WICHITA STATE UNIVERSITY
NATIONAL INSTITUTE FOR AVIATION RESEARCH

Advanced Manufacturing Technologies with Automation & Artificial Intelligence

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https://www.wichita.edu/industry_and_defense/NIAR/Laboratories/atlas/atlas.php

sme - Aerospace Composite Forum Agenda
July 19-20, 2022
Wichita, Kansas

ATLAS
ADVANCED TECHNOLOGIES LAB FOR AEROSPACE SYSTEMS

Wichita Manufacturing Legacy

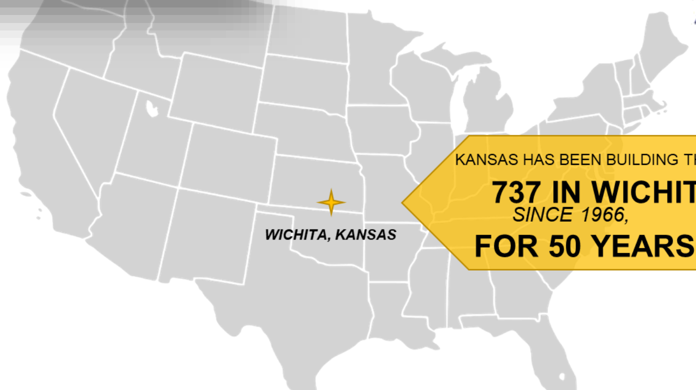
AIR CAPITAL · WICHITA · OF THE WORLD

1943-1946

- 4.2 / day
- 100 / month
- 157,000 manhours down to 20,000

1951-1956

1957-1963



KANSAS HAS BEEN BUILDING THE
737 IN WICHITA
SINCE 1966,
FOR 50 YEARS

AIRBUS
AN EADS COMPANY

BOMBARDIER LEARJET

Beechcraft

Cessna
A Textron Company

BELL

SPIRIT AEROSYSTEMS

B-21 RAIDER
Northrop Grumman B-21

Spirit AeroSystems has over
13,000 EMPLOYEES
IN WICHITA
AND ARE PRODUCING
52 - 737's
a month

787 PRODUCTION – SECTION 41

Bell V-280

Sikorsky CH-53K

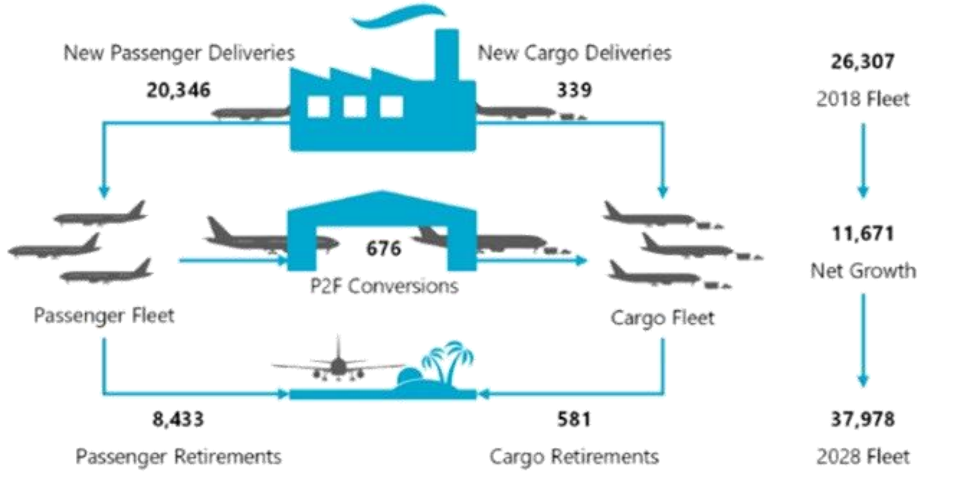
F-35

KC-46A Tanker

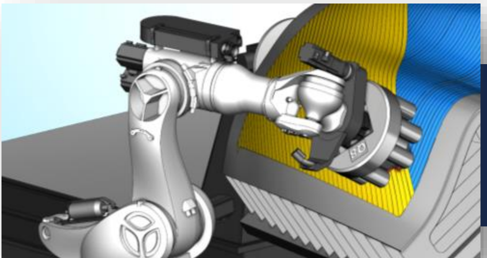
P-8A, P-8I

Background

- Productivity and quality benefits from automated fiber placement (AFP) are becoming more attractive for complex composite components that historically were only possible to build by hand.
    - Dynamic environment provides agility required for flexible rates and adaptive production processes
- Although AFP has significantly improved the production rates/quality, there are still challenges since the process requires integration of multiple disciplines such as robotics, nondestructive inspection (NDI), and process modeling.
- Quality assurance through inspections and process controls are essential to ensure that material is laid up and processed according to specification with appropriate consolidation and with no process-induced defects.
    - Manual inspection process that can consume 20-70 percent of the production time diminishes the benefits of automation to improve production rate, and
    - Operator/training/environment dependent ➔ Inconsistent!



Source: Oliver Wyman Global Fleet & MRO Market Forecasts



Paradigm shift in aerospace manufacturing is required for achieving the demand for high rates and low cost while maintaining airworthiness.

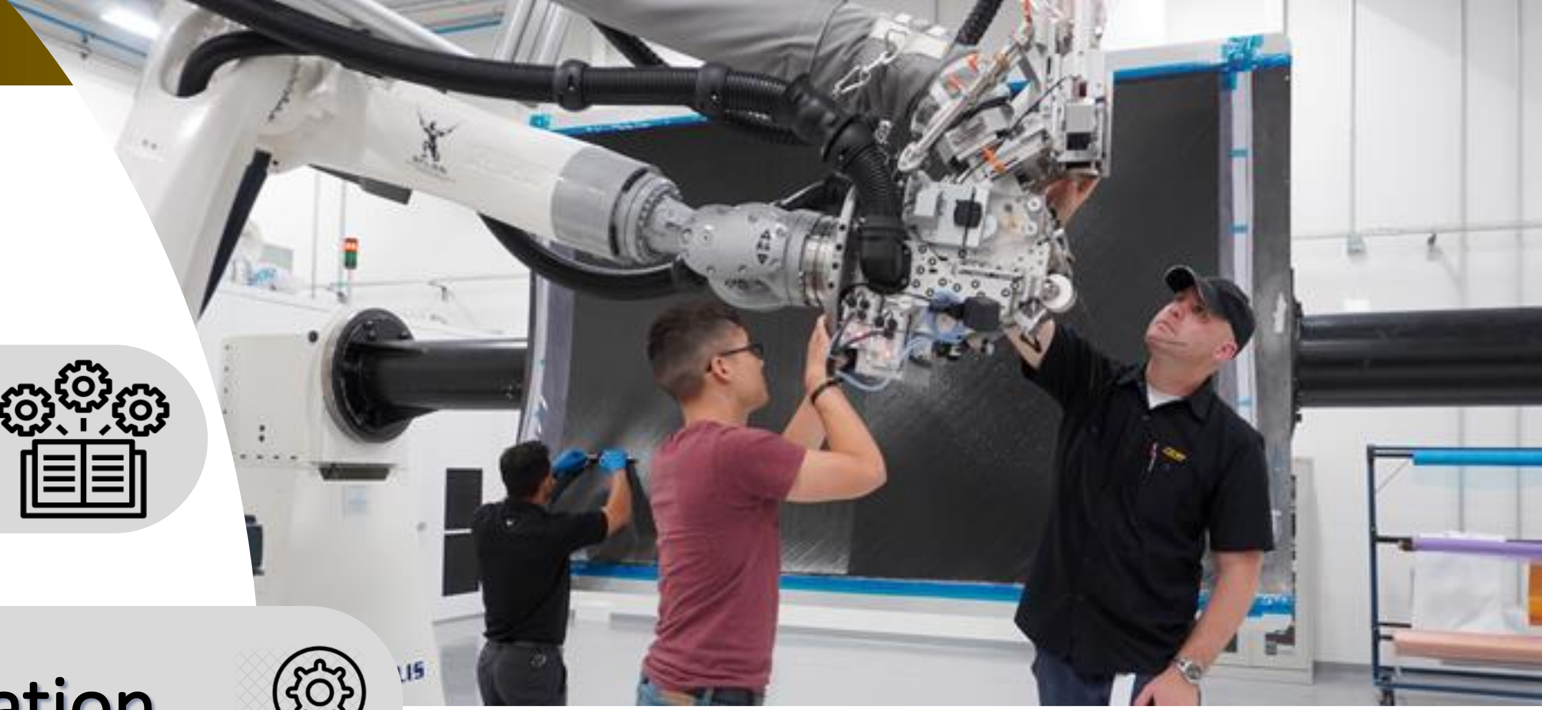
Outline

Automated Manufacturing

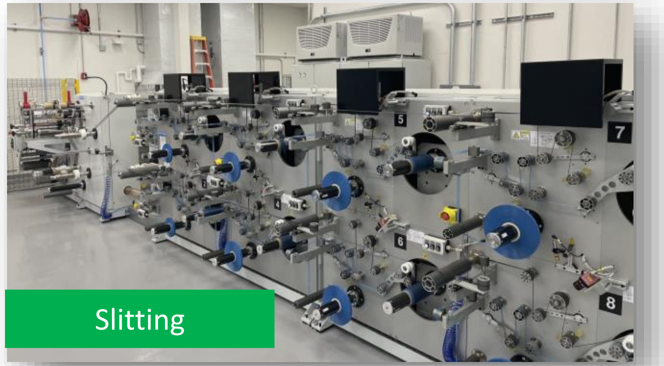
Quality Assurance & Optimization

Expansion of In-Process Inspections

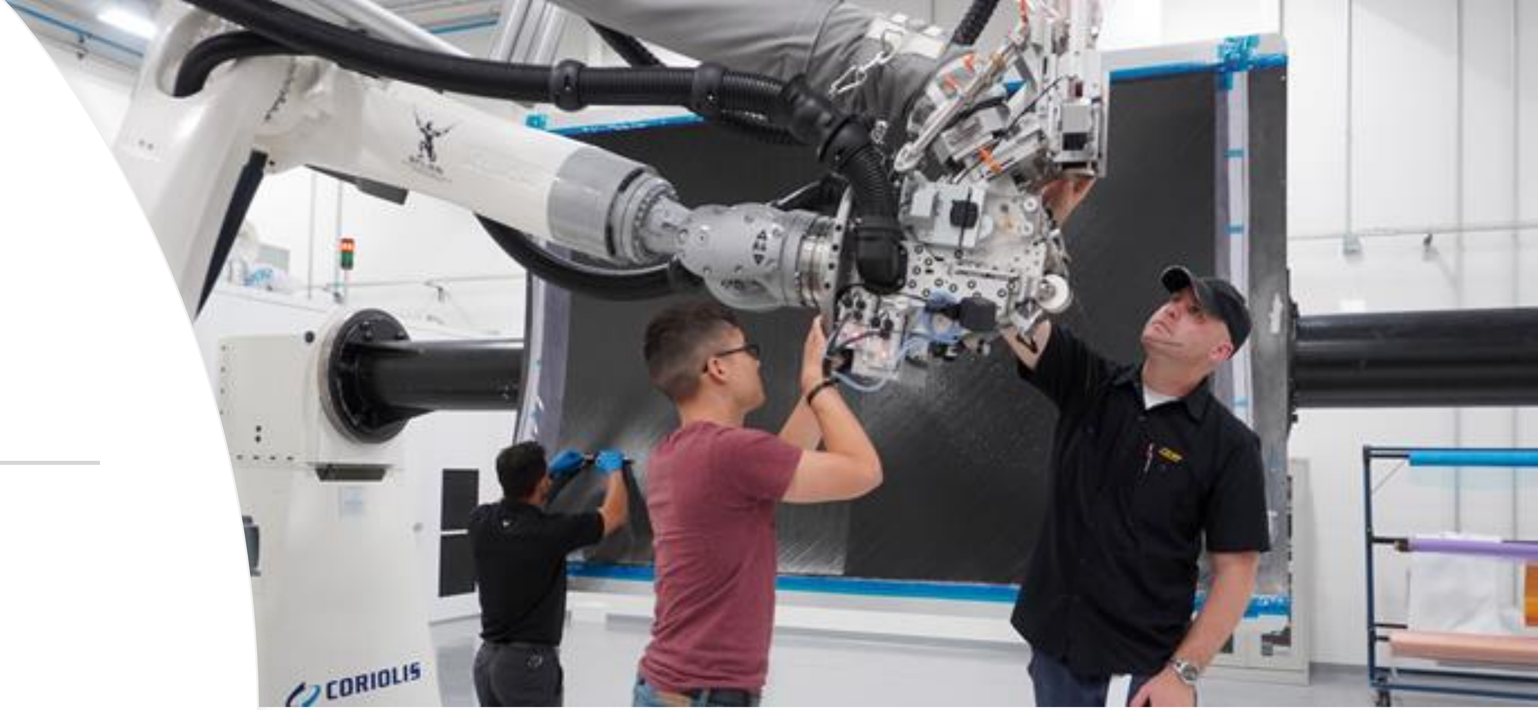
Summary

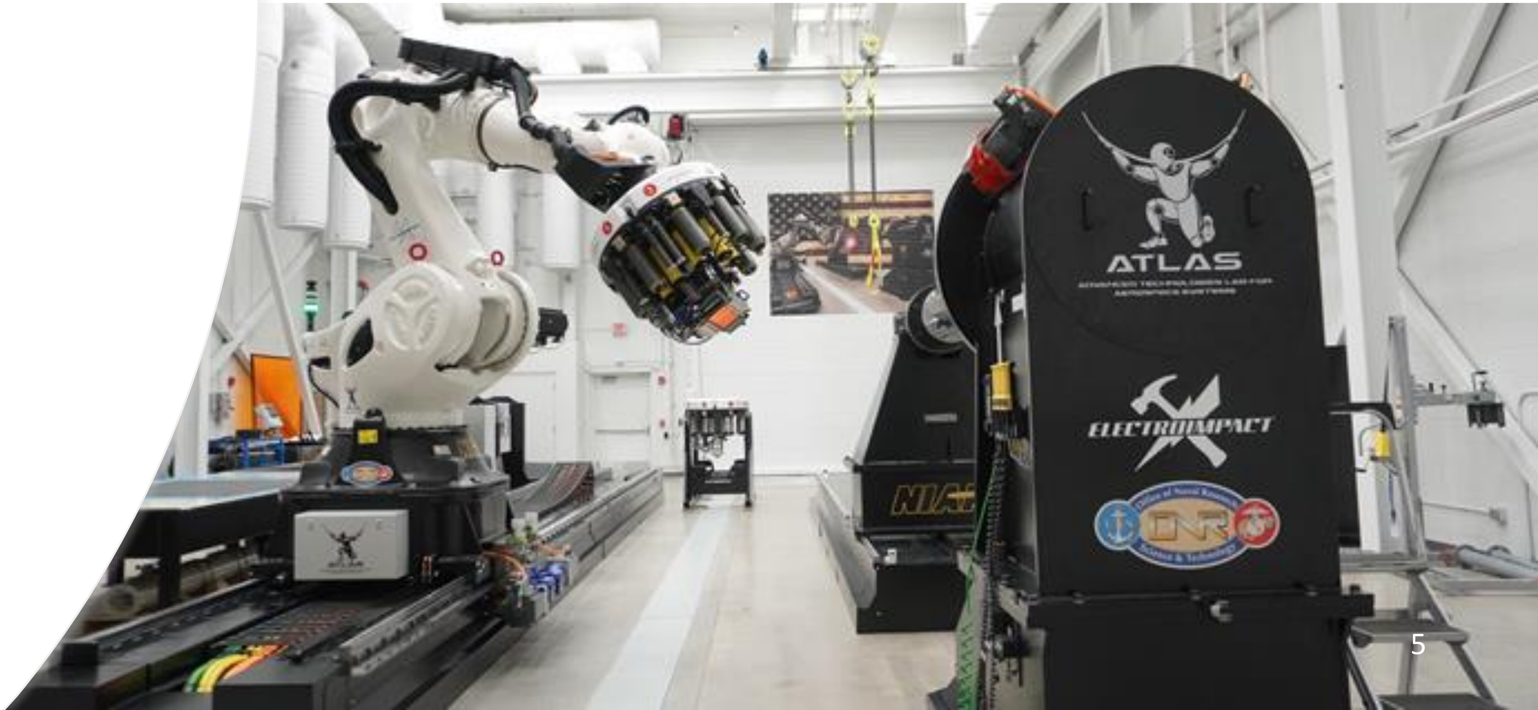


Automated Manufacturing Technologies

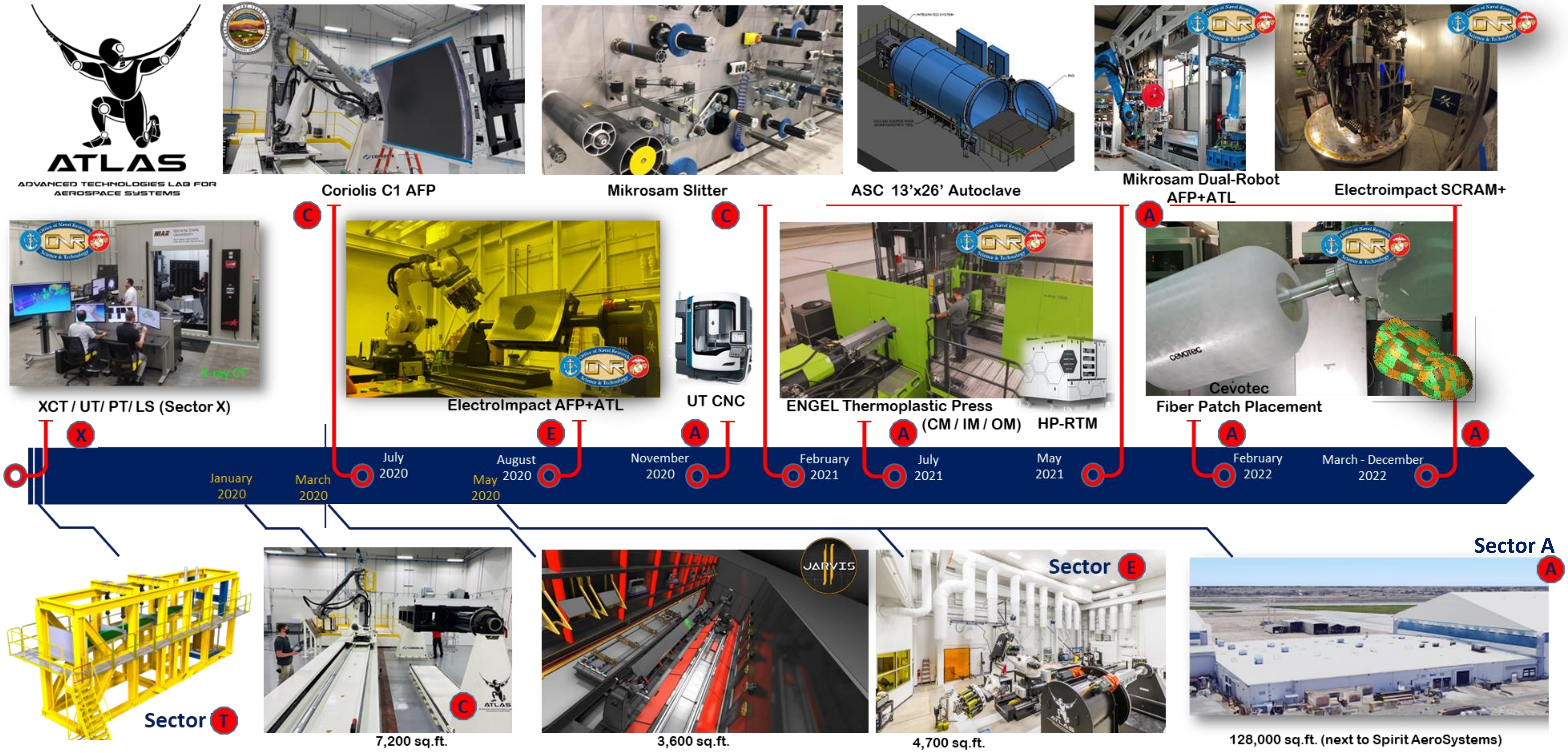


Slitting





Accelerated Decision-Making through Advanced Prototyping…



Comprehensive Digital Thread

Prepregging
(Thermoset & Thermoplastic)

Slitting
(Advanced QA)

Processing
(Cure Kinetics)

Prototype Tooling
(AM + AFP)

Manufacturing
(AFP, ATL, FPP, SCRAM^{++})

Inspections
(XCT, PT, LS, UT, EC)

Manufacturing Simulations
(Process Optimization)

Testing
(Multi-Scale & Env.)

Joint Autonomous Repair Verification and Inspection System (JARVIS II)

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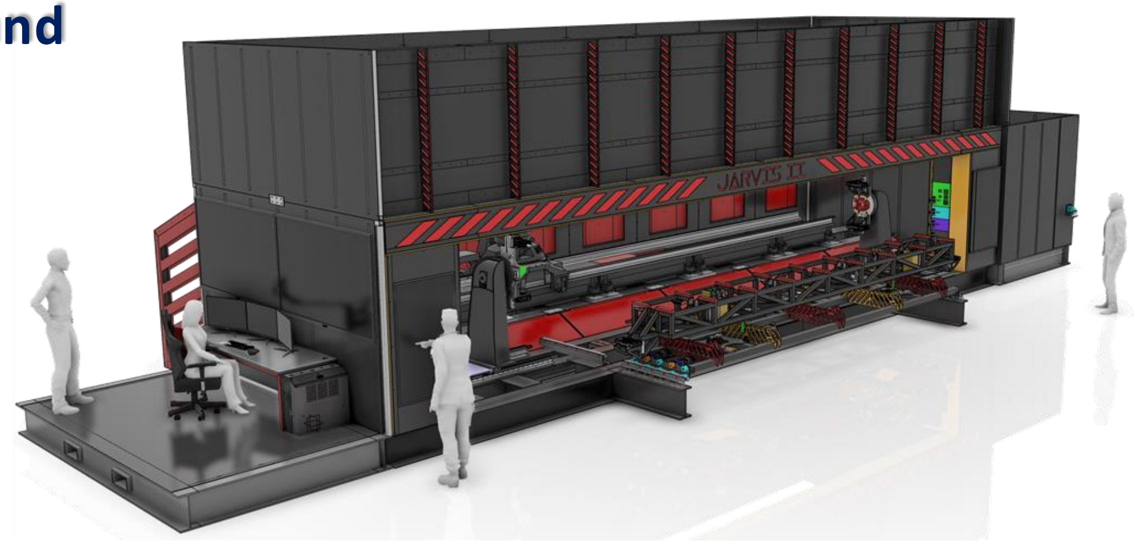
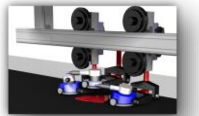


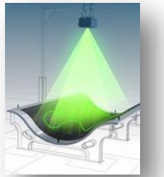
DEVCOM AVIATION & MISSILE CENTER

CCAD



Reverse Engineering

Laser Projection



Nondestructive Inspections

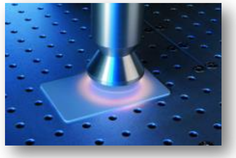
JARVIS

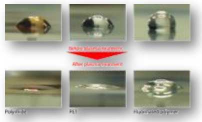
Robotics & Automation

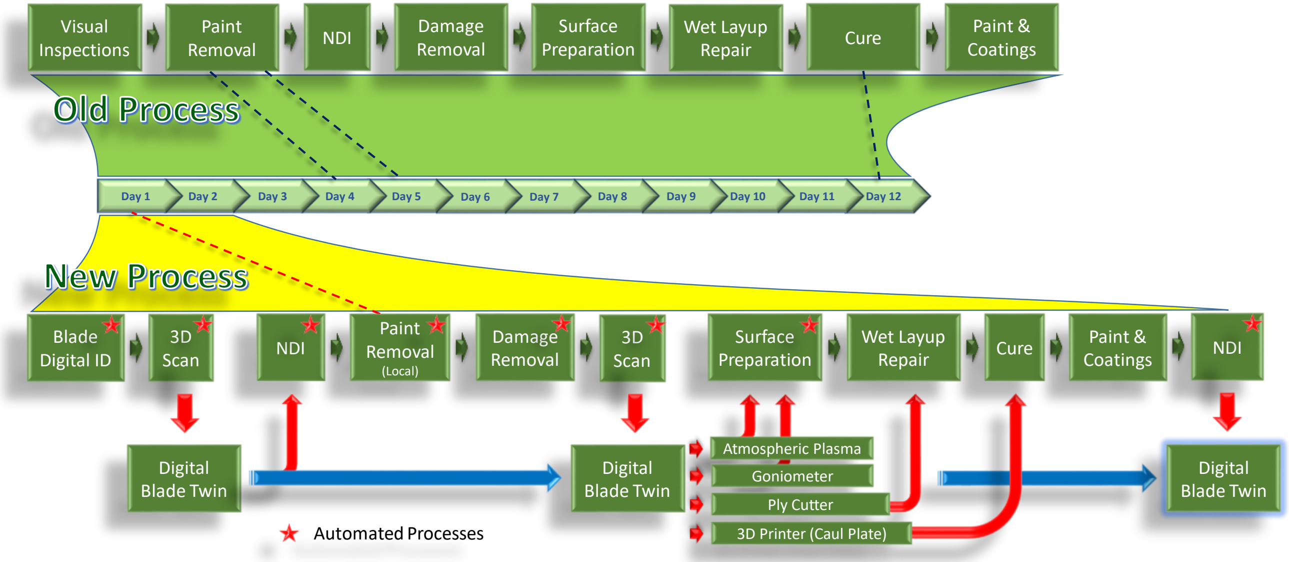
Automated Ply Cutting

Composite Repair
Damage Removal
Surface Preparation
Surface Analysis

Processing
In-situ Consolidation
Thermal Management







Repair and nondestructive inspection (NDI) of Black Hawk main rotor blades to improve mission readiness through integration of advanced technologies.

Digital Thread for Sustainment

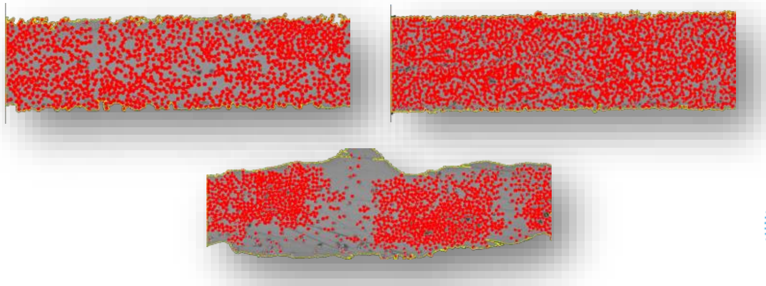
Accelerated Insertion of Advanced Materials

AFRL THE AIR FORCE RESEARCH LABORATORY LEAD | DISCOVER | DEVELOP | DELIVER

MODELING FOR AFFORDABLE SUSTAINABLE COMPOSITES (MASC)

NCAMP NATIONAL CENTER for ADVANCED MATERIALS PERFORMANCE

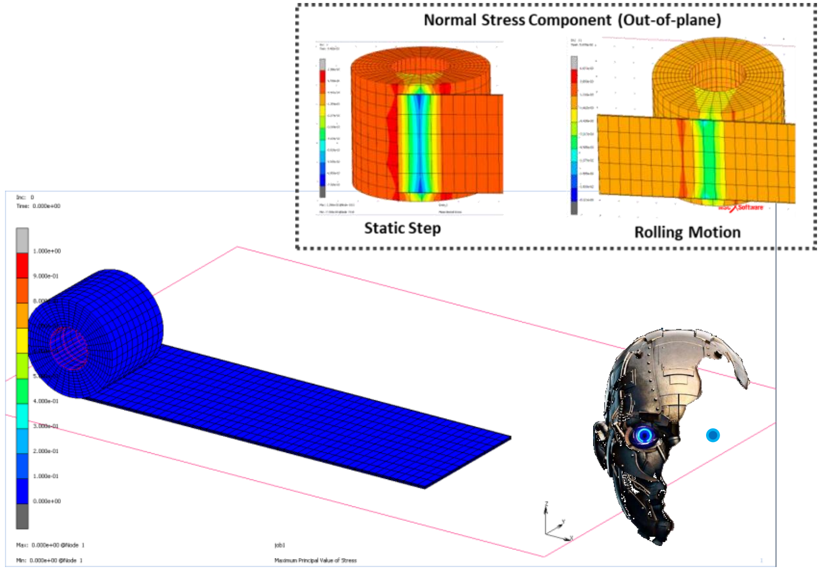
Slit Tape Characteristics



SOLVAY
victrex
TORAY Toray Advanced Composites
HEXCEL

Material Type	Vendor	Number / Name	Composition	GSM	Slit-Width
Thermoset	Solvay	30202946	IM7/5320-1	145	½”
	Toray	P172EBN-19	T1100G/3960	192	¼”
Bismaleimide	Solvay	BMI	IM7/5250-4	145	¼”
Dry Fiber Infusion	Hexcel	HITAPE	IM7/1078-1	280	¼”
Thermoplastic	Victrex	AE250	IM7/LMPAEK	148	¼”
	Solvay	APC	AS4D/PEKK-FC	145	¼”
	Toray	TC1225	T700/LMPAEK	145	¼”

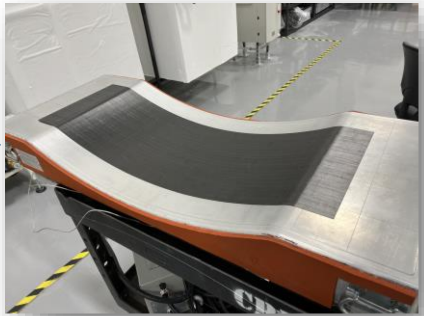
Process Development



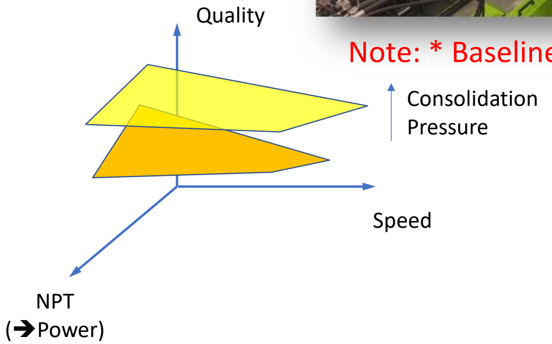
Machine Variability & Equivalency

In-situ Consolidation of AFP Thermoplastics

	Baseline*	Fairing			Fuselage Panel	Tool-less AFP	
Tool	Yes	Yes			Yes	No	
Tool Heating	Yes	Yes	Yes	No	No	No	
Curved Part	No	No	Yes	Yes	Yes	No	Yes
Equipment	AFP+AC/Oven AFP+Press	EI-1 (Laserline), EI-2 (VSSL), Coriolis, and Mikrosam			EI-1 (Laserline), EI-2 (VSSL), and Coriolis	Mikrosam	



Note: * Baseline require post-consolidation



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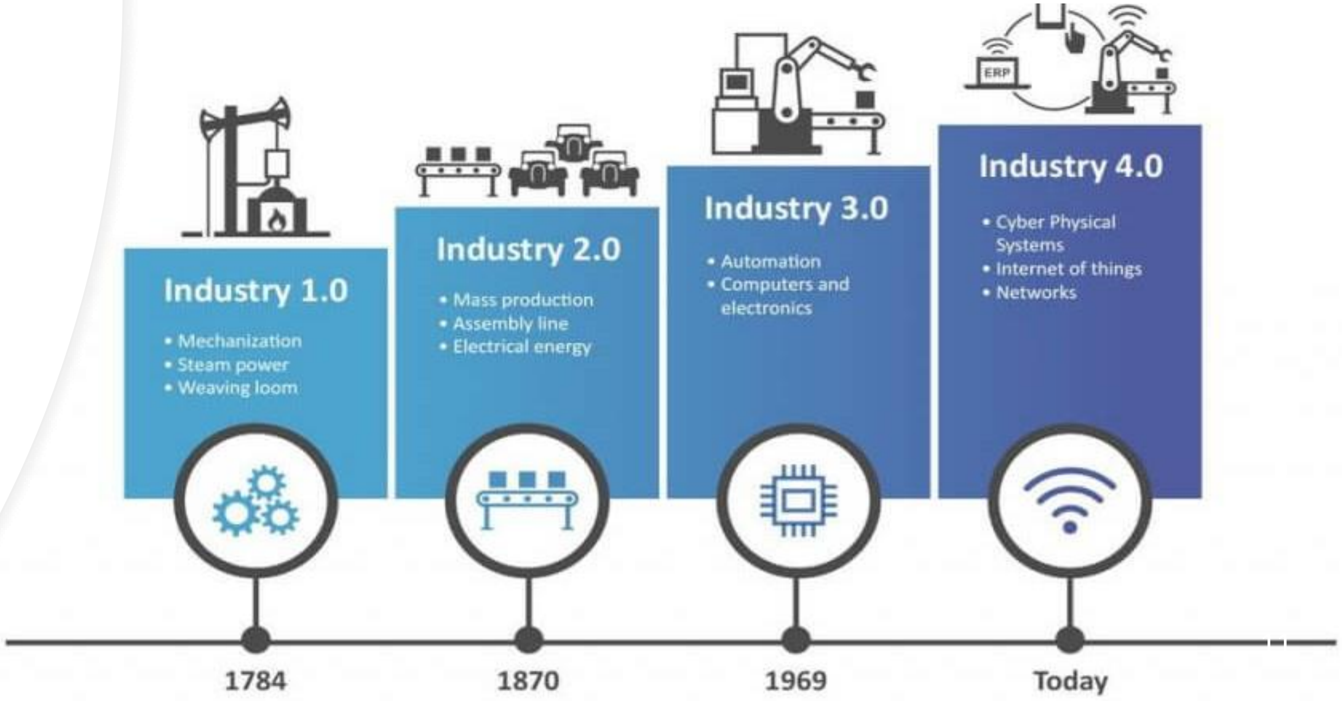
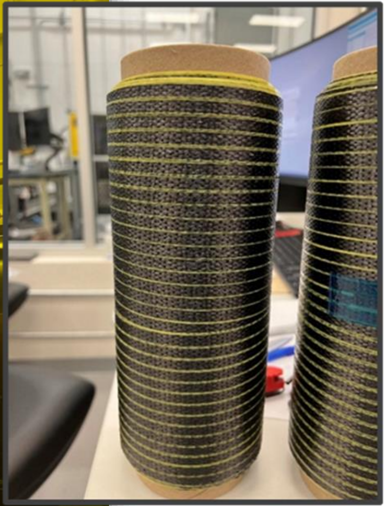
MODELING FOR AFFORDABLE SUSTAINABLE COMPOSITES (MASC)

Quality Assurance & Process Optimization

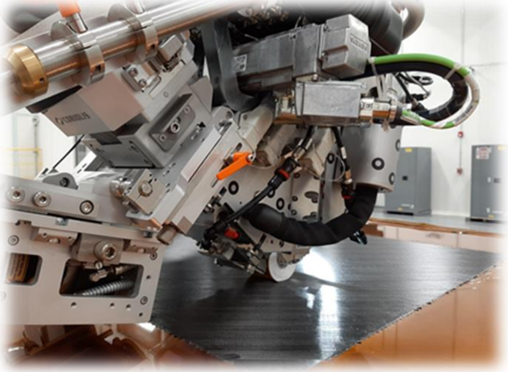


Quality Assurance of AFP/ATL



Inspections are carried out after every layer to ensure quality

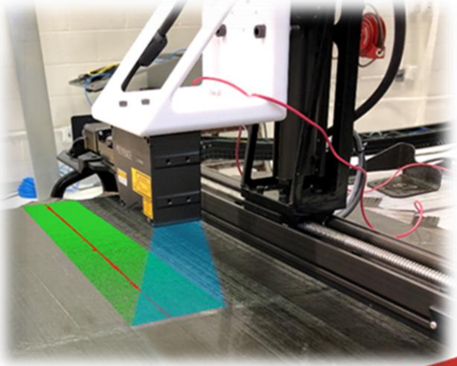
Road Map

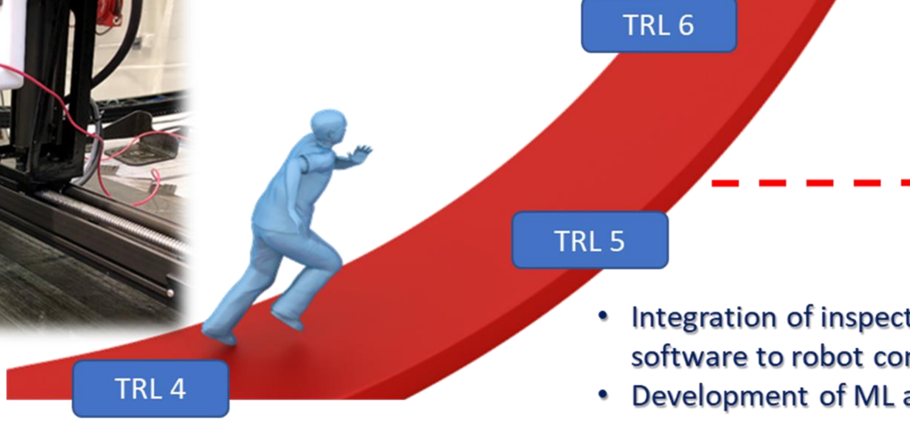


TRL 7

- Demonstration of system capability for DMT
- Demonstration of EoD interrogation
- DOE for PoD on 3D part
- Demonstration of AI algorithm for process optimization

- Integration of inspection system AFP robot Verification of ML algorithm for interpreting AFP defects in 3D space
- Development of AI algorithm for providing feedback to robot controls



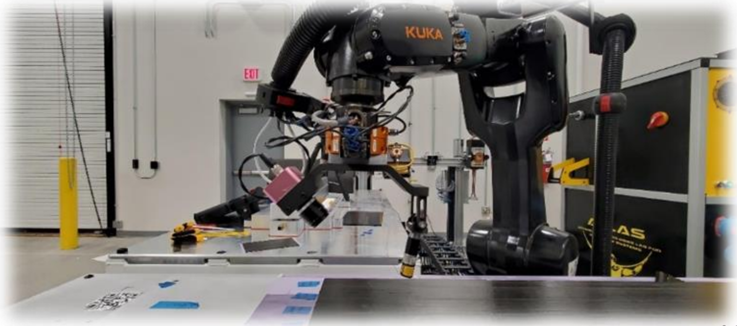


Manufacturing Environment

Laboratory Environment

TRL 5

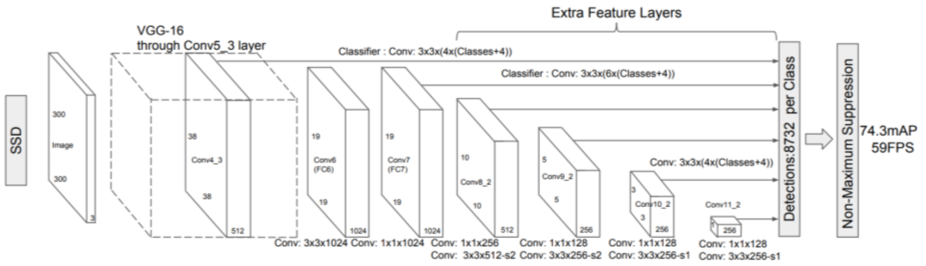
- Integration of inspection system and software to robot controls
- Development of ML algorithm for interpreting AFP defects
- Development of AI algorithm for providing feedback to robot controls

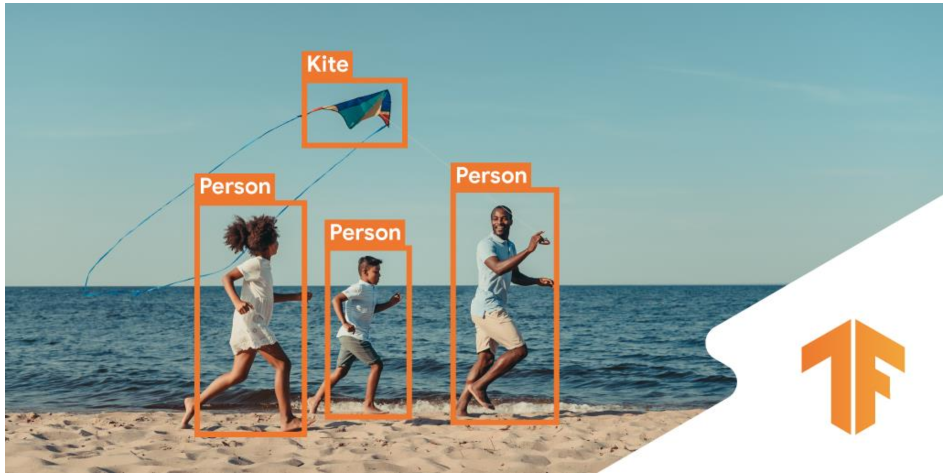


TRL 4

- Manual inspections for detecting AFP defects
- Software for converting point cloud into a defect map
- DOE for PoD on flat panels

Machine Learning Model

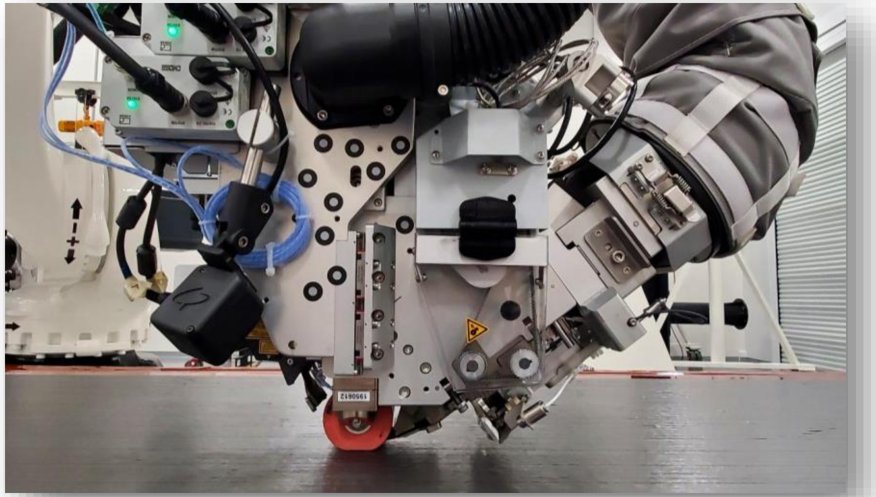




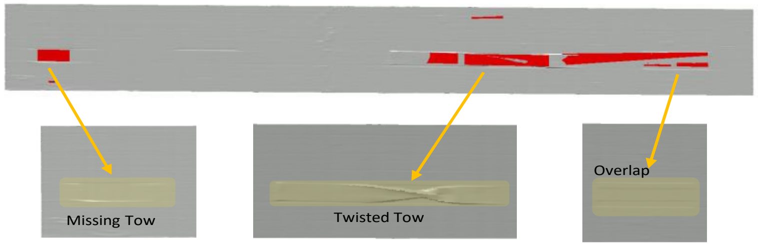
- Use Existing Machine Learning Architectures and Frameworks for object detection and classification.
- Develop a methodology to generate large amounts of training data.
  - Machine Learning Models can be trained to detect selected manufacturing features/defects.
  - Accuracy of the detection (PoD) is highly dependent on the training datasets and generation techniques.
- Develop optimal parameters for machine learning model training.
  - Analysis of actual defect characterization can be used to generate large amount of training datasets for machine learning models.
  - The models used in this research are primality used for classification of defects and features. Additional techniques are required to pinpoint the actual defect location.
- Train ML models to categorize critical defects/features

- Image classification ML Model – TensorFlow 2 Object Detection API
- General use – Train ML model with common objects to be classified
- AFP in-process inspection use – Train ML model with defect data.
  - Convert defect data to images and use the model for inspection, analysis, and detection

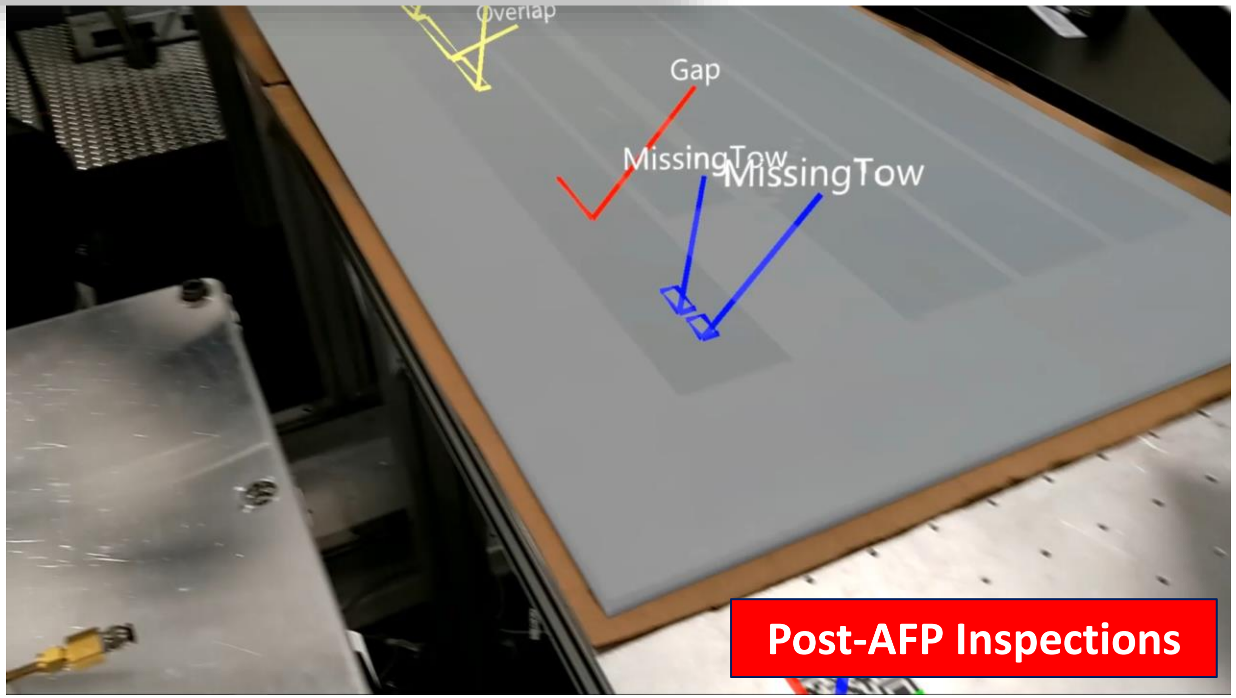
In-process AFP Manufacturing Inspection System (IAMIS)



In-process View



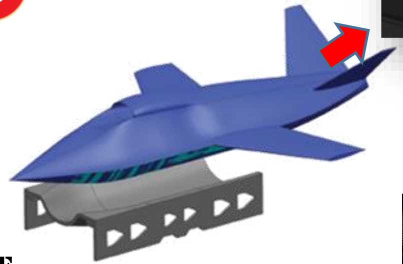
I A M I S
INPROCESS AFP MANUFACTURING INSPECTION SYSTEM



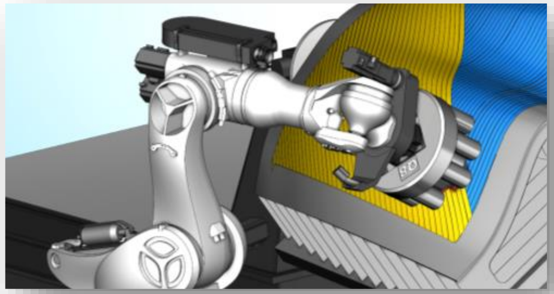
Post-AFP Inspections

Digital Manufacturing Twin (DMT)

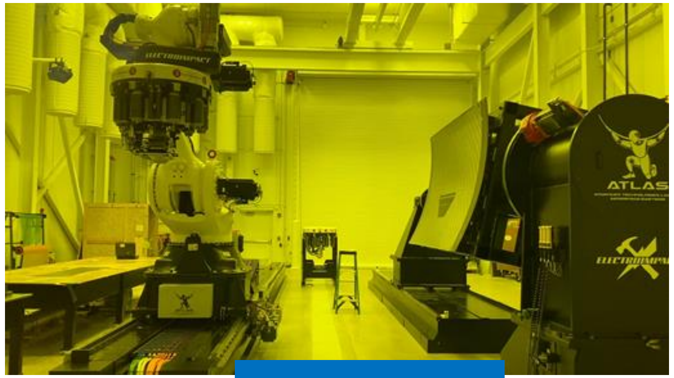
MODELING FOR AFFORDABLE SUSTAINABLE COMPOSITES (MASC)



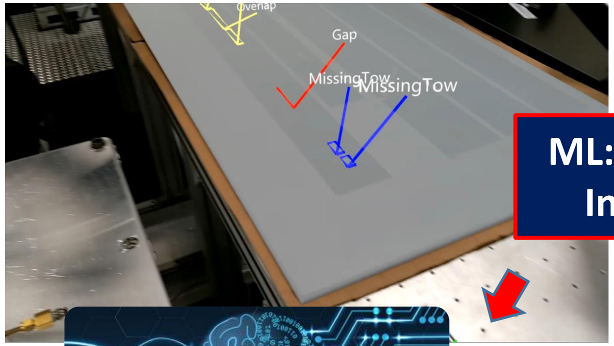
Computer-Aided Design



Manufacturing Simulations

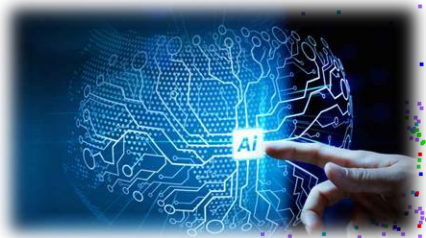


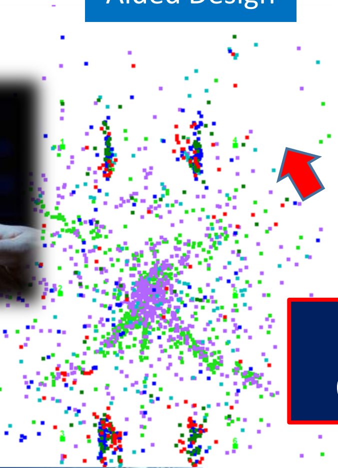
Automated Manufacturing



ML: In-Process Inspection

Lifecycle Management



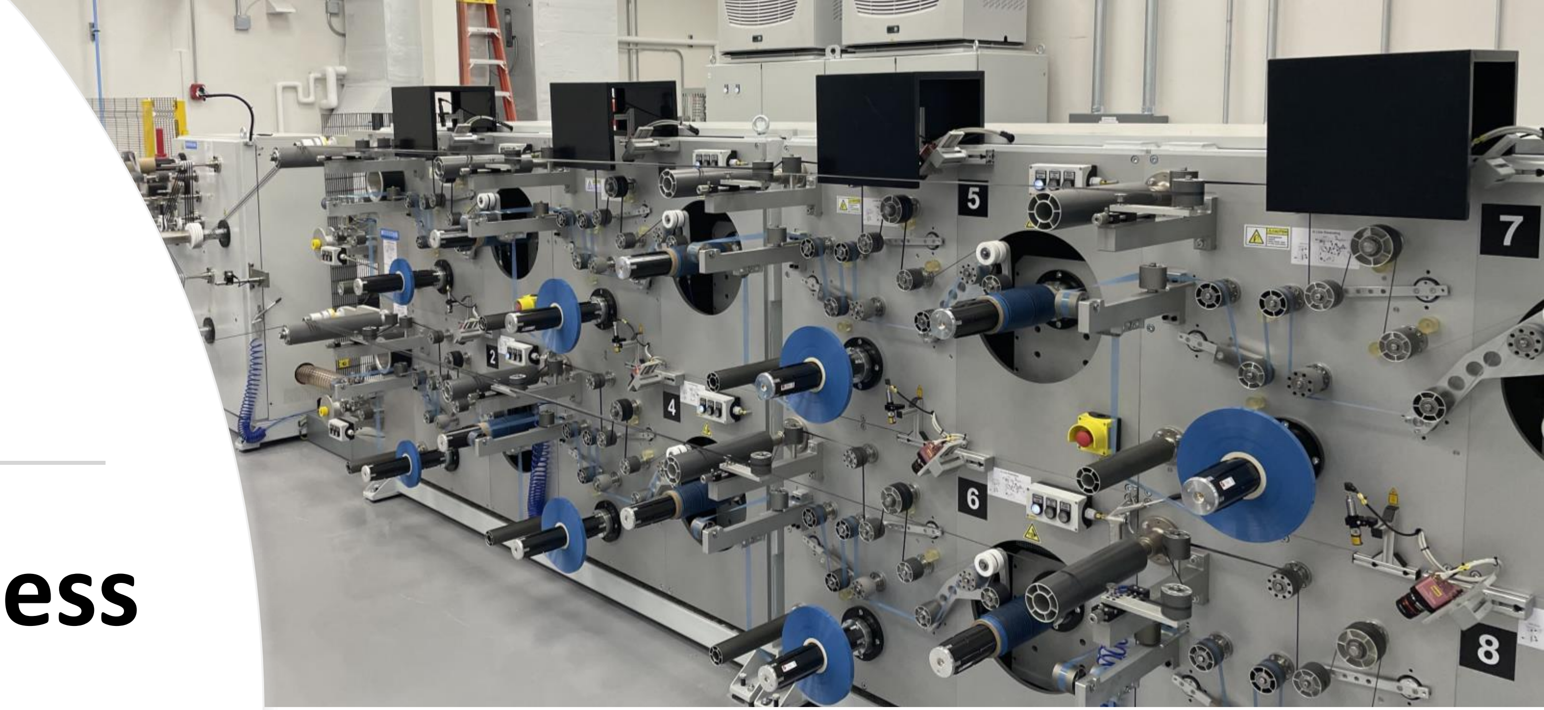


AI: Process Optimization

Increase Rate, Improve Quality, and Reduce Cost

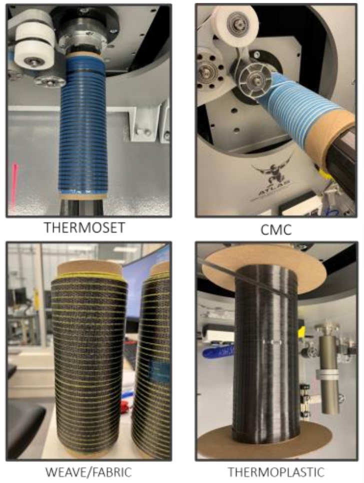
- Detecting manufacturing defects that are above certification basis through ***machine-learning algorithms*** for reducing time-consuming manual inspection processes that require interrupting the manufacturing process, and
- Using ***artificial intelligence*** for identifying manufacturing anomalies for optimizing process parameters (ex, lay down speed, heat input, compaction force, steering radii, etc.) in order to reduce manufacturing defects.

Expansion of In-Process Inspections

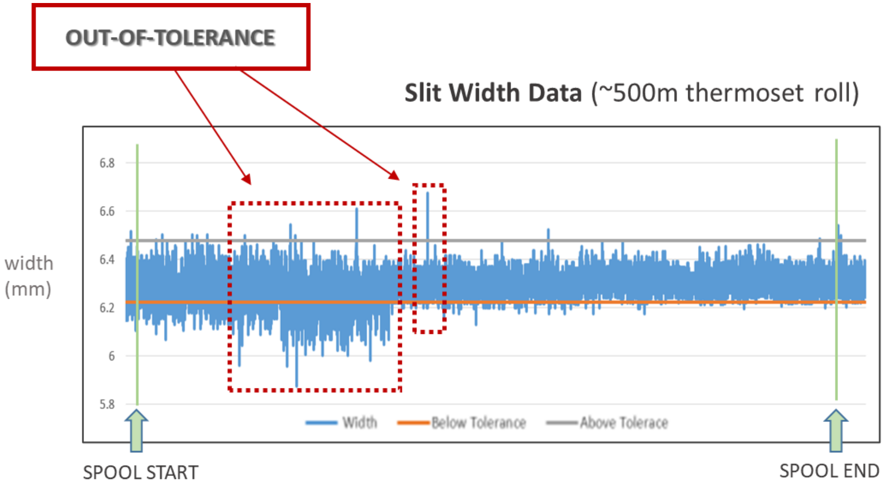


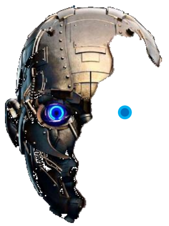
Prepreg Slitting

- IPLIS (In-Process Laser Inspection System)
  - Detect: Fuzzballs, FOD, Splice, Twist, Out of tolerance
- Hybrid: laser triangulation technique coupled with a high-resolution line scanning optical camera
  - Compute the peak position of a line with sub-pixel accuracy.
  - High speed (up to 18,000 fps) and detection accuracy.
- Quality Management System



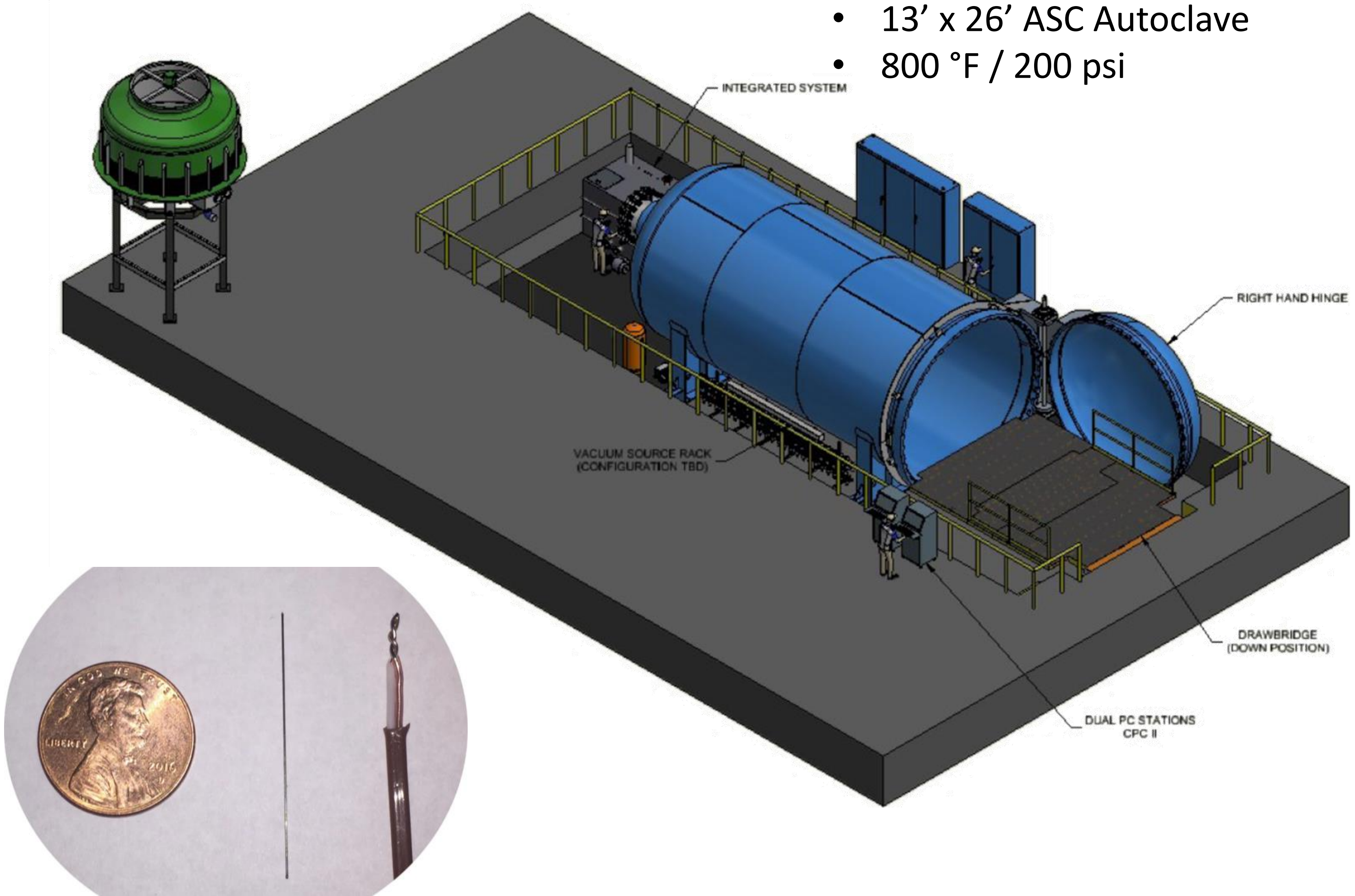
Slitting Specification & Effects of Defects



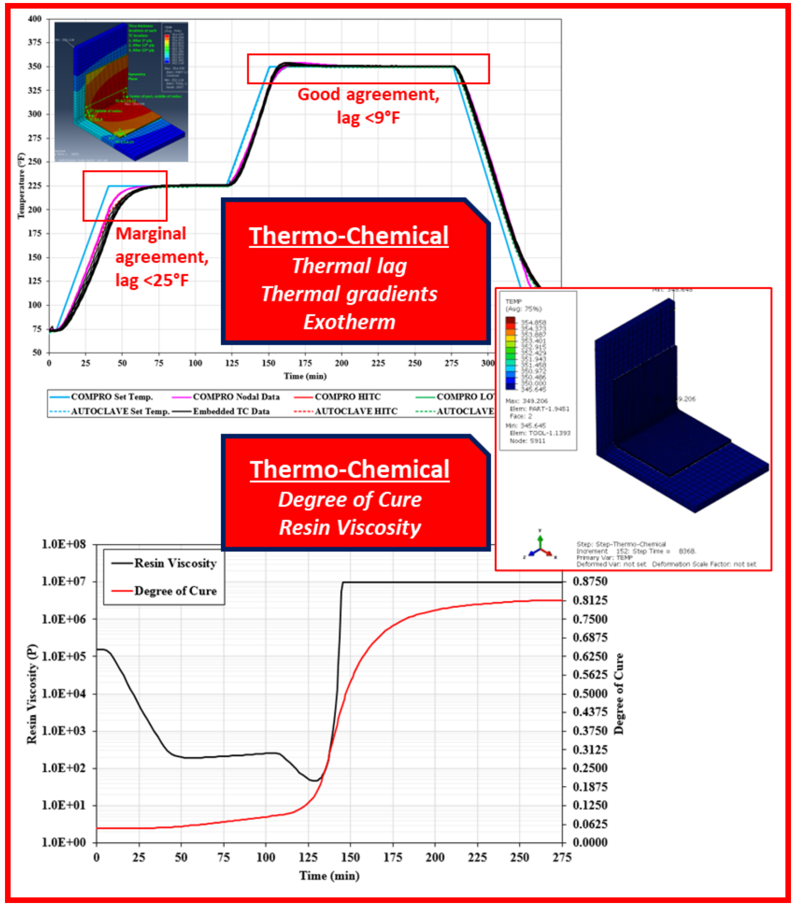


Material State Monitoring & Autoclave Control

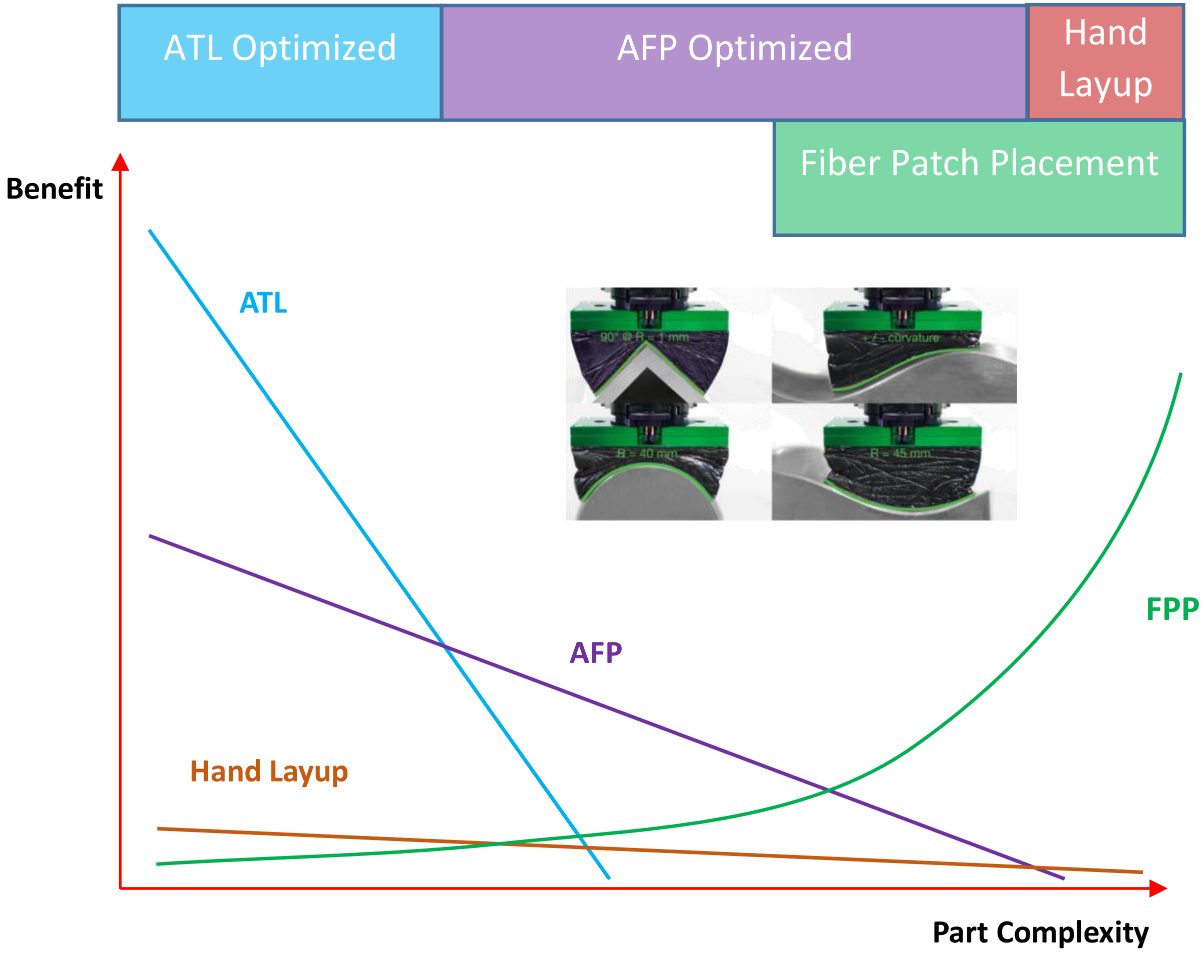
- 13' x 26' ASC Autoclave
- 800 °F / 200 psi

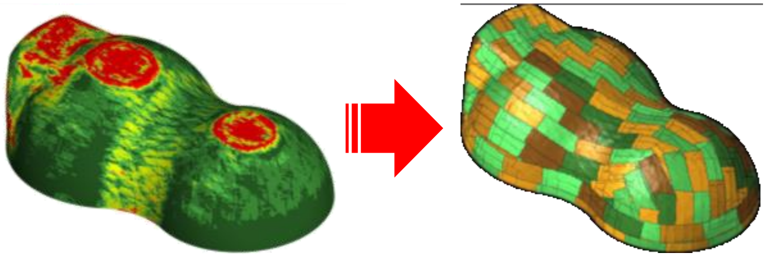


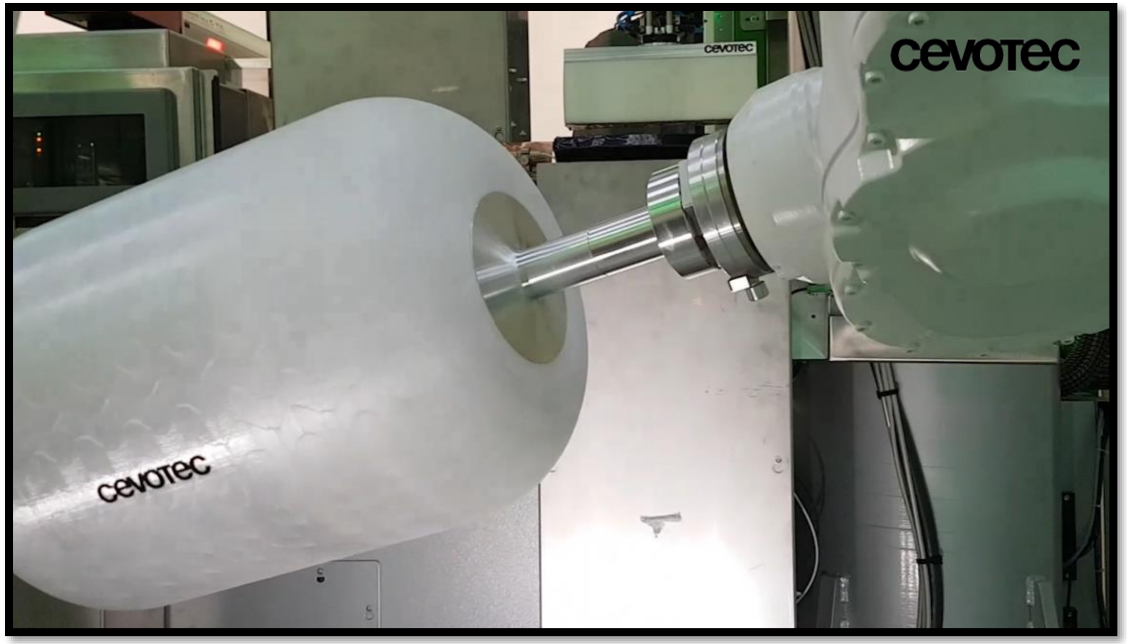
In-situ process monitoring with wireless sensors



Fiber Patch Placement (FPP)



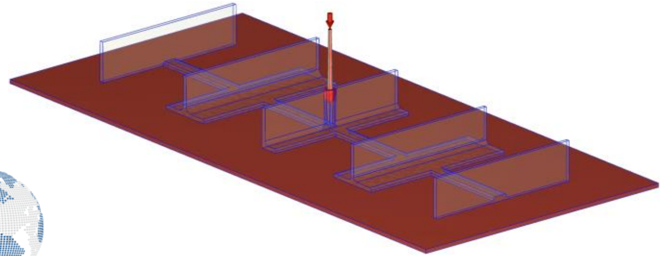


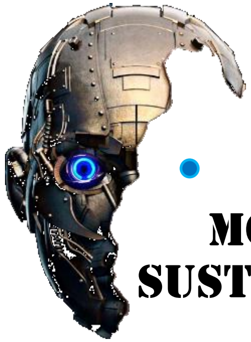


Over-Molding & HP-RTM

Clamping Force: 1,900 US Ton
Mold Size: 5.7 x 7.1 ft
Integrated HP-RTM

High-Rate Manufacturing





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MODELING FOR AFFORDABLE SUSTAINABLE COMPOSITES (MASC)

Summary

- In order to meet the demand , while ensuring safety, a paradigm shift in aerospace manufacturing is required for achieving the demand for high rates and low cost while maintaining airworthiness.
  - Recent advances in materials and heating technologies like laser and pulsed light solutions have enabled the automated manufacturing
  - In order to take full advantage of automation, it must be coupled with advanced materials, ML for decision making and AI for process optimization, and trained workforce.
  - Matured automated technologies from automotive can be implemented in aerospace, but require process optimization for achieving aerospace quality requirements
- The proposed IAMIS integrated robot controls enhanced with ML and AI framework improves manufacturing rate and quality, while reducing overall manufacturing cost, impacting the following key performance parameters (KPPs) associated with AFP:
  - ***Versatility*** – Human error associated with various levels of operator experience will be eliminated. In addition, MLA incorporated into the system will reduce recurring defects (improve quality) in part and reduce scrap rate (reduce overall cost).
  - ***Time to Deploy*** – IAMIS eliminates the need for costly and time-consuming secondary inspection processes that cause more than 20 percent of the manufacturing time (increase manufacturing rate).
  - ***Total Cost of Ownership*** – Lightweight low-cost inspection system can be incorporated to an AFP system with MLA to manufacturer quality parts with low scrap rate at a higher efficiency. Elimination of secondary inspection step not only save time, but also the cost of equipment, programming, and operators.

Acknowledgement

- **NIAR ATLAS Research Team**
  - Dr. Waruna Seneviratne and Dr. John Tomblin (Principal Investigators)
  - Tharaka Nandakumara (Research Engineer)

NIAR | Wichita State University | National Institute for Aviation Research

- **Office of Naval Research (ONR):** Development of Machine-Learning Algorithm for Reducing Defects in Automated Fiber Placement Process - Contract No. N00014-21-1-2687.
  - Dr. Anisur Rahman (Program Manager)

Department of the Navy | ONR | Science & Technology

- **Air Force Research Lab (AFRL):** Modeling for Affordable Sustainable Composites (MASC) - Contract No. FA8650-19-C-5212.
  - Dr. David Mollenhauer (Program Manager)
  - Dr. David Kingsley
  - Ms. Angela Babian

AFRL | The Air Force Research Laboratory | Lead | Discover | Develop | Deliver