ Layup



Fiber Paths in Idealized Model



Fiber Paths in As-Formed Model

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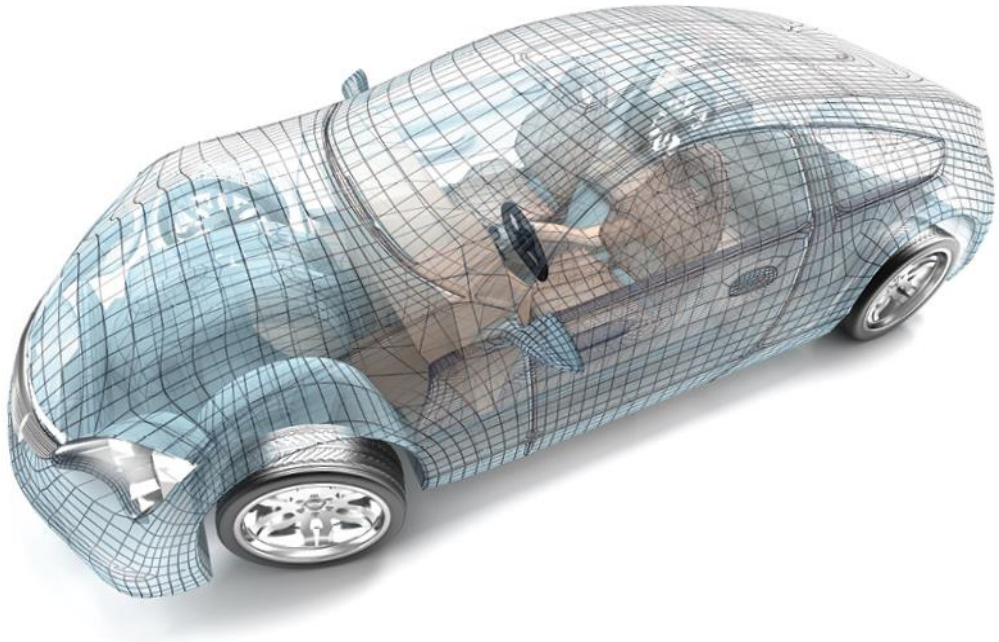
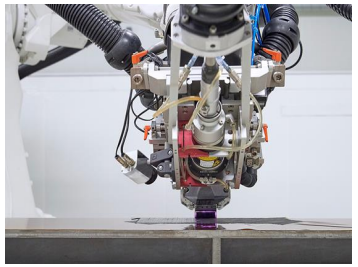


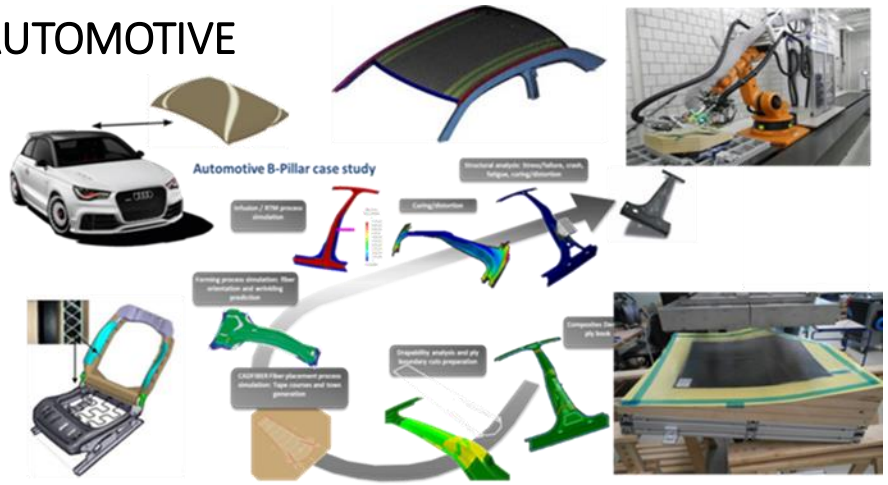
AUTOMATED FIBER PLACEMENT (AFP) Of Thermoplastic Composites

Presented By: Burak Uzman
General Manager
Coriolis Composites USA Inc
burak.uzman@coriolis-composites.com

CORIOLIS is a global provider of AFP Equipment to the Aerospace and Automotive Markets



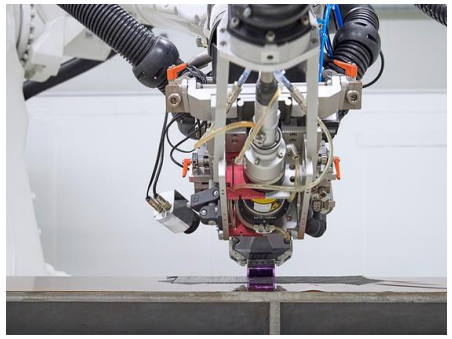
AUTOMOTIVE



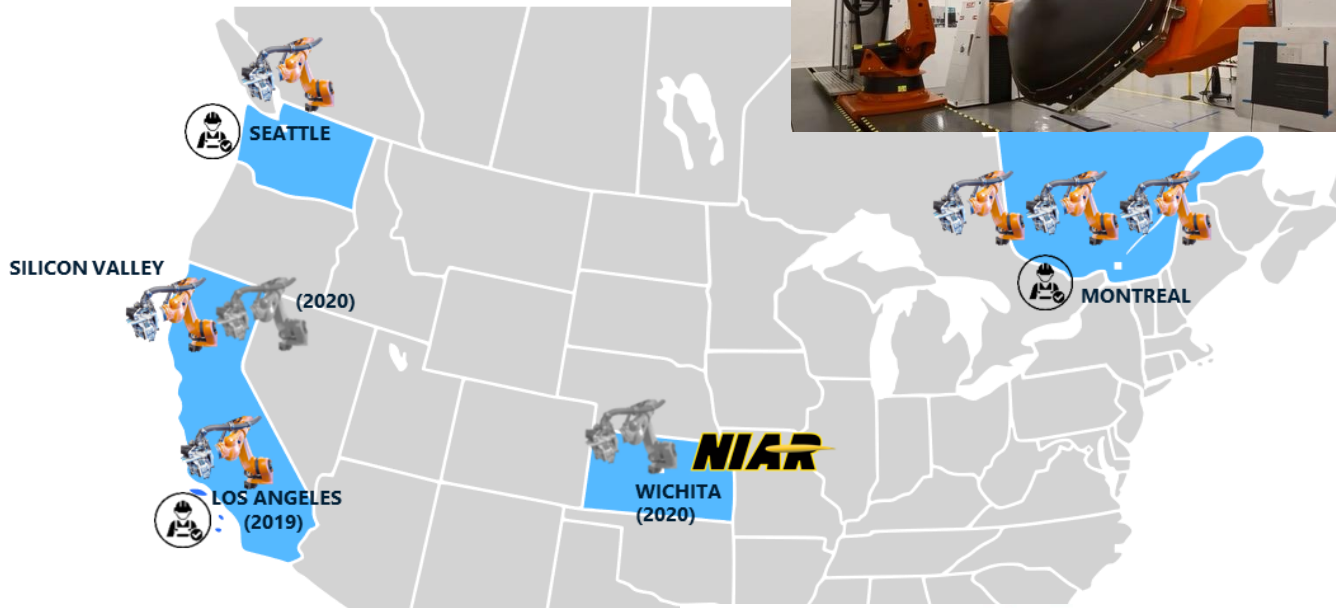
AEROSPACE

70+ machines @ 14 countries

Strong American Product Support Infrastructure

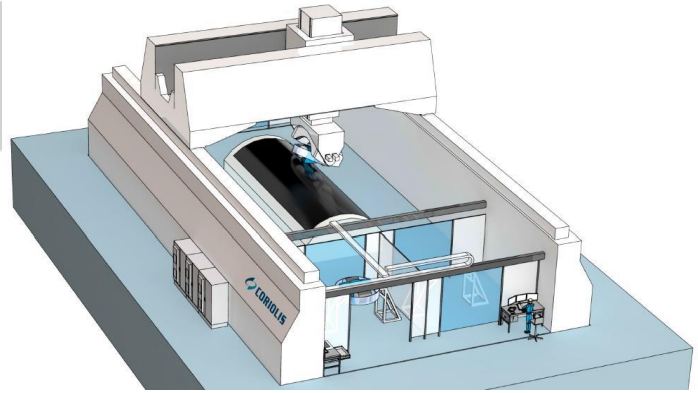


8 Machines in North America



3 Product Support Offices

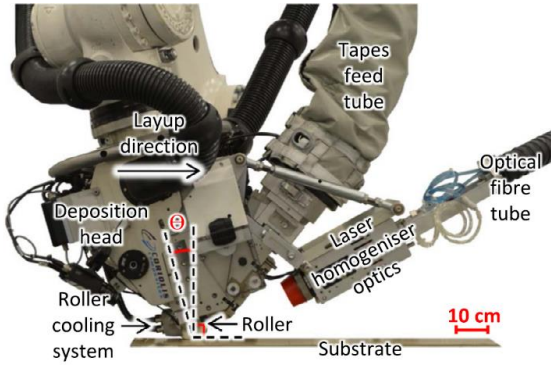
- Seattle
- Los Angeles
- Montreal

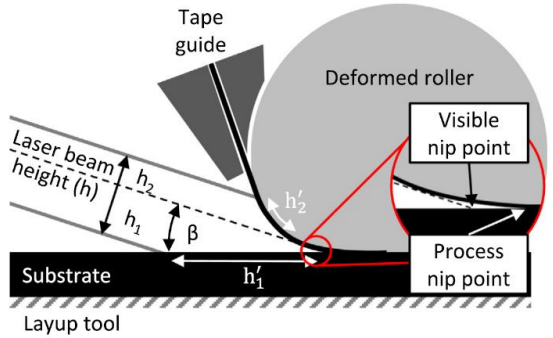


Will Thermoplastics replace Thermosets?

No. May be.

Depends on the part and application.

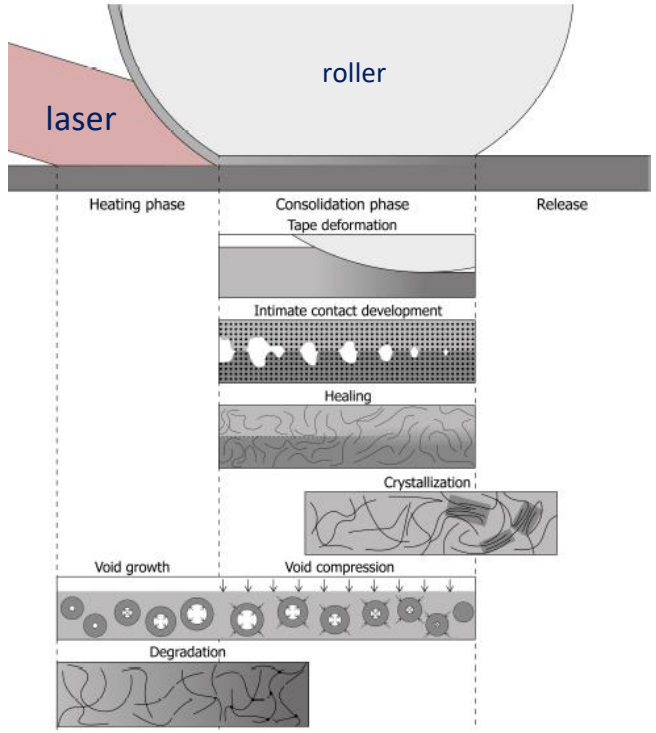




Why AFP Thermoplastics instead of Thermosets?

Because Interlaminar Strengths Matter !

- Interlaminar Tensile Strength (ILTS)
- Interlaminar Shear Strength (ILSS)
- Interlaminar Fracture Toughness (G1C & G2C)



Possibility of Out of Autoclave Processing

Very Small and Very Large Parts

- In-Situ (Very Large Parts)
- Fast In-Situ + Thermal Annealing (Large Parts)
- Fast Layup + Thermoforming (Small Parts)

Others

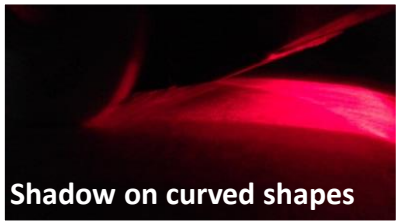
- Weldability
- Impact Damage Tolerance (..there is a limit! won't survive hangar rash but may be a tool drop)
- Flame, Smoke, and Toxicity (e.g. interiors)

In-Situ Consolidation Paradox

- Interlaminar Properties Require Time and Pressure
- More Time -> Slower Process !!!
- AFP Process is expected to be fast

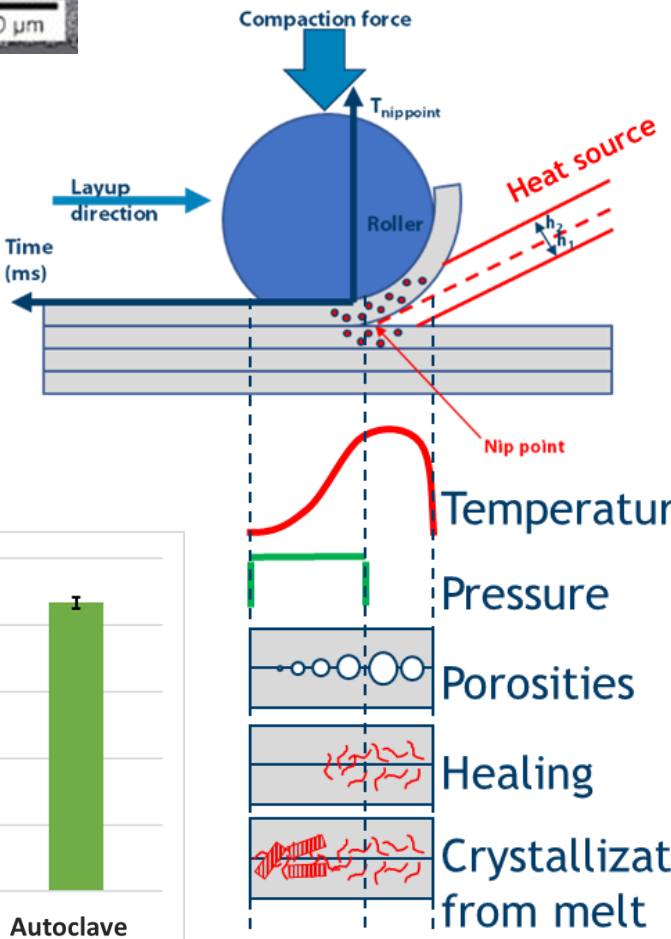
Real Parts Have Ply Drop-Offs

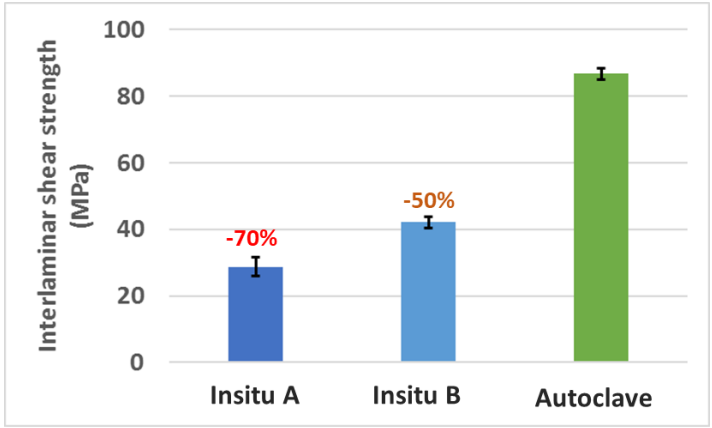
- First Impression is very important - Literally
- Matrix flow under temperature and pressure



Real Parts Have Compound Contour Surfaces

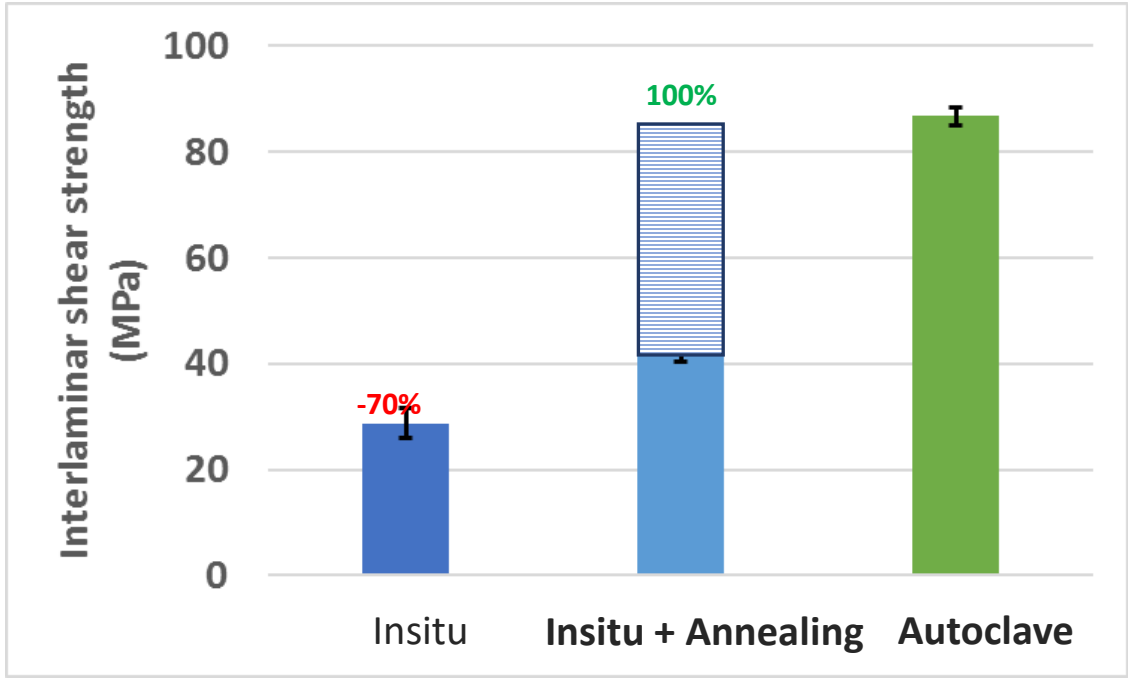
- Convergence Zones and Gaps
- Laser Shadow Casting
- Matrix flow under temperature and pressure



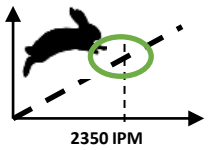


High Speed Consolidated Layup with Annealing

- High Speed Layup (~ 2350 IPM)
- Annealing does not require expensive CAPX
- Autoclave Equivalent Material Properties
- Areas of Discontinuity Still Challenging

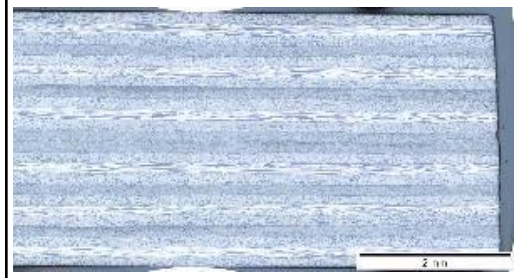


AFP layup high speed



ANNEALING

Consolidated Laminate



- 0.5% Porosity
- 44% Crystallinity
- 100% Autoclave Mechanical Properties

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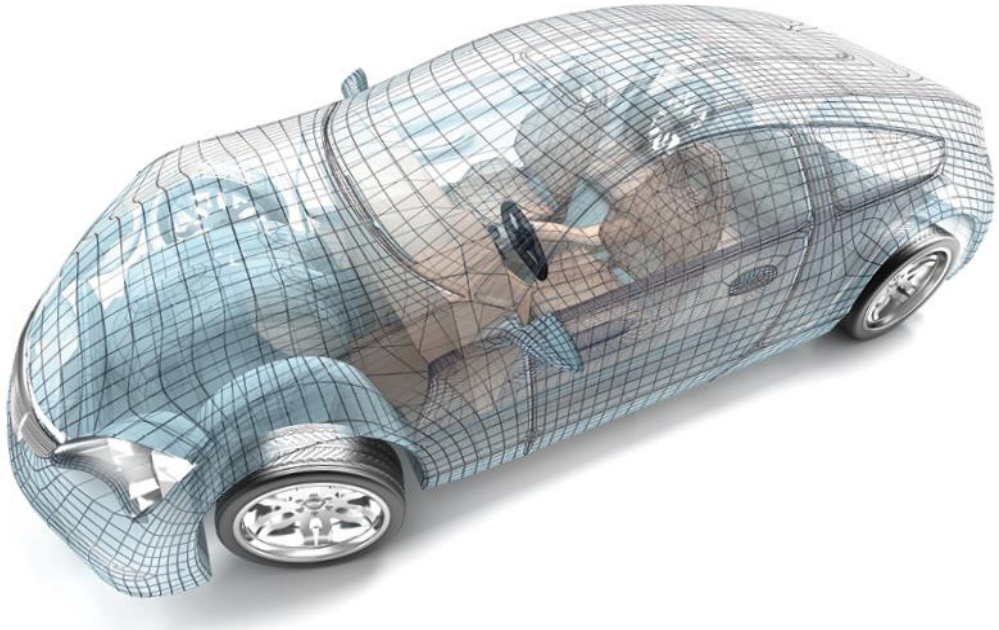


In Situ Fabrication of Thermoplastic Composites via Automated Fiber Placement

Presented By: Darrin Teeter
CEO/CTO
Fiber Dynamics, Inc.

FIBER DYNAMICS

Innovation through Production Capabilities at Fiber Dynamics

- Founded in 1991 to capitalize on research efforts in composites Resin Transfer Molding producibility at the National Institute for Aviation Research
- Developed products for Light Aircraft and Bicycles, then diversified to General Aviation, Motorsports, Medical, Defense, etc.
- Current focus on innovation driven design-build programs and automation driven processes

NIAR
WICHITA STATE UNIVERSITY





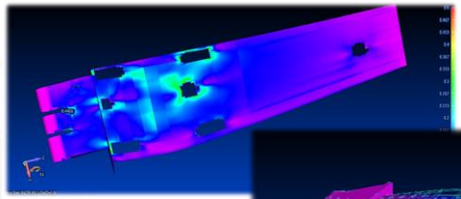
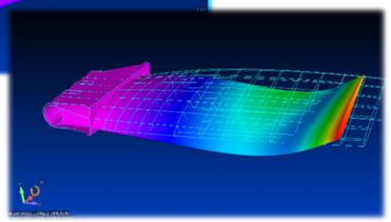






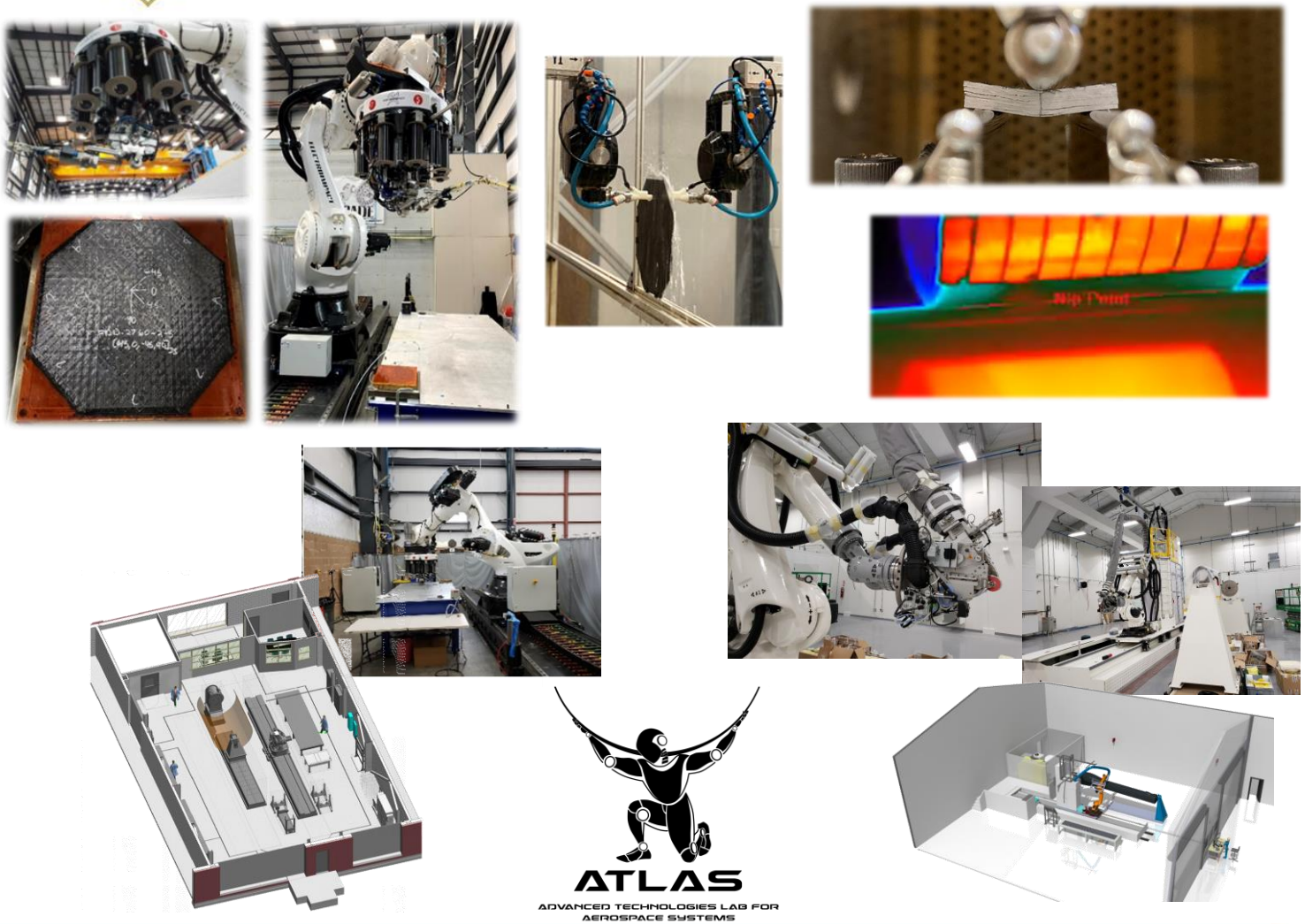




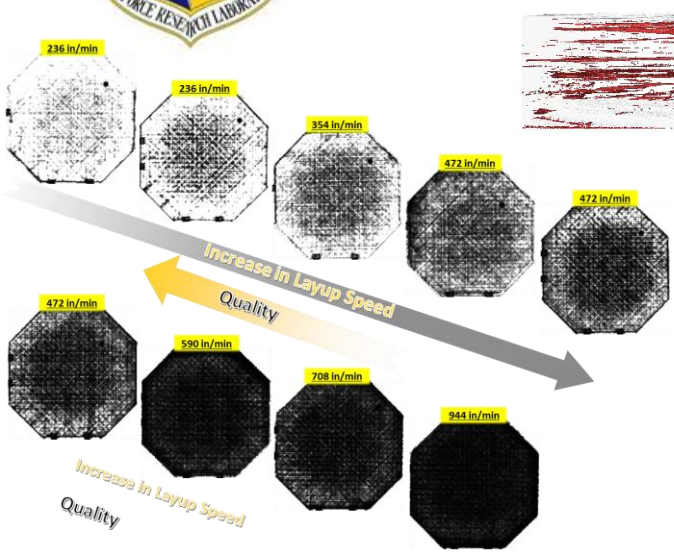
Fiber Dynamics Thermoplastic Composite In Situ AFP Research

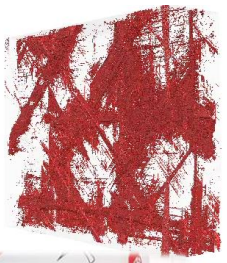
- Funded by Air Force Research Lab SBIR AF191-093: Innovative Methods for Thermoplastic Composites on ATL/AFP
- Research focused on achieving in situ AFP thermoplastic mechanical properties similar to autoclave cured thermosets and to build a demo part
- Initial AFP work performed using NIAR's ATLAS equipment at Electroimpact's RCADE Lab with Toray TC1225 LM-PAEK

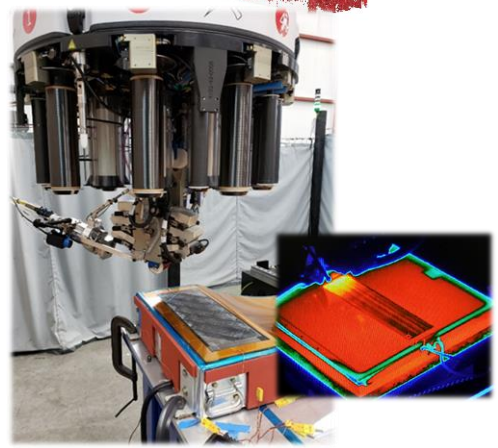


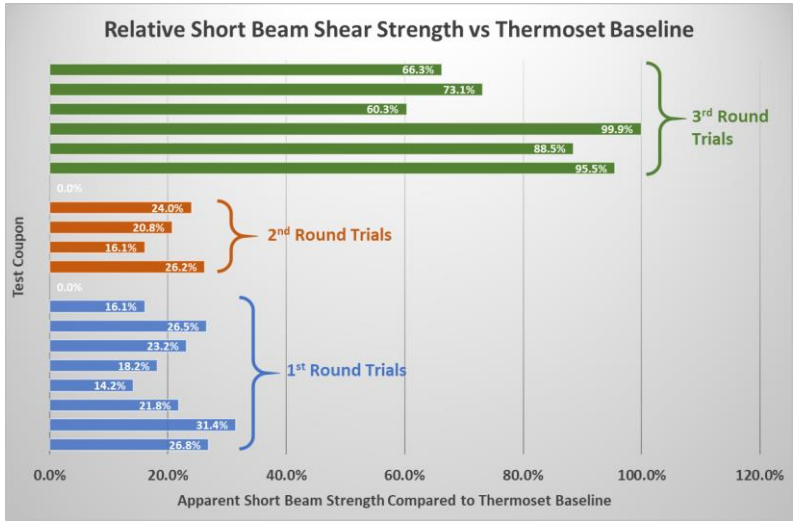
SBIR Test Coupon Fabrication & Evaluation

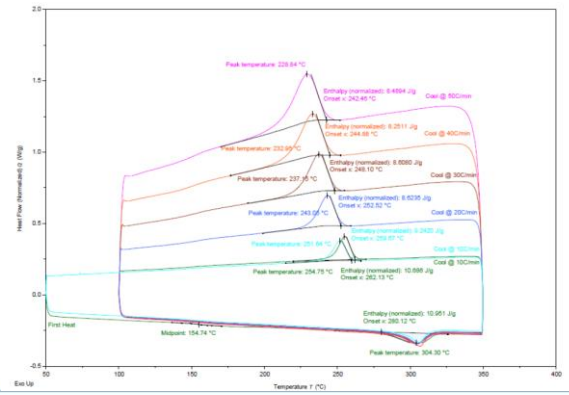
- Three process trials conducted with multiple process variables on two batches of Toray TC 1225 LM-PAEK
- Multiple tests performed:
  - Through-Transmission Ultrasonic Inspection
  - X-ray Computed Tomography
  - Void Content Analysis (Acid Digestion and Image Analysis)
  - Degree of Crystallinity via DSC
  - ASTM D2344 – Short Beam Strength Testing
  - ASTM D6641 – Combined Loading Compression
  - ASTM D3518 – In-Plane Shear
  - ASTM D5528 – Mode I Fracture Toughness

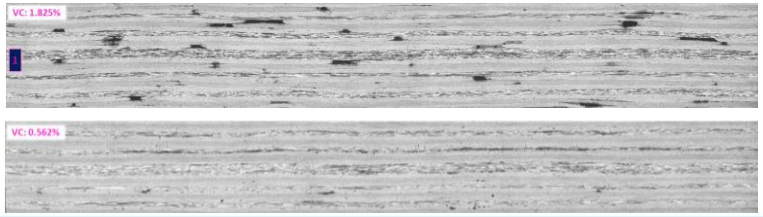






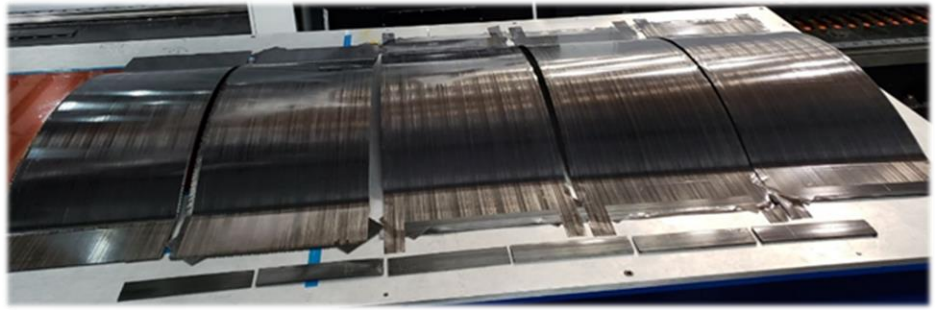


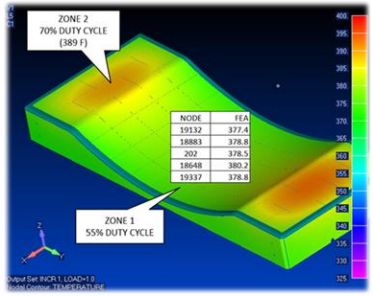


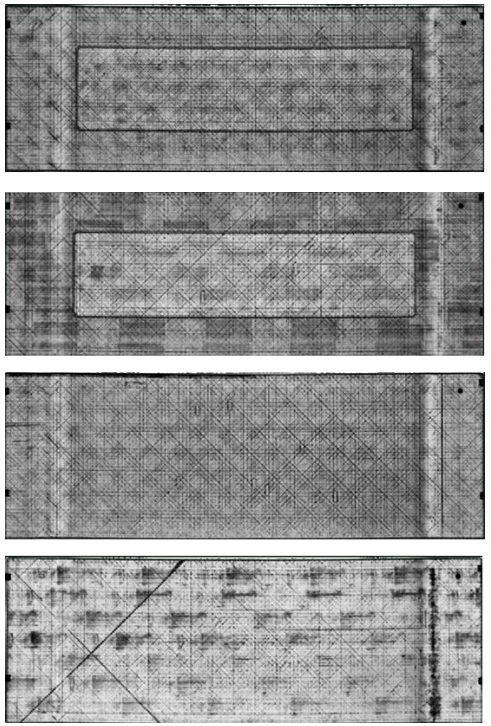


SBIR POC Part Fabrication & Evaluation

- Five 16-24 ply POC Parts produced utilizing results of process trials
- Additional testing in progress
- Ongoing research efforts to enhance process quality and speed:
  - Improved heating methods to promote crystallinity, molecular reptation and throughput
  - Innovative heated tooling
  - Raw material improvements
  - Matrix shear-thinning methods
  - Thermal process modeling







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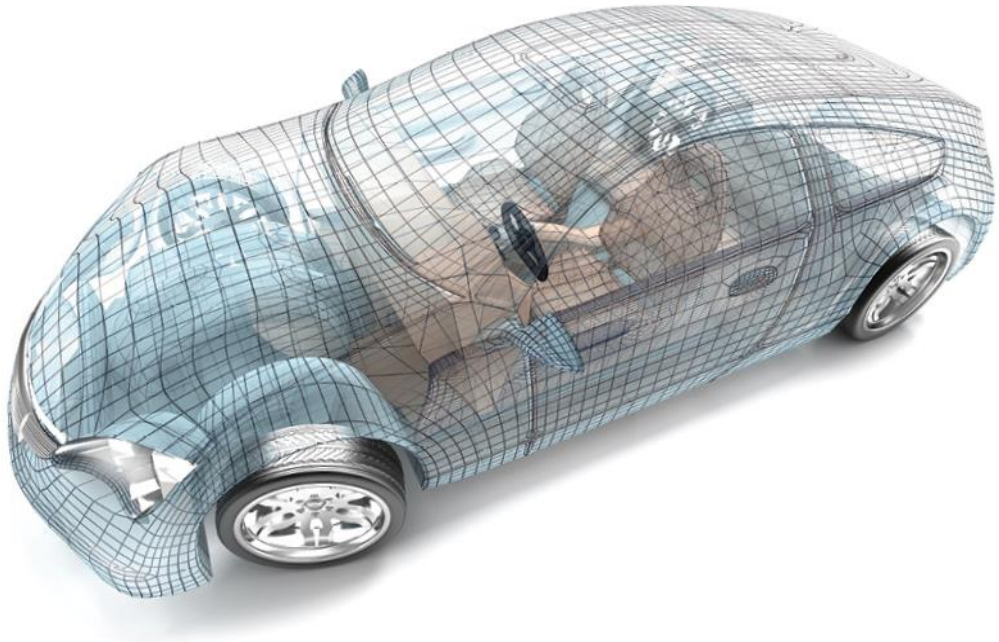


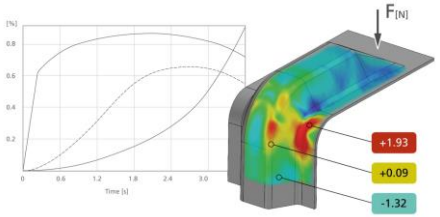
InSitu NDE Monitoring of Thermoplastic Quality

Presented By: John Tyson II, PE
President
Trilion Quality Systems

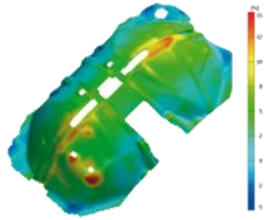
Trilion Quality Systems

gom a ZEISS company | certified partner

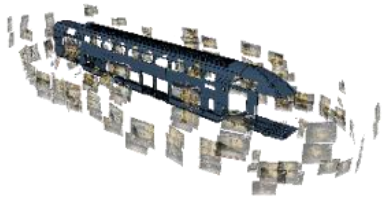
ARAMIS
Optical Strain measurement
3D Digital Image Correlation
Dynamic Photogrammetry
PONTOS Live



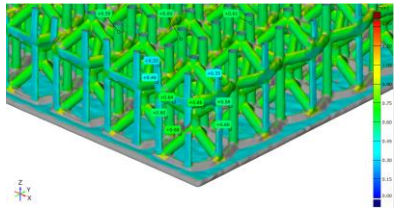
ARGUS
Sheet Metal
Optical Forming Analysis
Photogrammetry



TRITOP
Mobile Optical CMM
Automated Stitching
Photogrammetry



GOM CT
Metrology CT Scanner
3D X-Ray



ATOS
3D Scanning
Structured Light
Photogrammetry

ARAMIS High-Speed
Wide range of High-Speed Cameras
1,000 FPS to 5M FPS

TRILION ENGINEERING SERVICES
Non-contact optical measurement services

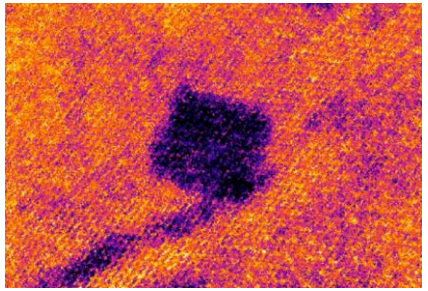
ARAMIS Thermography
Wide range of Thermal Cameras
InSitu NDE – Thermography NDT - SHM

Trilion Quality Systems – optical systems transforming manufacturing

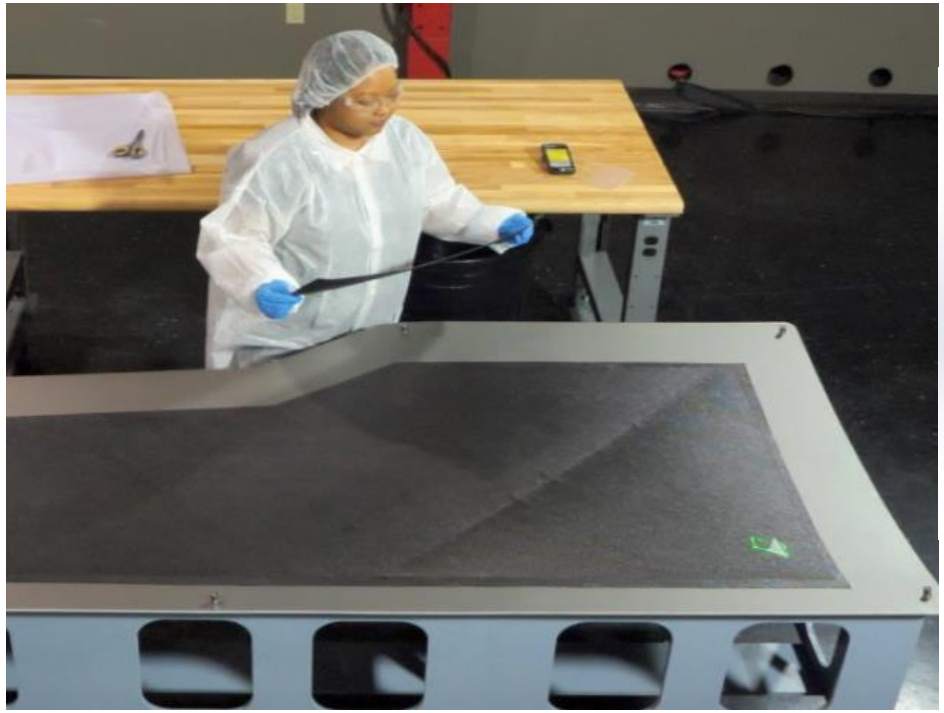
Digital-Twin	Trilion Digital-Twin captures all CAD, manufacturing & QA data into easily operated, real-time, graphical database.
In-Situ NDE	InSitu NDE provides real-time build quality data, so that parts can be made right the first time.
Digital Assembly	RVAT Digital Assembly provides real-time guidance of build positioning and tolerances, documenting each stage As-Built.
Structural Testing	ARAMIS Optical Strain greatly reduces cost and test time, while measuring all points holistically, rather than known problem points.
Structural Health Monitoring	ARAMIS Thermography NDE measures all points on vehicle robotically, using Digital-Thread to see minute changes, with the power of 1M SG.

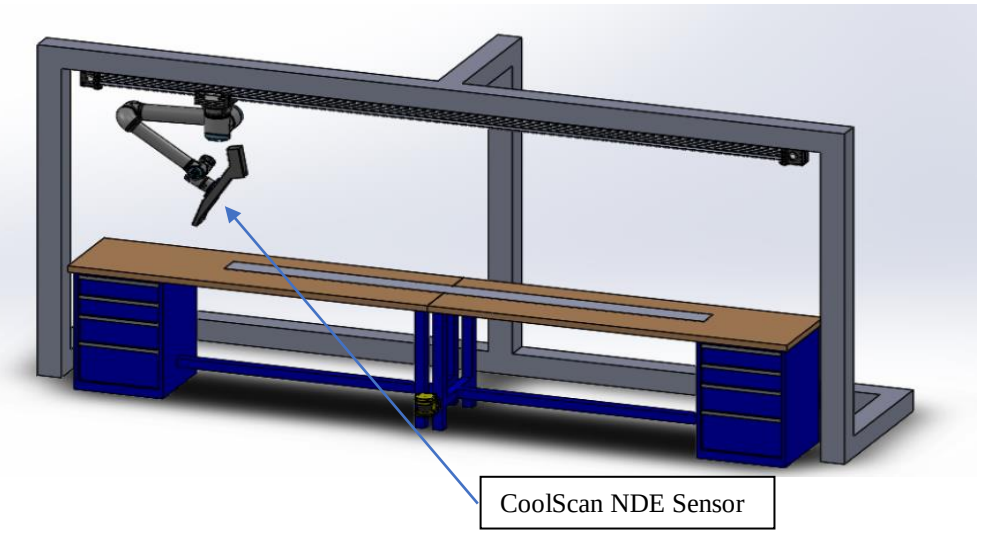
CoolScan™ InSitu NDE – Quality Composite Build – Hand Layup – Build it right!

- **Hand Layup Guidance**
- **Ply Placement Validation**
- **Fiber Alignment**
- **Interply FOD Detection**
- **Build Quality Assurance**
- **Digital Twin documentation**



Detection of internal FOD & Bridging
CoolScan™ InSitu NDE





Composite Build – Hand Layup CoolScan™ InSitu Quality

Jidoka – Real-time defect detection and fix

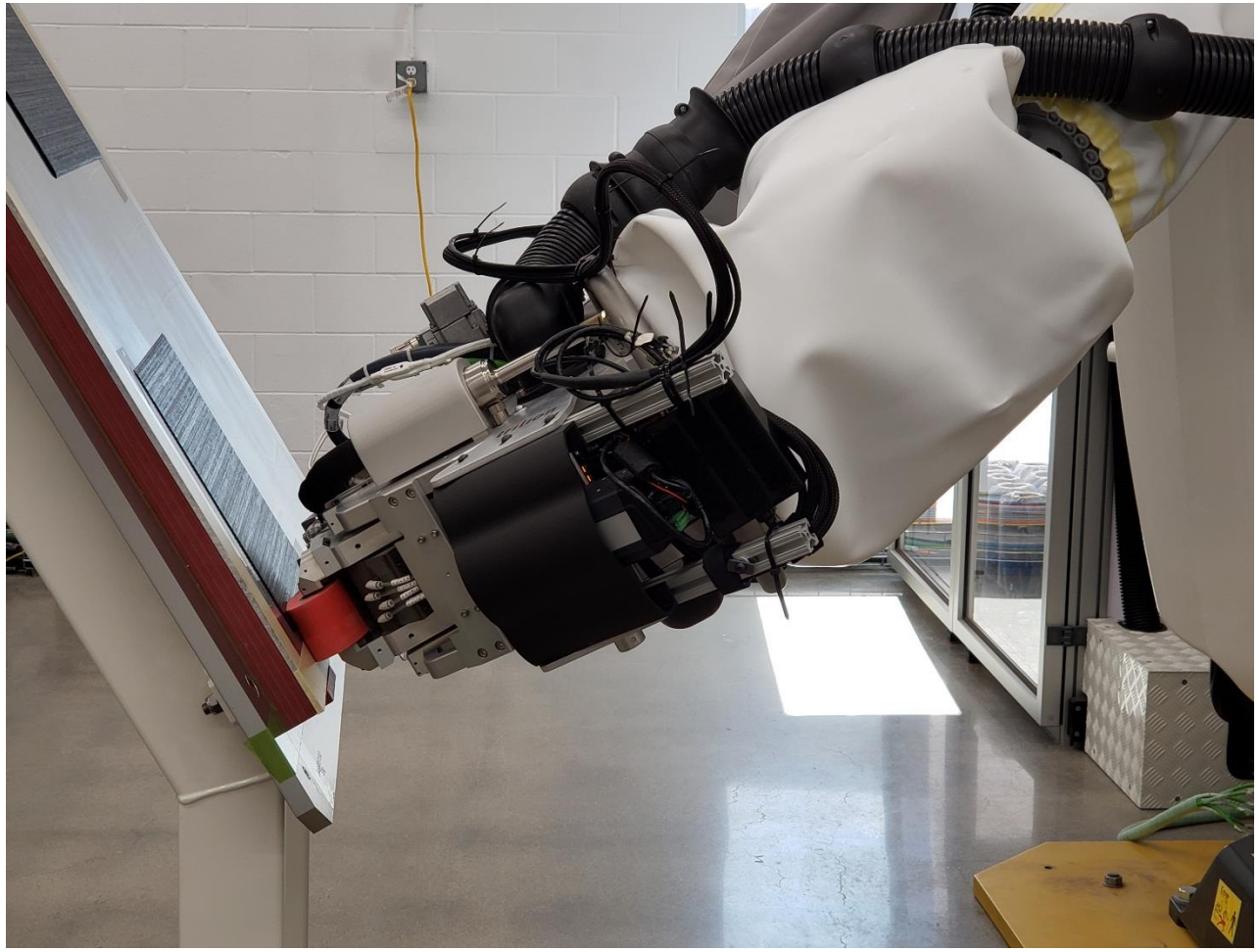
- **Real-time 3D Build Quality**
  - **Digital-Thread ➡ Digital-Twin**

Indication	Definition	Tolerance
End-of-Ply (EOP)	Check Placement of Ply to CAD	<6mm
Fiber Alignment	Check Fiber Alignment to CAD	+/- 5°
Void/Bridging	Detect Voids and Bridging	Repair
FOD	Detect Backing, Fuzz, FOD	Repair
3D Shape to CAD	N.A. in tool, Post Curing Scan	Per Requirements
Bond Quality	N.A. with autoclave curing	

InSitu Digital-Thread tracks composite build in true 3D space, compares build plan with actual, and checks indications to tolerances.

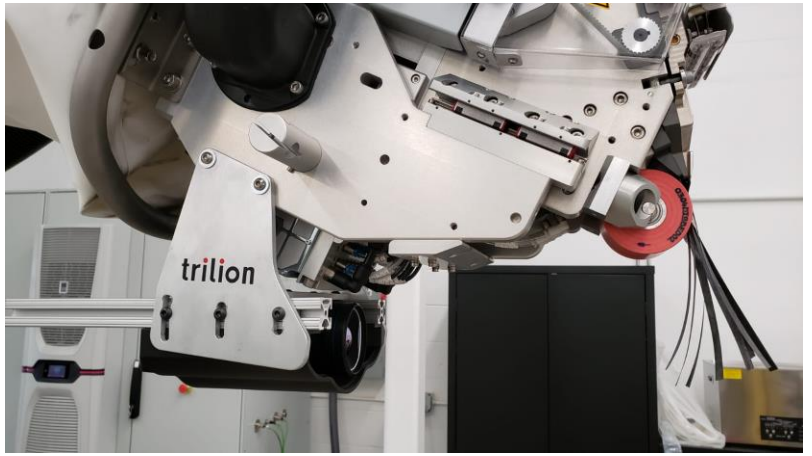
Composite Build – ATL/AFP InSitu Quality

Jidoka – Real-time defect detection and fix



In-Situ NDE – Bond Quality

Bond quality known at every point of the component build.



Trilion InSitu NDE system on Joby Coriolis Robot Head.

Composite Build – ATL/AFP InSitu Quality

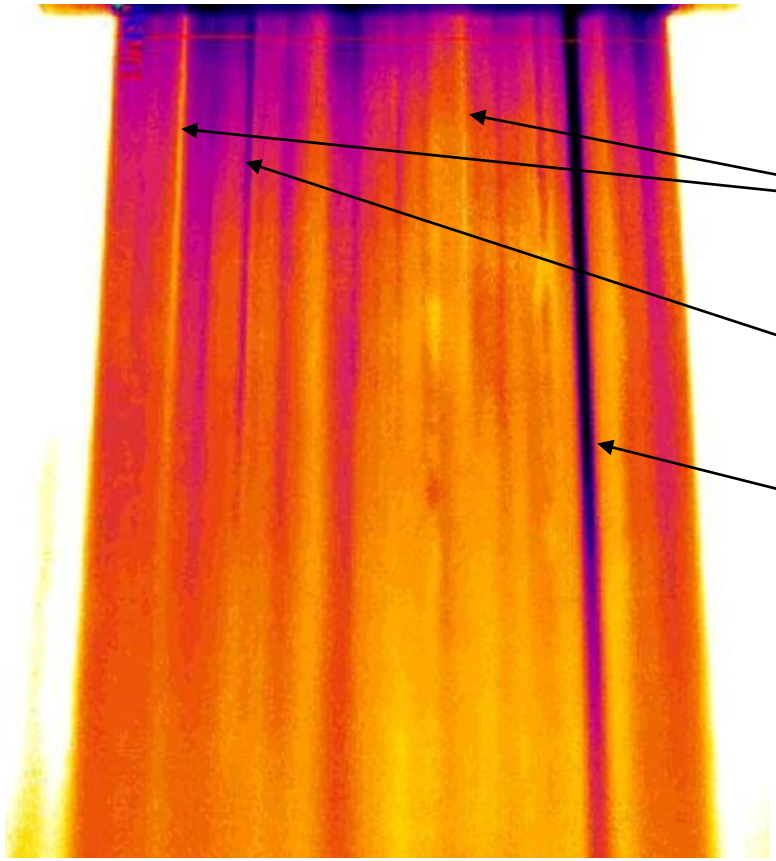
- **Real-time 3D Build Quality**
- **Jidoka – Real-time defect detection and fix – Continuous Workflow**
  - **Digital-Thread ⟹ Digital-Twin**

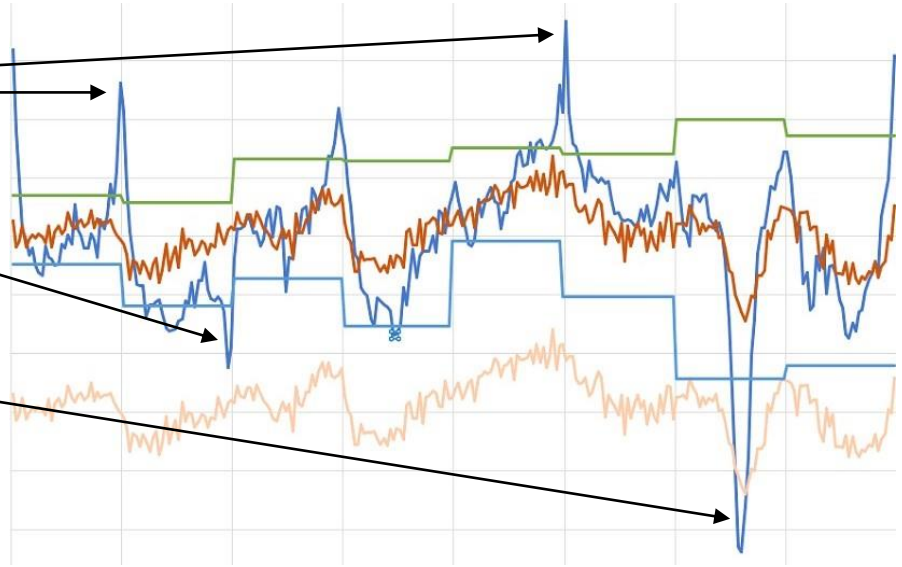
Indication	Definition	Tolerance
Gap	Gap between tows/tape	<2mm
Lap	Tow overlapping adjacent	<2mm
Twist	Tow twist	Repair
Splice	Tow splice	tba
Buckling/Puckering	Tape turn buckling	QA; undesirable
Void	Tow voids, disbonds, bridging	<4mm
FOD	Foreign material, fuzz	Repair
3D Defect Stacking	Voxel detection of defect stack	QA; undesirable

InSitu Digital-Thread tracks composite build in true 3D space, compares build plan with actual, and checks indications to tolerances.

Composite Build – ATL/AFP InSitu Quality

- **Real-time 3D Build Quality**
  - **Real-time Defect Detection – In-Situ NDE**



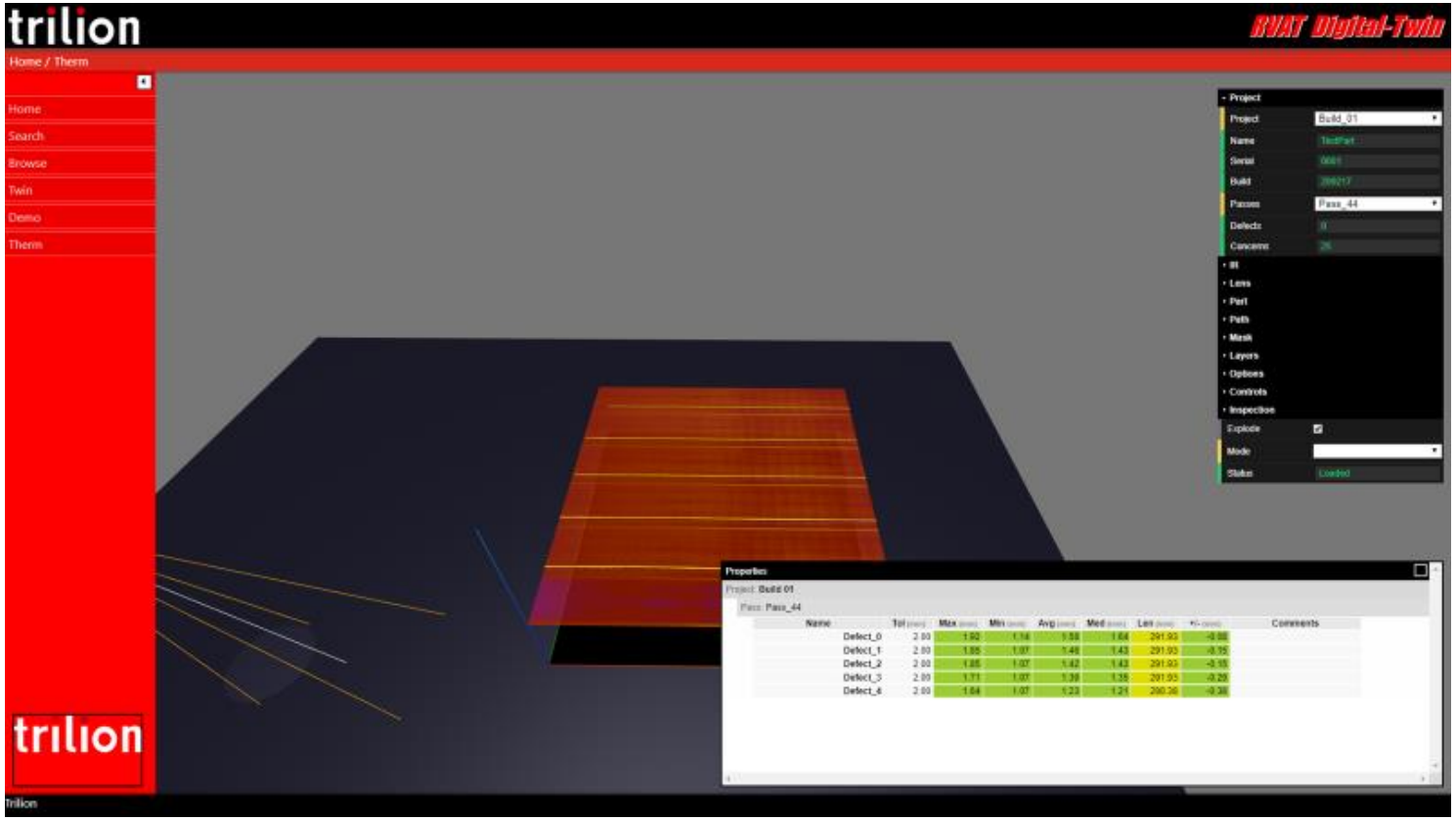


During AFP Layup & Consolidation

- Cool (black) = poor bonding or lap

Composite Build – ATL/AFP InSitu Quality

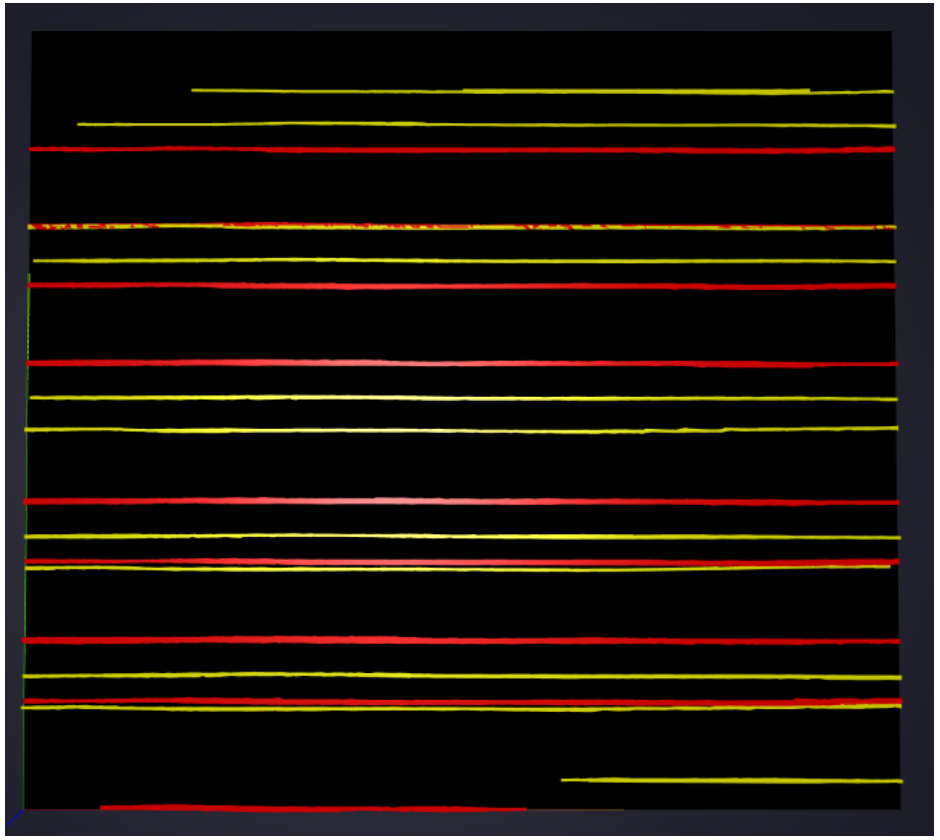
- **Real-time Build Quality – Voxel View of Entire Panel**
  - **Digital-Thread ⟹ Digital-Twin**



Analysis of one layer shows the detail of each step of the build.

Composite Build – ATL/AFP InSitu Quality

- **Real-time 3D Build Quality**
  - **Real-time Defect Detection – In-Situ NDE**



Panel report showing Voxel "X-Ray" view of all defect indications through all the layers together.

	Tol (mm)	Max (mm)	Min (mm)	Avg (mm)	Med (mm)	Len (mm)	+/- (mm)	
Defect_0	2.00	2.64	1.28	1.93	1.92	291.93	0.64	Gap Void > Tol
Defect_1	2.00	2.50	1.28	1.74	1.71	291.93	0.50	Gap Void > Tol
Defect_2	2.00	2.50	1.07	1.78	1.78	291.93	0.50	Gap Void > Tol
Defect_3	2.00	2.28	1.21	1.59	1.57	291.93	0.28	Gap Void > Tol
Defect_4	2.00	1.78	1.21	1.35	1.35	117.41	-0.22	
Defect_5	2.00	1.50	1.07	1.19	1.14	118.91	-0.50	

	Tol (mm)	Max (mm)	Min (mm)	Avg (mm)	Med (mm)	Len (mm)	+/- (mm)	
Defect_0	2.00	1.92	1.14	1.58	1.64	291.93	-0.08	
Defect_1	2.00	1.85	1.07	1.46	1.43	291.93	-0.15	
Defect_2	2.00	1.85	1.07	1.42	1.43	291.93	-0.15	
Defect_3	2.00	1.71	1.07	1.39	1.35	291.93	-0.29	
Defect_4	2.00	1.64	1.07	1.23	1.21	280.38	-0.36	

	Tol (mm)	Max (mm)	Min (mm)	Avg (mm)	Med (mm)	Len (mm)	+/- (mm)	
Defect_0	2.00	2.71	1.14	2.02	2.07	291.93	0.71	Gap Void > Tol
Defect_1	2.00	2.71	1.14	2.02	2.07	291.93	0.71	Gap Void > Tol
Defect_2	2.00	2.42	1.57	2.01	2.00	291.93	0.42	Gap Void > Tol
Defect_3	2.00	2.50	1.35	1.93	2.00	291.93	0.50	Gap Void > Tol
Defect_4	2.00	2.42	1.14	1.92	2.07	141.87	0.42	Gap Void > Tol

	Tol (mm)	Max (mm)	Min (mm)	Avg (mm)	Med (mm)	Len (mm)	+/- (mm)	
Defect_0	2.00	1.85	1.07	1.43	1.43	291.93	-0.15	
Defect_1	2.00	1.85	1.07	1.34	1.35	291.93	-0.15	
Defect_2	2.00	1.57	1.07	1.29	1.28	291.93	-0.43	

	Tol (mm)	Max (mm)	Min (mm)	Avg (mm)	Med (mm)	Len (mm)	+/- (mm)	
Defect_0	2.00	2.21	1.07	1.70	1.71	291.93	0.21	Gap Void > Tol
Defect_1	2.00	2.21	1.07	1.59	1.64	291.93	0.21	Gap Void > Tol
Defect_2	2.00	2.07	1.07	1.55	1.57	291.93	0.07	Gap Void > Tol
Defect_3	2.00	1.85	1.07	1.51	1.57	291.93	-0.15	Stacking Error
Defect_4	2.00	1.35	1.07	1.14	1.14	245.95	-0.65	
Defect_5	2.00	1.50	1.07	1.15	1.07	136.59	-0.50	

Composite Build – ATL/AFP InSitu Quality

InSitu NDE – Jidoka - Continuous Workflow

- **Faster Production Builds**
  – Reduce the time for inspection, done automatically in real-time
- **Higher Product Quality**
  – Build it right the first time
- **Cost Avoidance**
  – Improve the efficiency & throughput
  – Building right from CAD
- **Digital-Twin**
  – Quality Digital-Threads all graphically accessible in the Digital-Twin
- **FAA Certification**
  – Following your procedures accurately & document it fully

THANK YOU FOR YOUR ATTENTION

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