



IACMI Facilities and Capabilities Update

Dale Brosius

CCO

February 1, 2017



Institute for Advanced Composites Manufacturing Innovation



Vehicles
Michigan

Wind Turbines
Colorado



Focus Areas

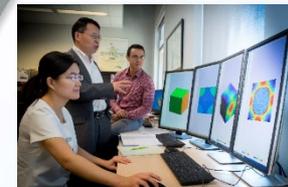
Composite Materials & Process Technology
Tennessee



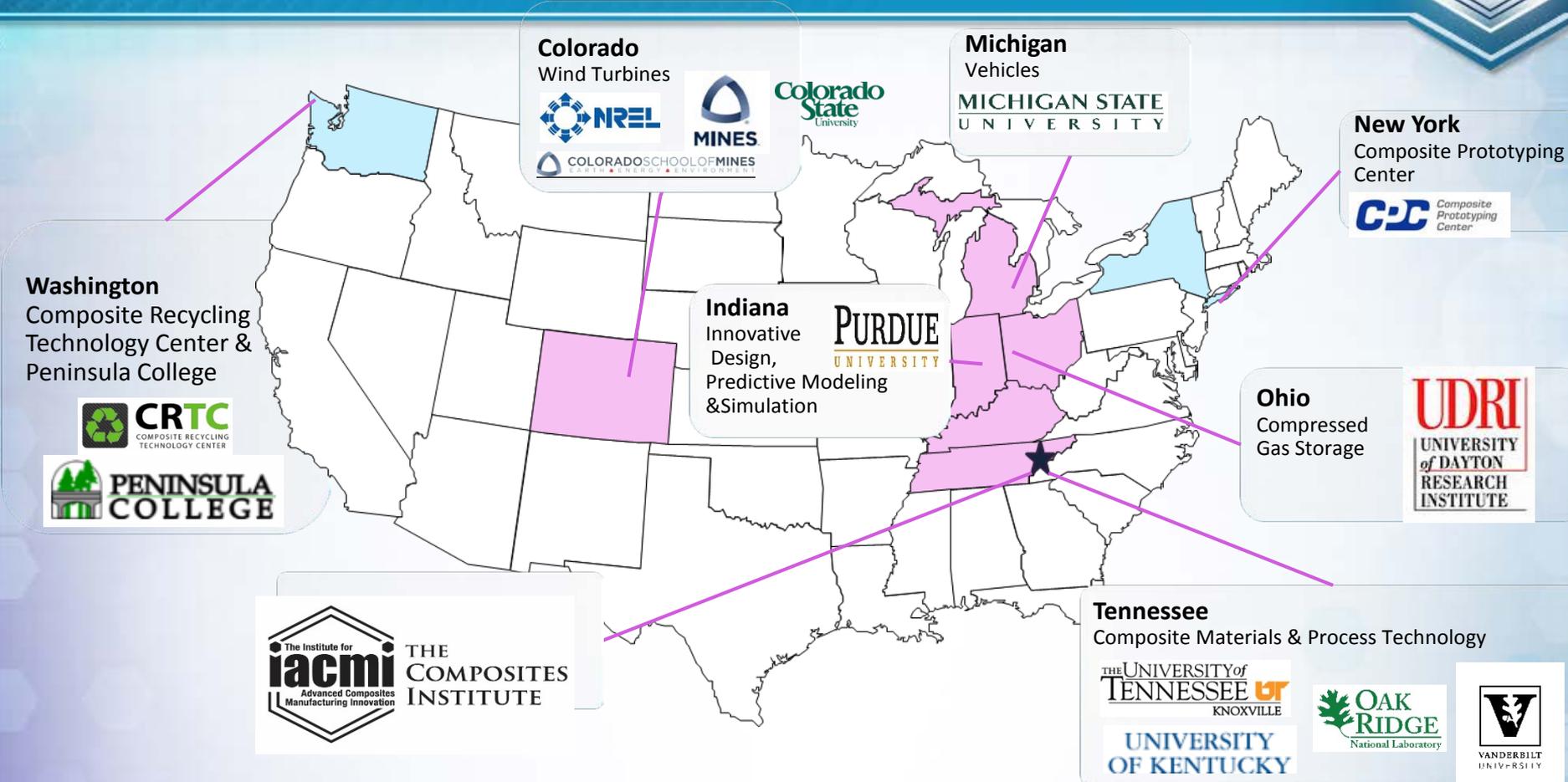
Compressed Gas Storage
Ohio



Innovative Design, Predictive Modeling & Simulation
Indiana



IACMI – A National Institute for Advanced Composites



- Technical Goals:**
- Lower carbon fiber–reinforced polymer (CFRP) cost
 - Reduce CFRP embodied energy
 - Improve composite recyclability into useful products

Scale-up Across IACMI Core Partners



Solution Spinning Line

Carbon Fiber Technology Facility

Pultrusion Pilot/Full Scale

Sub-Scale Blade Prototyping

Full Scale Component Prototyping

KY

TN

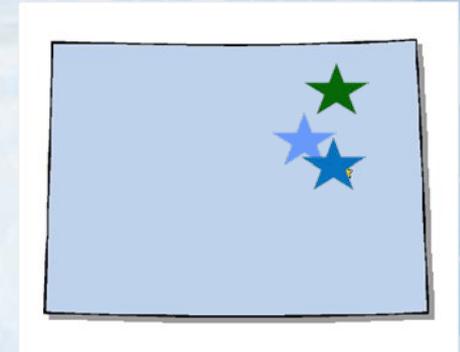
TN

CO

CO

IN





Wind Turbines



IACMI Wind TA Composites Manufacturing and Education Technology (CoMET) Facility



- Manufacturing space focused on composite manufacturing innovation
- 55' x 200' – 10,000 sq. ft.
- Adjacent to blade test facility
- Full-scale blade component manufacturing



IACMI Composites in Wind Demonstration



- NREL/NWTC hosted the IACMI 'Composites in Wind' Demonstration at the newly renovated CoMET facility on June 14 and 15, 2016
- Over 150 attendees from industry, academia and government participated in interactive composite manufacturing demonstrations
- The event successfully opened the new NREL manufacturing space that will focus on composite manufacturing innovation and workforce development
- Attendees enjoyed a tour of the NWTC field and structural testing facilities



IACMI Wind TA CoMET Facility Capabilities



- Rapid prototyping of new blade materials and production methods
- Full scale blade component tooling and fixtures (root, spar cap, tip, shear web)
- Infusion (VARTM), pultrusion, pre-preg, RTM, hand lay-up (small parts)
- Polyester, vinyl-ester, epoxy, thermoplastic / fiberglass, carbon fiber
- Comprehensive composite production equipment (mixers, vacuum, dispensers)
- Molding, assembly, bonding, finishing
- Segmented 3D printed tooling
- Large area rapid NDE / In-situ measurement / Post molding inspection
- Performance Modeling and manufacturing Simulation
- Composite panels, material test coupons and components
- Structural testing: coupons, component, sub-structure, joints
- Workforce training: composite technicians and engineers

Dual Crane System

- ◆ Two crane system permits handling of long parts like blades and tools
- ◆ Independent or slaved controls
- ◆ 2 x 10 ton capacity
- ◆ Rails run length of facility



MVP Automated Dispensing Machine

- ◆ MVP automated mixing and dispensing machine
- ◆ Designed for use with polyesters, vinyl esters and ELIUM® thermoplastic



Graco Automated Dispensing Machine

- ◆ Graco automated mixing and dispensing machine
- ◆ Designed for use with epoxy infusion systems



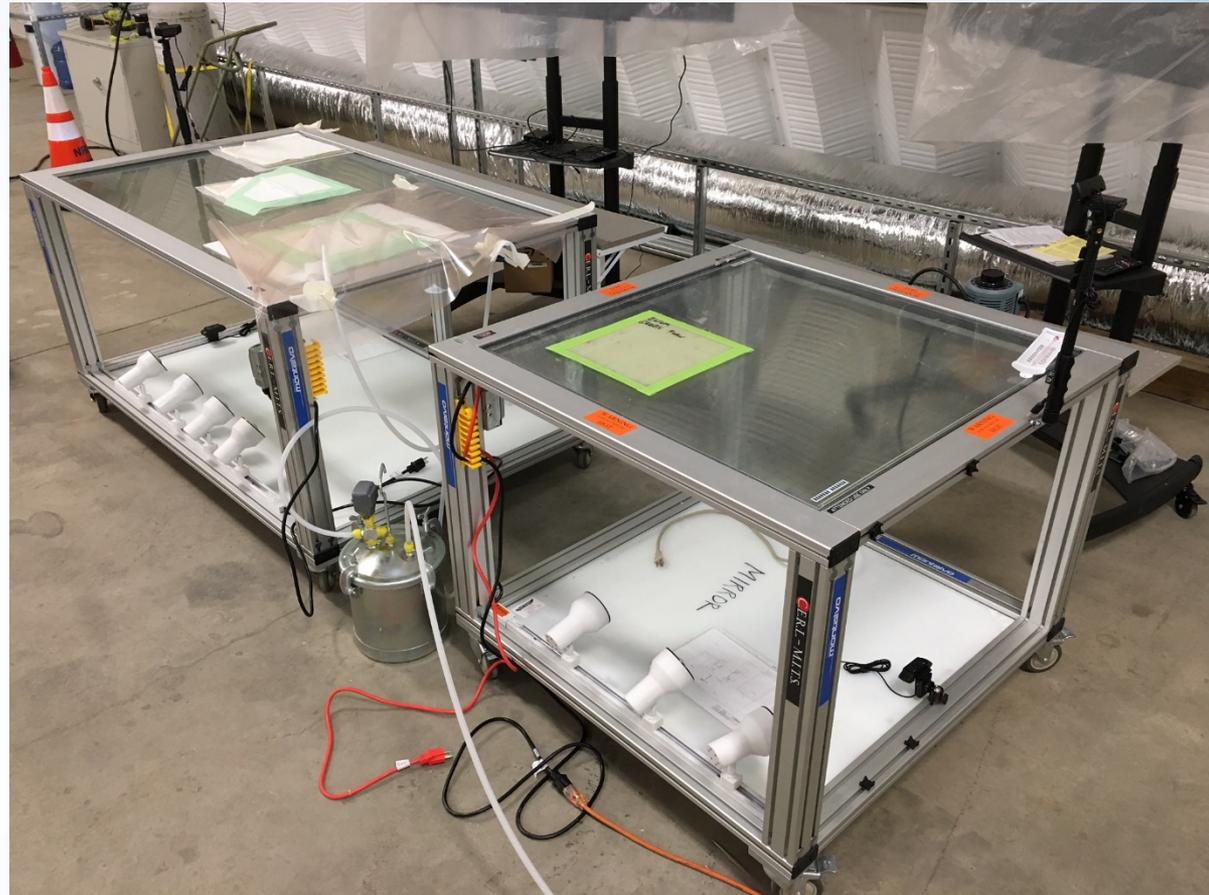
Large Capacity Vacuum Pump

- ◆ Multiple station valves enable up to four individual vacuum sources for larger infusions



Glass molding tables

- ◆ Glass tables enable two side observation of infusion flow
- ◆ Smaller of the two tables is heated to study effects of temperature



Wind Blade Tooling



9m BSDS blade components
Courtesy TPI Composites

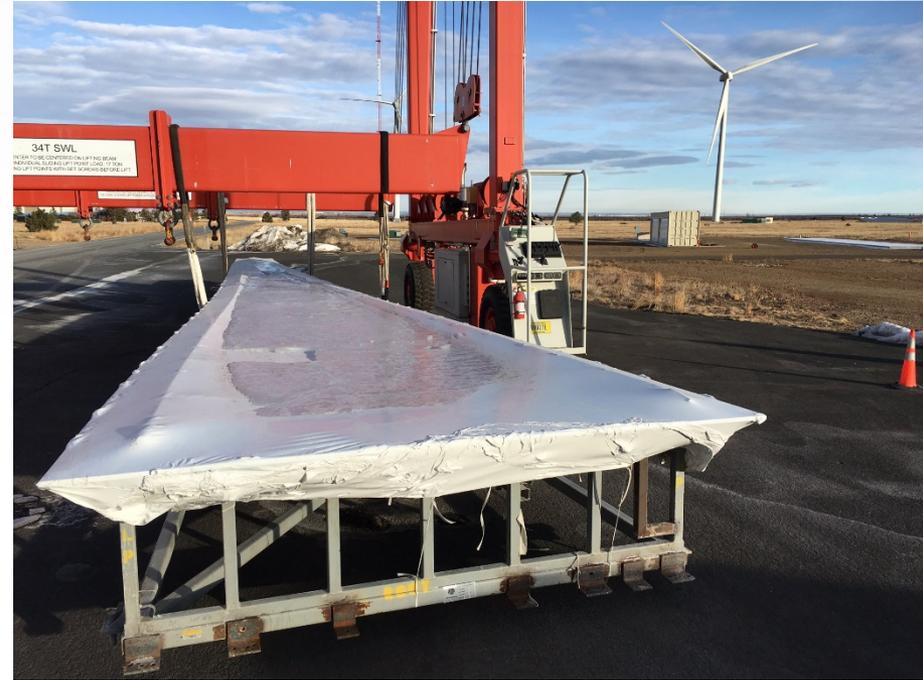


Portion of 60m spar cap infusion mold
Courtesy DowAksa

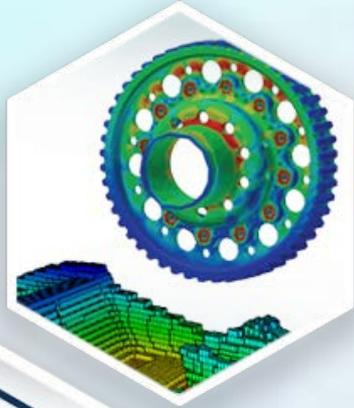
Wind Blade Tooling



48.5m blade tip mold
Courtesy GE



Large shear web mold
Courtesy GE



Design Modeling and Simulation

Indiana Manufacturing Institute (IMI)

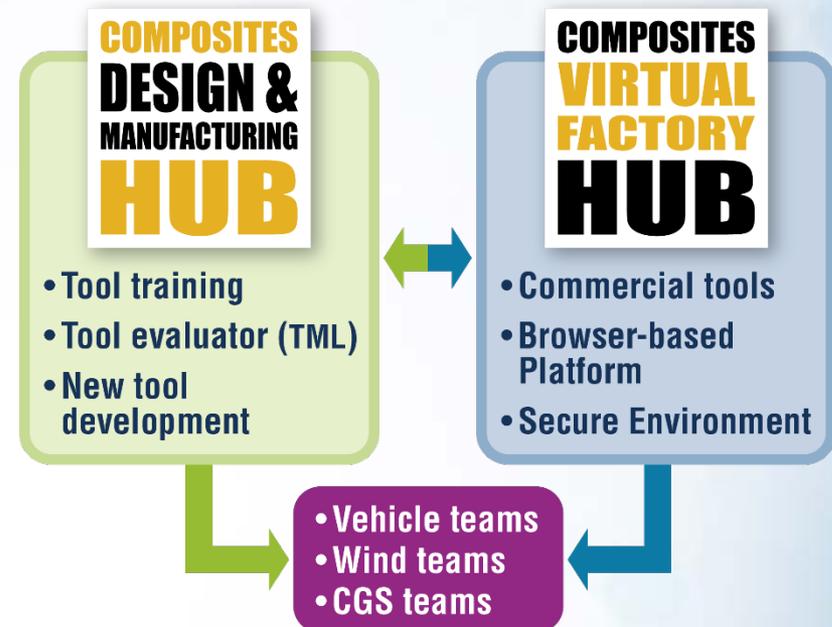


- IACMI Design, Modeling and Simulation TA occupies 30,000 sq ft
- Over 30,000 sq ft available for location of relevant industry labs
- Occupied Summer 2016

Leverage Computing Power to Enhance Design Confidence



- Create Composites Virtual Factory HUB (cvfHUB)
- Develop platform for hosting and integration of commercial software tools for composites
- Provide end-to-end simulation for composites
- Correlate at multiple scales prediction and reality
- Make tools and knowledge available to entire value chain to enhance confidence and reduce cost
- Implementation is underway, rollout commences mid-2017



Simulation Software



Integration of many major commercial simulation tools



PAM-FORM
PAM-RTM
PAM-DISTORT
PAM-CRASH



CATIA
SIMULIA
BIOVIA
ENOVIA
DELMIA



HYPERWORKS
MDS



SwiftComp
VABS

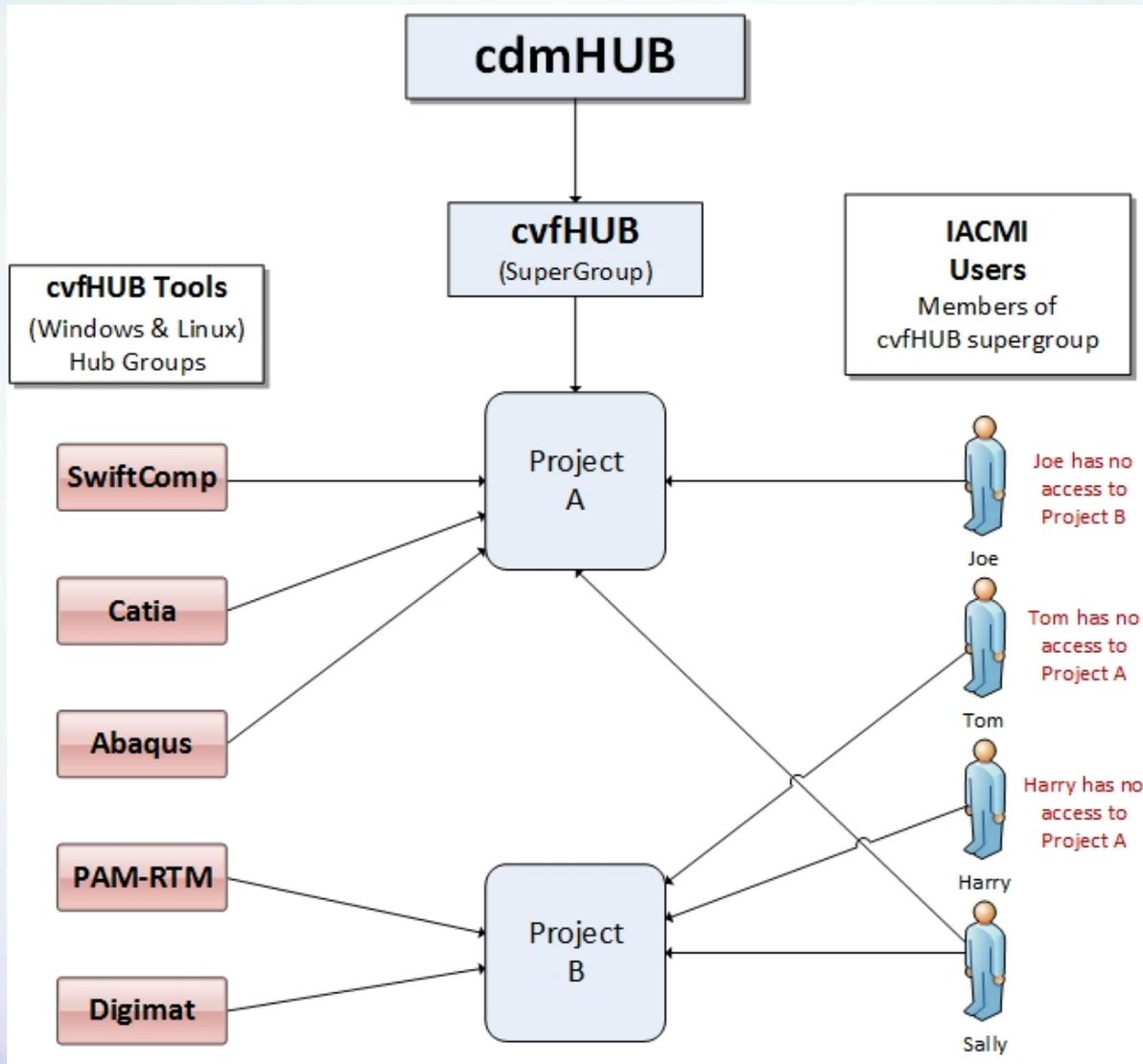


COMPRO
RAVEN

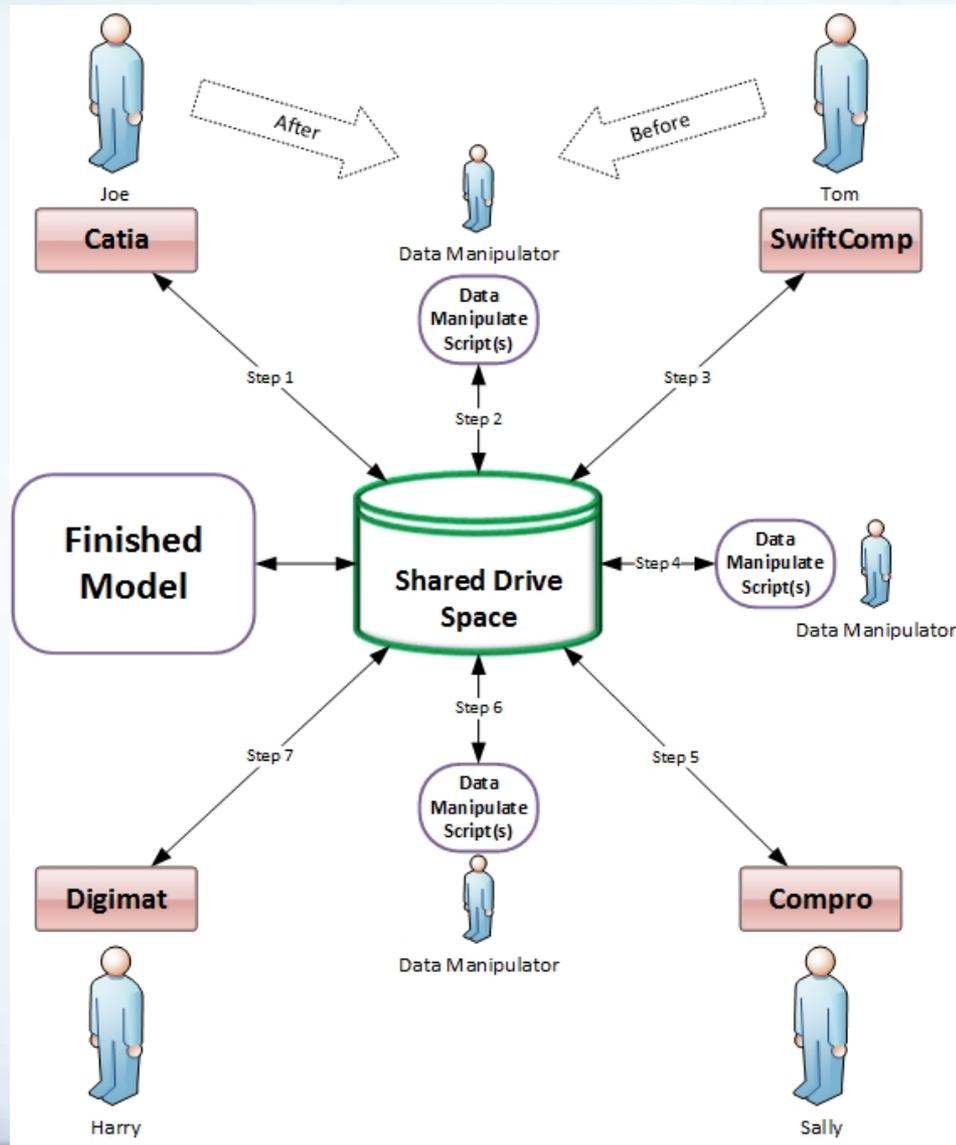


DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

Project team member access on cvfHUB



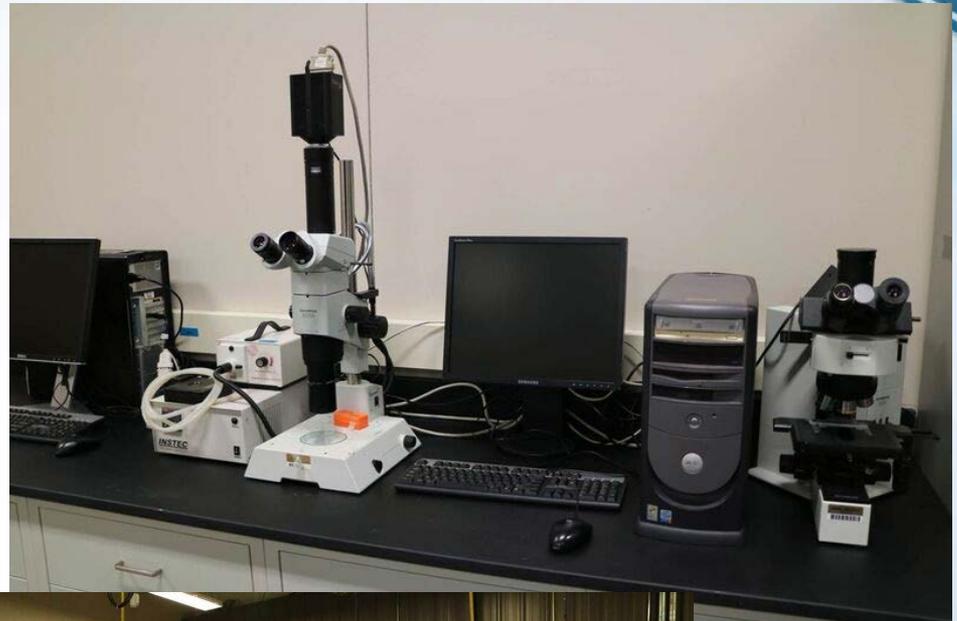
Project collaboration on cvfHUB



Validation Labs

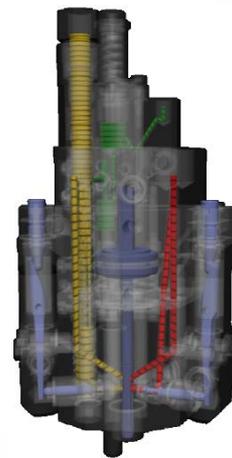


Validation Labs



Cannon High Pressure RTM Unit

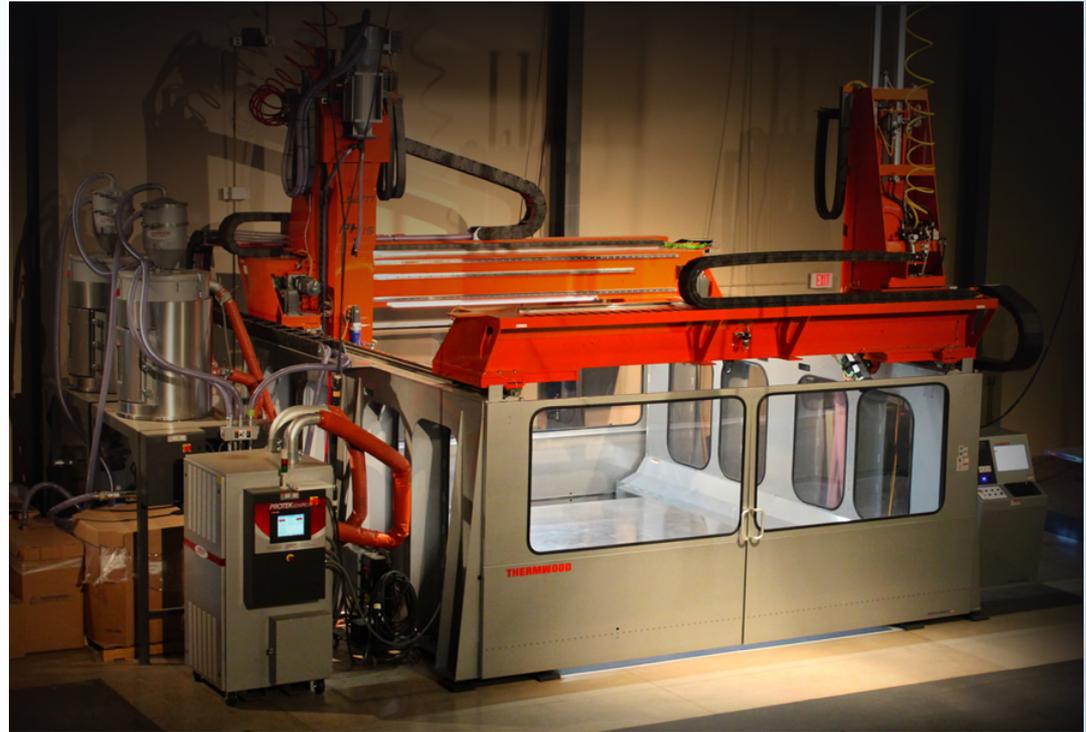
- ◆ HP RTM system for 2 component epoxies
- ◆ Flow rates:
 - ◆ Resin 12-120 g/s
 - ◆ Hardener 3-50 g/s
- ◆ Heated tanks for both resin and hardener
- ◆ LN 6 EPX high pressure recirculating mixhead, 100 bar (1500 psi)
- ◆ On order, delivery anticipated Q2 2017



LSAM Acquisition



- Large Scale Additive Manufacturing (LSAM) machine
- Combines polymer FDM with machining in same cell
- 10 ft x 10 ft working envelope
- On order, will be delivered and installed by mid-2017



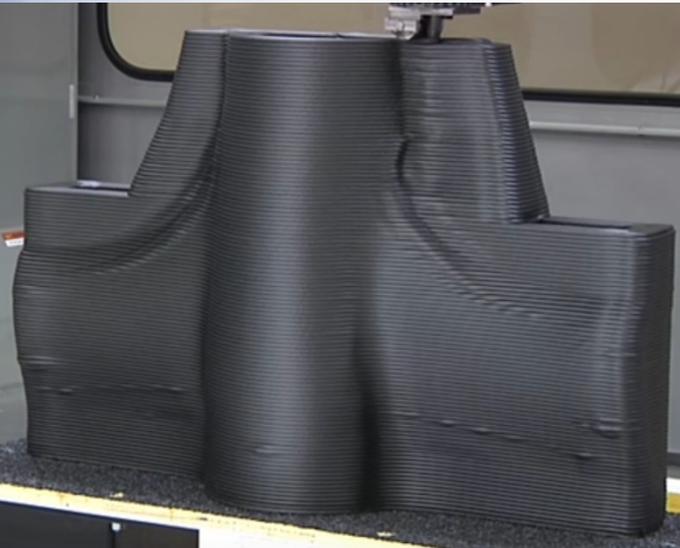
LSAM
Large Scale Additive Manufacturing

THERMWOOD

PURDUE
UNIVERSITY

Example Application

Print



Machine



Finish

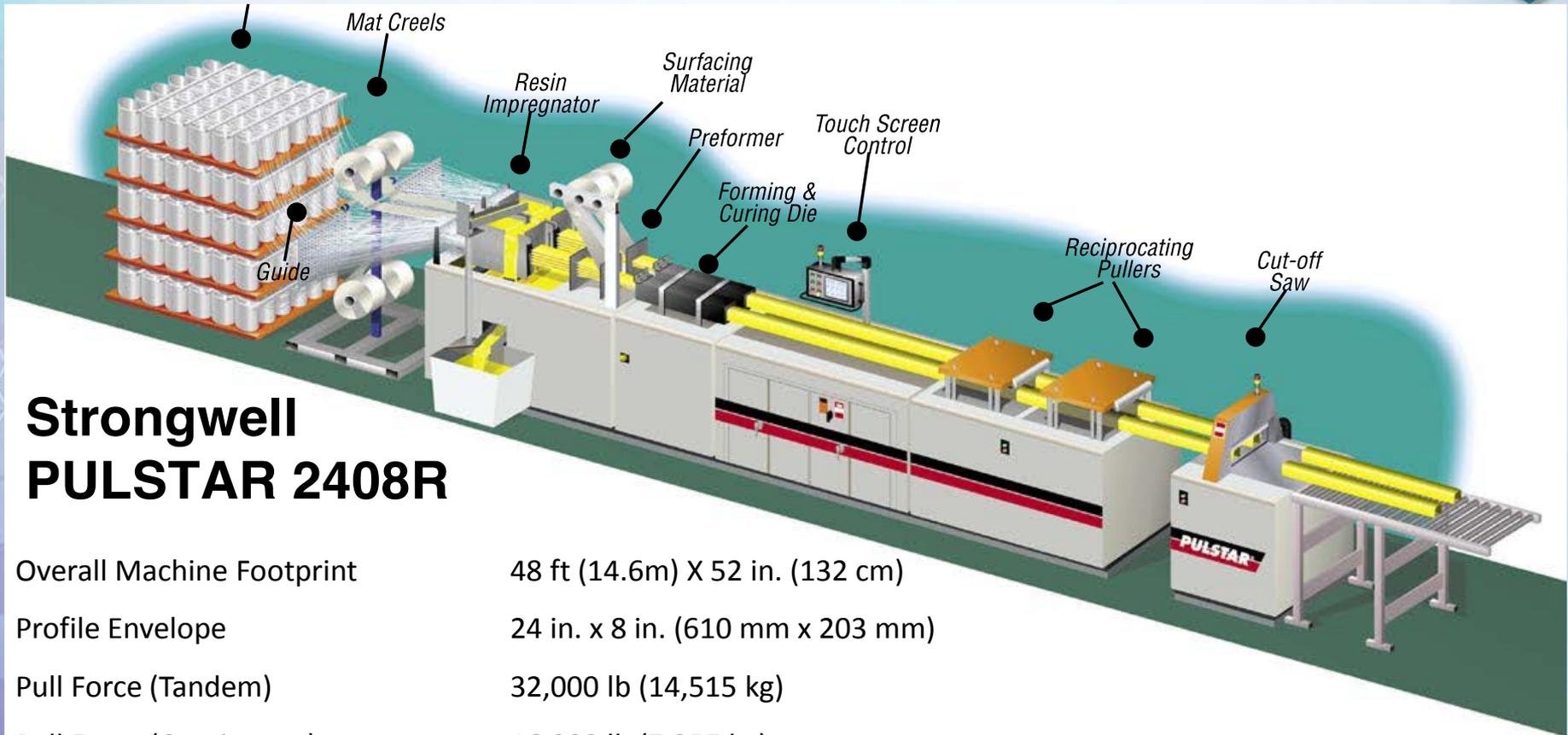




Composite Materials and Processes



IACMI Pultrusion Machine



Strongwell PULSTAR 2408R

Overall Machine Footprint	48 ft (14.6m) X 52 in. (132 cm)
Profile Envelope	24 in. x 8 in. (610 mm x 203 mm)
Pull Force (Tandem)	32,000 lb (14,515 kg)
Pull Force (Continuous)	16,000 lb (7,257 kg)
Clamp Force	24,000 lb (10,886 kg)
Speed Range	1-120 in./min (2-305 cm/min)

Source: Strongwell

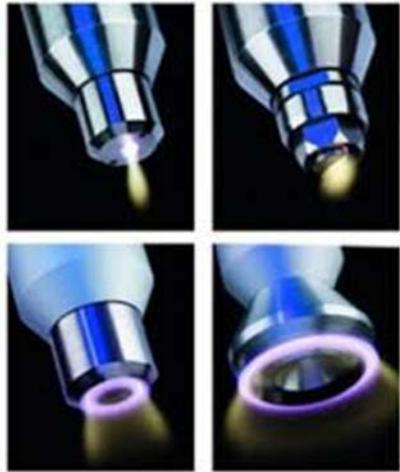
IACMI Pultrusion Machine



01.06.2017 16:16

Machine delivered to ORNL
Will be installed and operational later in 2017

Plasmatreat unit at MDF (Jet - RD1004 / Generator - FG5001 / Transformer - HTR1233) - MDF

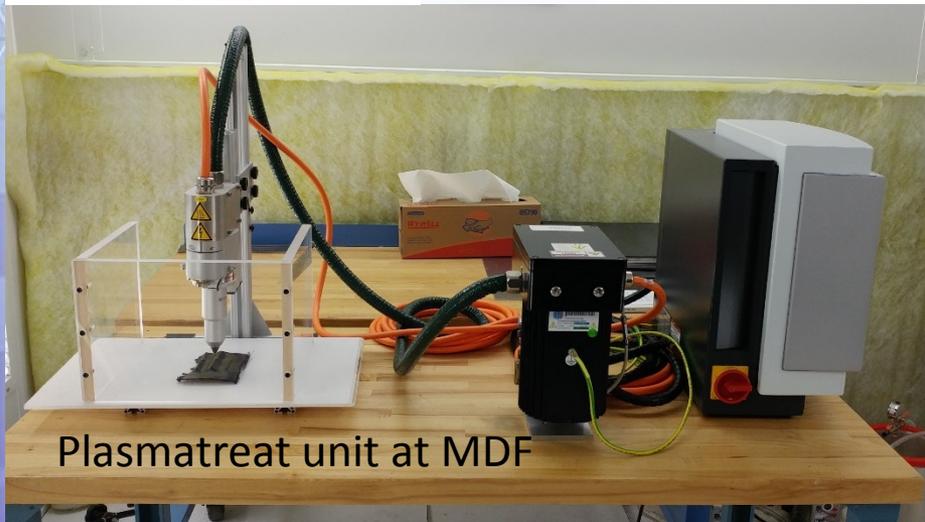


Resource Member

Enabling plasma treatment for surface enhancement

Tennessee (in place) and Michigan (planned)

- State-of-the-art FG5001 Plasma Generator
- Cleaning, etching, polymerization, surface activation and increased manufacturability.
- Bonding enhancement of low surface energy substrates
- Fiber treatment
- Surface and Interface enhancement
- Overmolding/tape bonding
- Multi-material joining
- Additive manufacturing layer by layer
- Product development



Plasmatreat unit at MDF

RocTool Induction Heating / Fast cycle processing of composites (MDF)

Equipment specifications

- ◆ Induction generator DZ150KW
- ◆ Tactile interface – RT 21
- ◆ Closed cooling unit - R45 model
- ◆ Performance cooling
- ◆ RocTool Technology / Tool Hardware

IACMI projects

Compression molding

Class A surface finish

Fast cycle time in recycled and virgin carbon fiber thermoplastic mats

Evaluation of range of material forms and resin for processing-quality-cycle times



Representative System and parts



Recycling Shredder (UTK)



MS-1714 Dual Shaft Shear Shredder

- Feed Chamber Opening: 17" x 14"
- Discharge Opening: 17" x 14"
- Infeed Hopper: Open Top: ½ Cubic Yard
- Diameter of Shredding Knives: 7-1/2" Thickness of Knives: 5/8"
- Motor: 15HP, 1800RPM Voltage: 480/3/60



IACMI projects

- Shredding aerospace end of life parts
- Recycling thermoset cured resins and composites
- Glass and carbon fiber thermoplastic shreds
- Reprocessing in extrusion-compression, injection-compression and other downstream processes



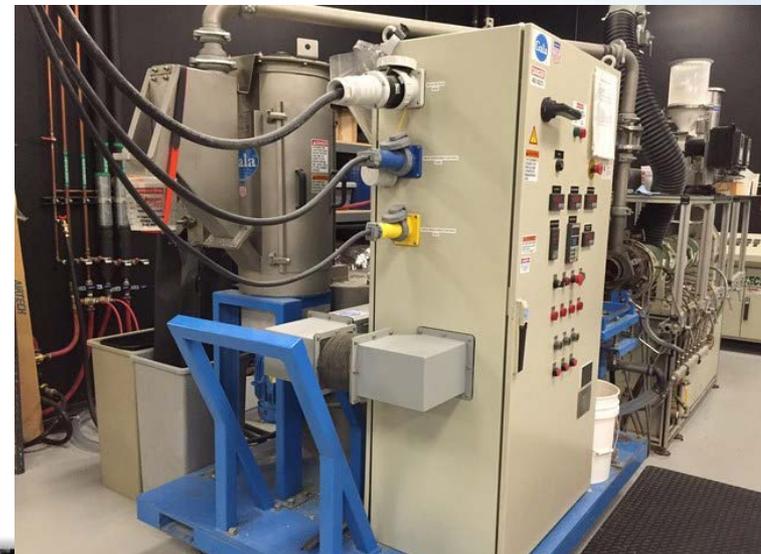
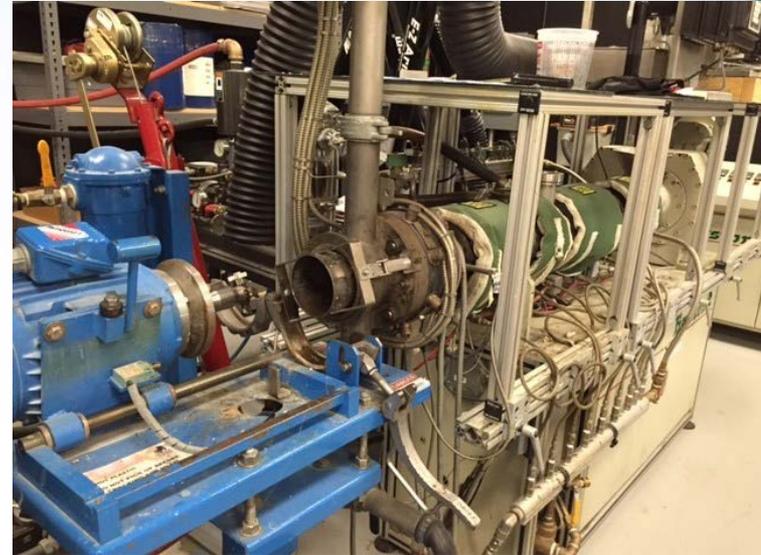
Multiphase Compounding – Pelletizing Line (UTK_

Specifications

- Berstorff Model ZE25x30D Gala Pelletizing Line
- Complete Lab Size Under Water Pelletizing Line
- Screw size – 25 mm
- L/D ratio- 30:1
- 15 HP, Gear Box Ratio 4:1

IACMI Use/projects

- Compounding of LCCF and other fibers with a range of olefin and engineered resins
- Multiphase – syntactic foams and color compounds
- Production of noodles, pellets and tapes
- Feedstock for multiple processes



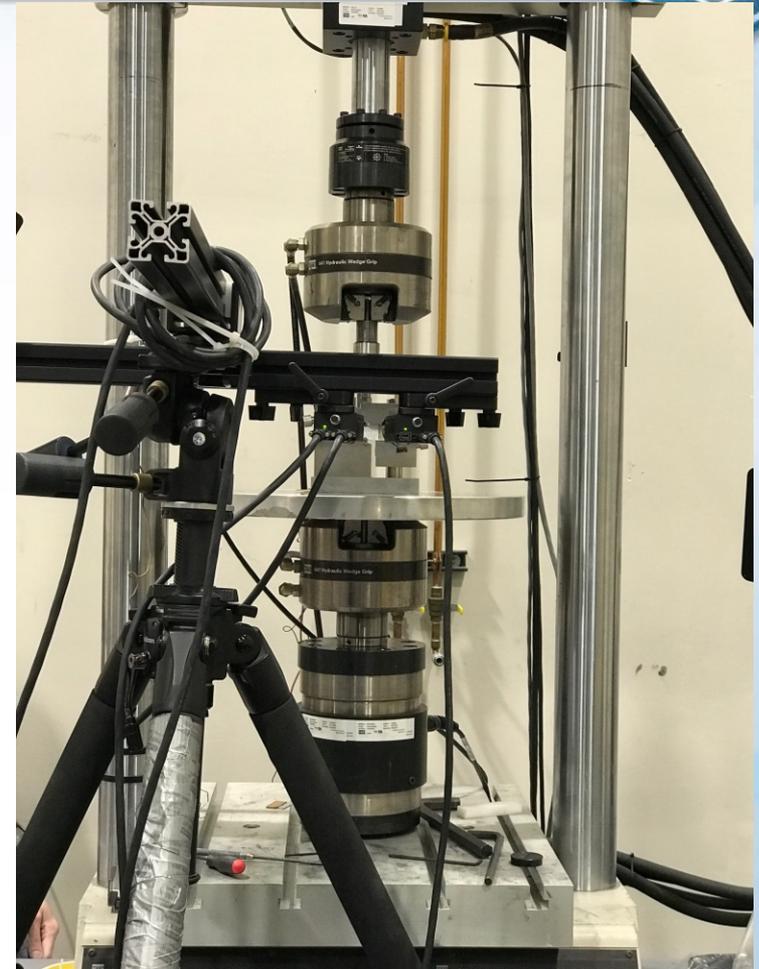
Fiber Reinforced Composites Testing Fixtures Acquisition / Commissioning

Iosipescu Shear Test Fixture
(ASTM D5379)

WTF-SB Three Point Short
Beam Shear Test Fixture (ASTM
2344)

WTF-OH Boeing Open Hole
Compression Test Fixture
(ASTM D 6484)

WTF-II IITRI Compression Test
Fixture
(ASTM D 3410)

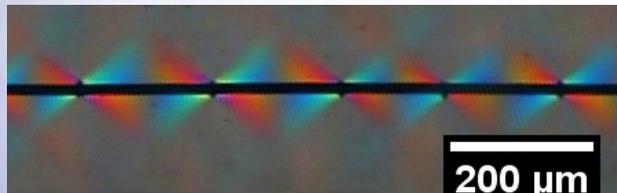
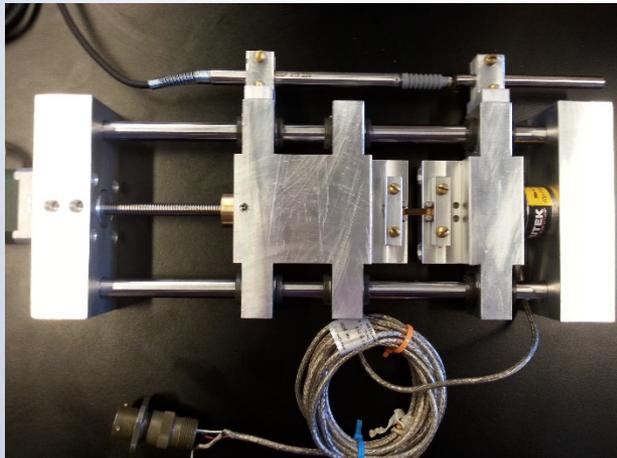


Shear Testing with 3-D Image
Correlation Capabilities

Integrated Load Frame and Olympus BX53 Reflected/Transmitted Light Microscope



IACMI Use/projects: Interfacial Shear Strength for Optimizing Carbon Fiber Surface/Interphase with Matrix Resin



Polarized light images in transmission mode of a fragmented single T700 carbon fiber in an epoxy composite

BX53 A Great Solution for System Flexibility with Comfortable Operability

The BX53 is a versatile system microscope that can be configured to meet virtually any research need. It supports a wide range of fluorescence imaging applications, and has a range of advanced features for enhanced operating ease and process flexibility.



Equipment Commissioned for Precise Measurement of Density of Fibers and Composites



AccuPyc II 1340 Temperature Controllable Automatic Gas Pycnometer

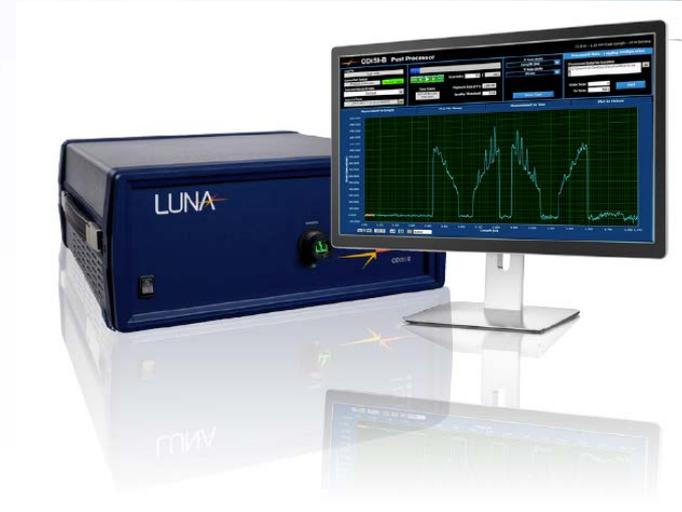
10-cm³ sample capacity. Used for the determination of true volume and true density of solids and powders at controlled temperatures using an external recirculating bath. Operation in either standalone configuration using internal computer and keypad, or controlled by a PC running optional AccuPyc Windows[®] Software



Upgrade of LUNA Fiber Optic Strain and Temperature Sensing (ODiSI-B 5.0) System

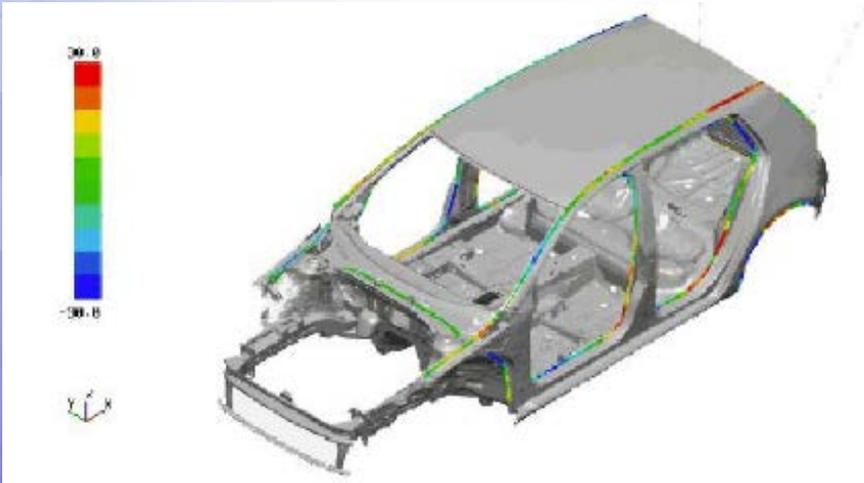


- **OPT06003 Full SW & HW upgrade - includes ver 5.0.0 and upgrade to electronics, optical network, new standoff, High Definition sensing upgrade, system alignment and test. High-Speed CFG option.**
- **FBI Gauge 3D Visualization Software Package Acquisition**



ODiSI - Key Benefits

- High definition sensing offers unprecedented visibility into a design's structural performance
- Low profile and flexible sensors ideal for embedding within composite structures and measuring strain on curved surfaces
- Corrosion resistant, dielectric, and immune to EMI/RFI
- An ideal tool for validating FE models of composite structures



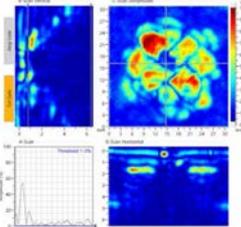
Mobile NDE Lab Technologies



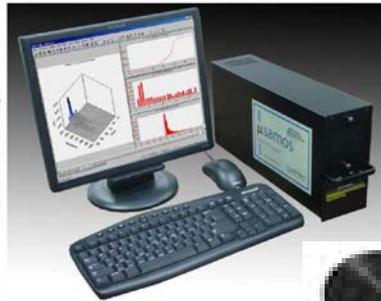
Flaw detection in composites



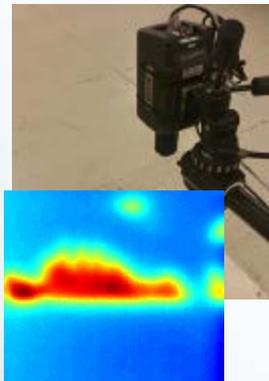
Sonacam- Air coupled active in-line ultrasonic NDE 09/2016



Mistras Acoustic Emission System 01/2017



Olympus EPOCH 650 Portable Ultrasonic NDE Systems 01/2017



FLIR High Resolution IR Camera 03/2016

Fiber Quality

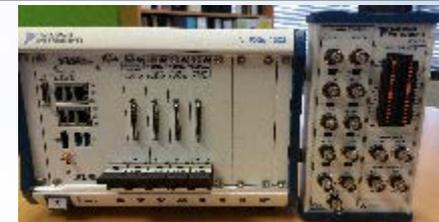


Keyence Laser Profilometer 08/2015

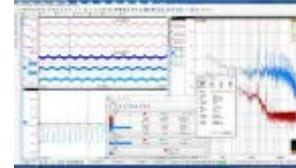


Keyence Laser-Displacement Sensors 08/2015

Cure Monitoring



National Instruments PXI 16 bit, 4 MHz signal driver 12/2016



HBM 100 Ms/Sec High Speed Data Acq. System 04/2016

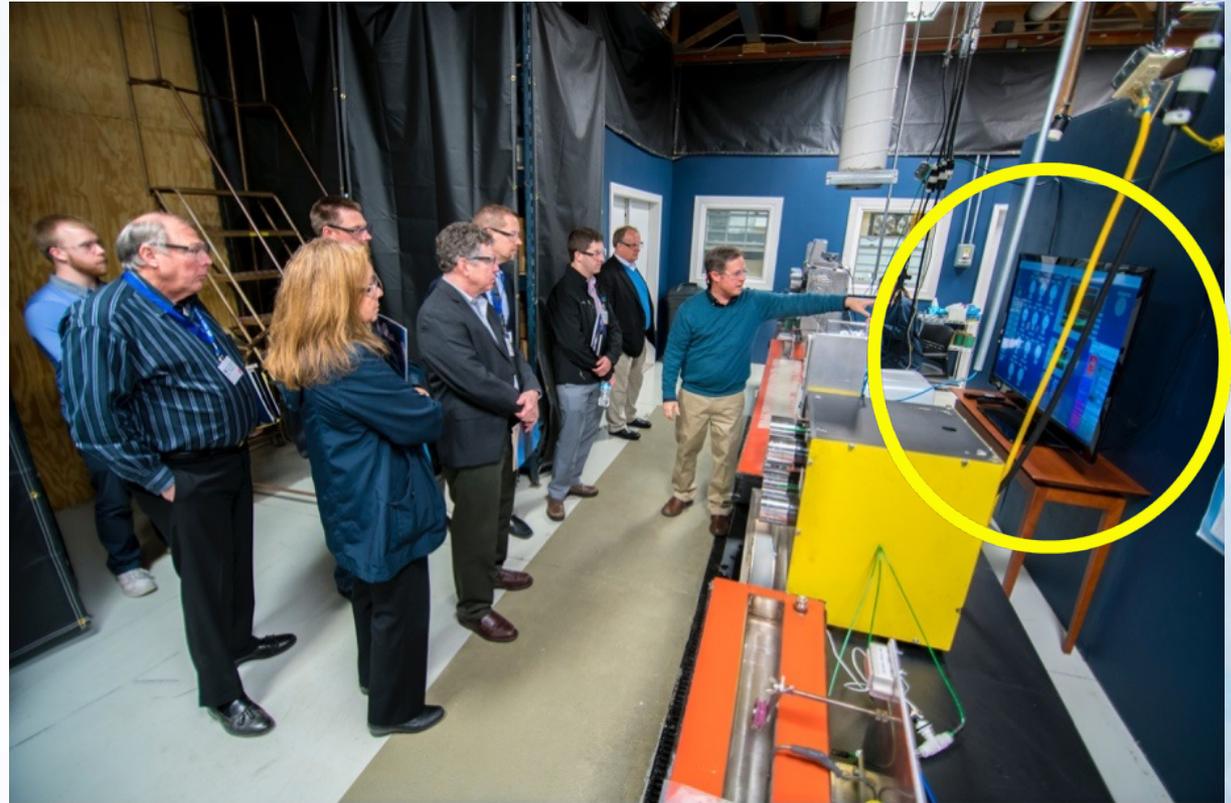
UKY CAER solution spinning line for multifilament continuous tow



Heads UP, Real-Time Spinning Data Acquisition and Logging



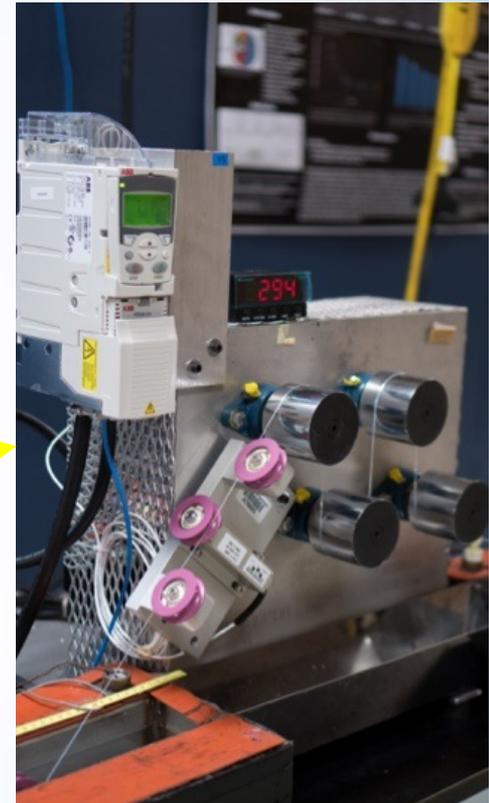
- ◆ Polymer dope
 - ◆ Flow rate
 - ◆ Amount remaining
 - ◆ Temperature
- ◆ Filtration pressure drop
 - ◆ Temperature
- ◆ Spinneret pressure drop
 - ◆ Temperature
- ◆ Tow tension down the line
- ◆ Godet drive linear speeds
 - ◆ Tow draw ratios



Tow tension and line-speed monitoring in real time

Line speed
digital
input/output
control at
each of the
godet/roller
stations

Tow tension
monitor
system



New Capability: Robotic Single Filament Tensile Testing and Linear Density



- ◆ FAVIMAT +
- ◆ Vastly increases single filament testing efficiency
- ◆ 100s of filaments per sample



Compressed Gas Storage

Composites Manufacturing at UDRI



- ◆ 12" PREPREGGER
- ◆ 3 AUTOCLAVES
- ◆ 7 HYDRAULIC PRESSES
- ◆ RTM
- ◆ VARTM
- ◆ FILAMENT WINDING
- ◆ PULTRUSION
- ◆ INJECTION MOLDING
- ◆ 60" TACKIFIER
- ◆ 3D PRINTERS
- ◆ HAND LAY-UP
- ◆ RESIN FILM INFUSION
- ◆ LARGE OVENS



UDRI – Laboratory Consolidation and Upgrades

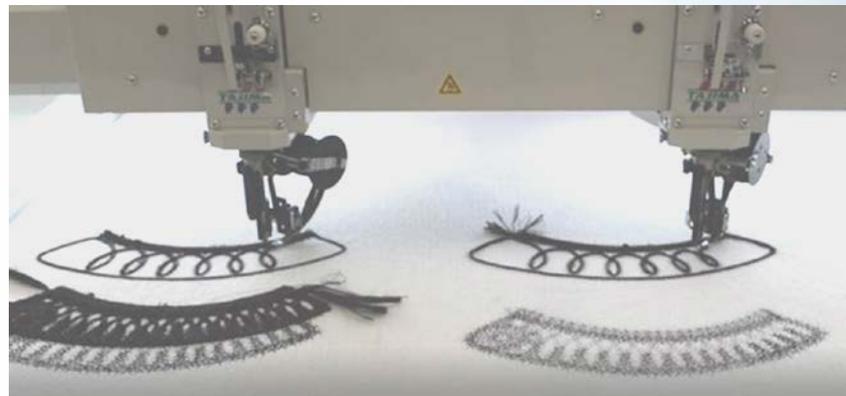


- ◆ Performs basic and applied research, engineering services, and testing
- ◆ Third in the U.S. in funded materials research
- ◆ More than 460 professional research staff
- ◆ Moving equipment from several campus labs to HQ building
- ◆ Move is underway and will be completed over 2017



Net Shape Preforming

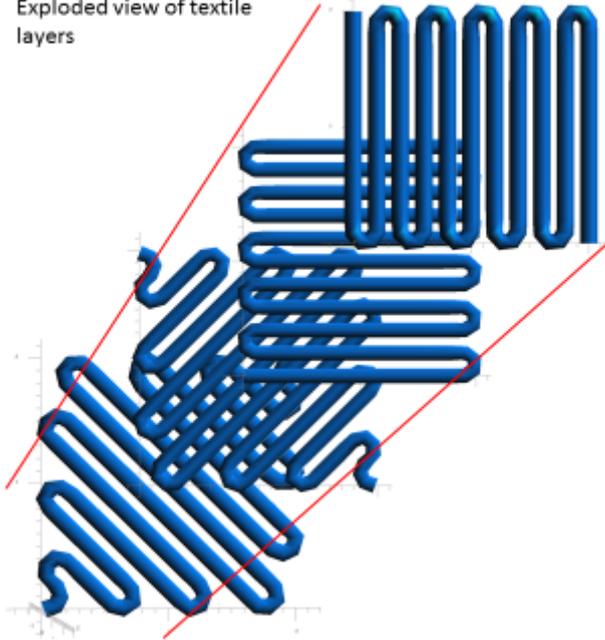
- ◆ Twin-head LayStich machine has been delivered to UDRI
- ◆ Capable of producing net shape preforms with minimal fiber waste and with intricate geometries, including localized reinforcement.
- ◆ Will be used to prepare structural inserts for injection overmolding



Net Shape Preforming

Simulation and fabrication of quasi-isotropic preform

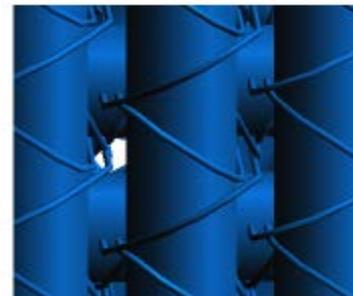
Exploded view of textile layers



Back Side – Quasi-Isotropic Laystitch preform.
Differential amount of stitching is an artifact of the number of layers printed to show the quasi-isotropic nature of the preform.



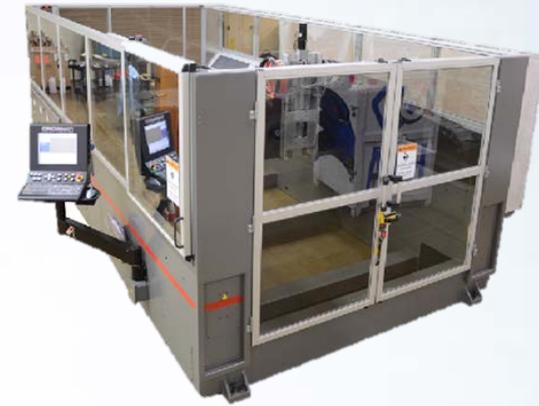
Front Side – Quasi-Isotropic Laystitch preform (0, +/- 45, 90 Degree Layers all visible).



High Temperature Tooling by Additive Manufacturing



- ◆ Collaborative effort with Cincinnati, Inc (1 hour from UDRI)
- ◆ Focus on single sided tooling capable of 350F and 100 psi cure (autoclave, Rapidclave, e.g.)
- ◆ Focus material is specially formulated carbon fiber filled polysulfone. Other materials, such as PPS and PEI have also been trialed.



Rapidclave® curing



- ◆ Globe Machine installing Rapidclave® equipment at former National Composite Center site
- ◆ Provides heating and cooling capabilities on single sided tooling at rates over 10X that of autoclave processing at similar pressures, e.g., 100psi
- ◆ Time on equipment is being made available to UDRI under consignment for IACMI projects
- ◆ Expected installation late Q1 2017



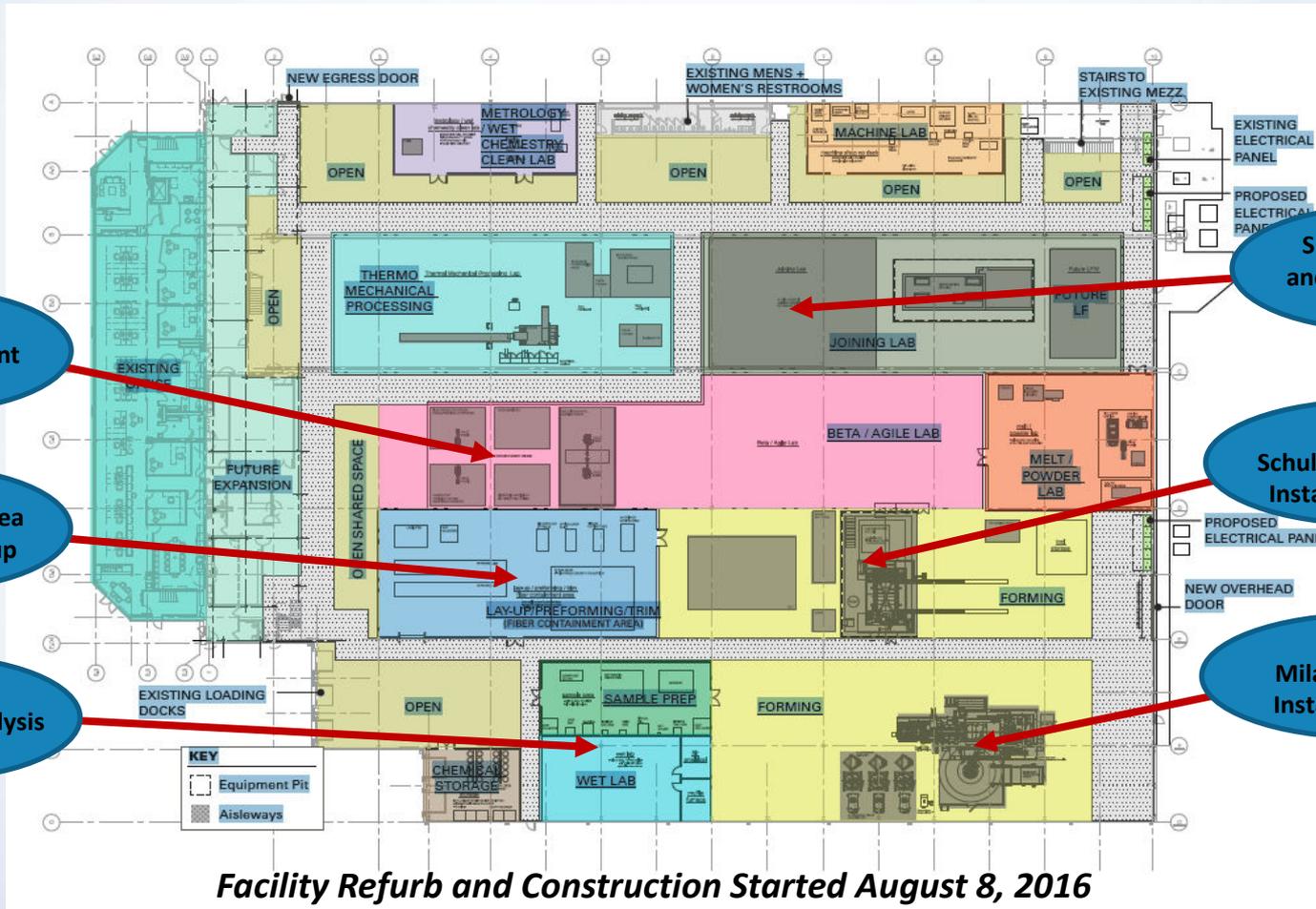


Vehicles

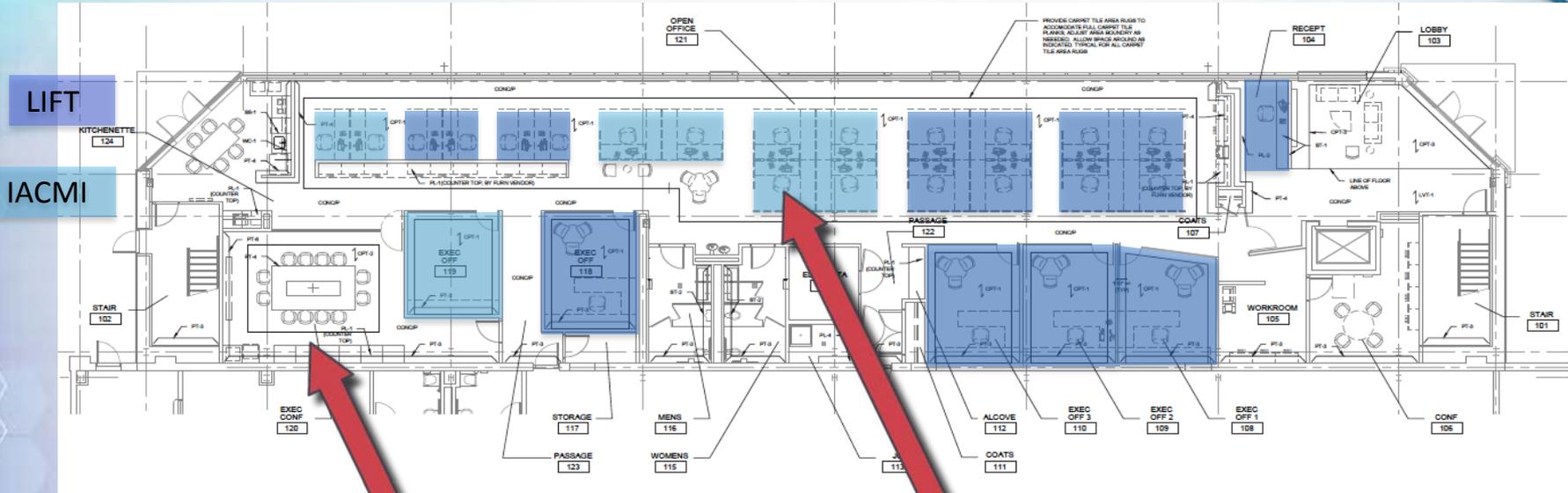
- ◆ Vehicles Technology Area includes two locations
- ◆ Michigan State University
 - ◆ East Lansing
 - ◆ Detroit (“Corktown”)



IACMI/LIFT VTA-SUF Facility Layout



Corktown Facility – First Floor Office



Executive Conference Room

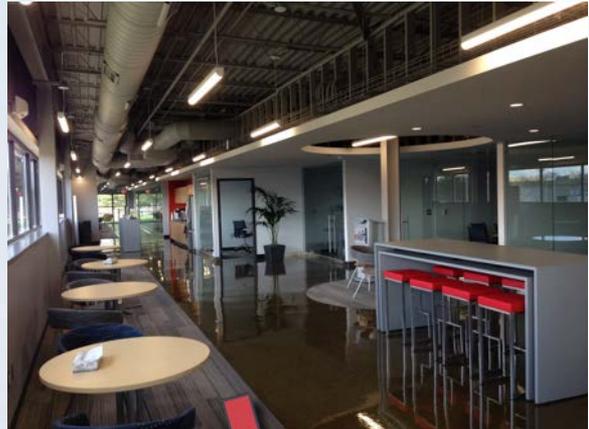


Modular Office Space

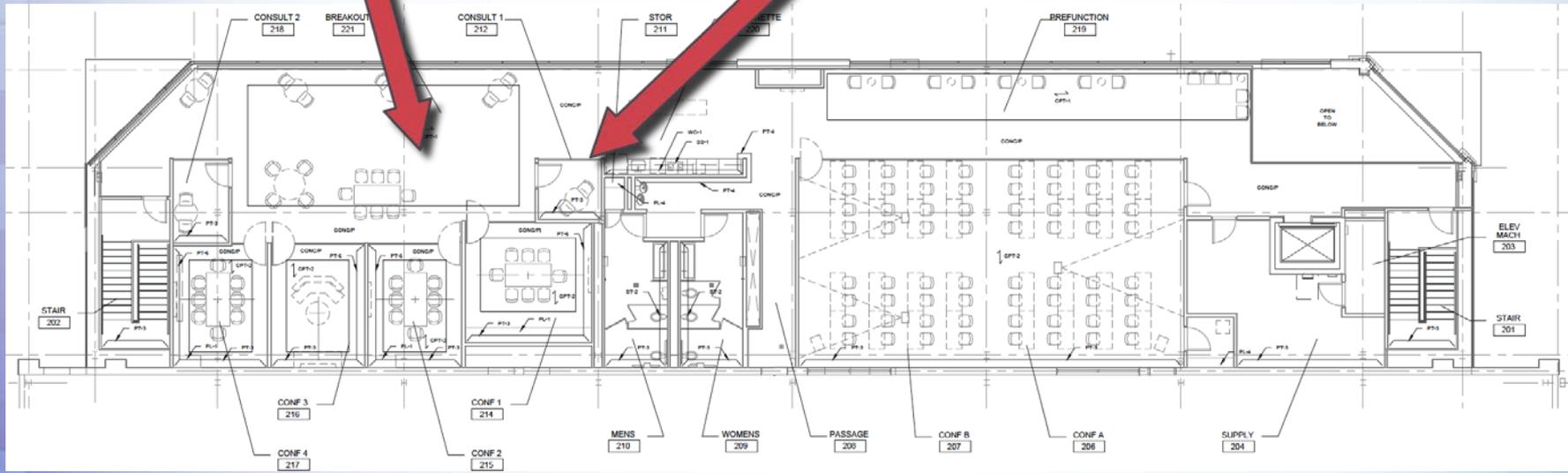
Corktown Facility – Collaboration & Training



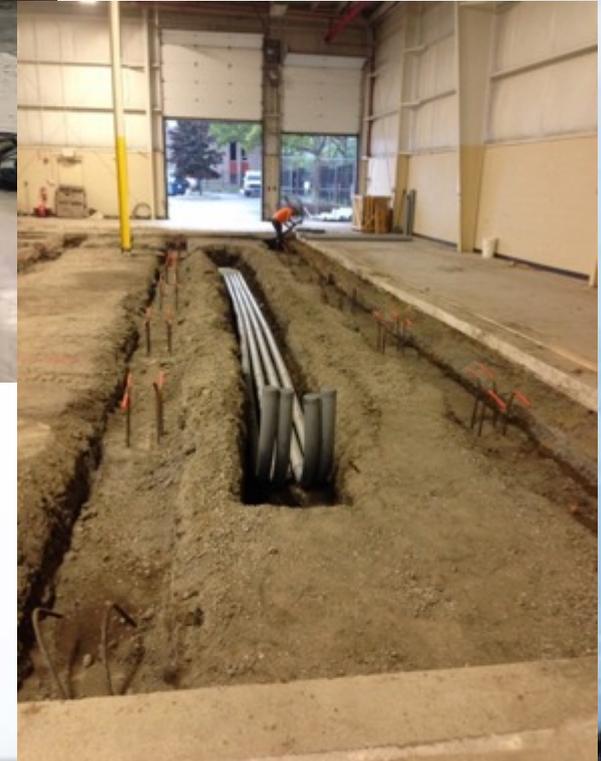
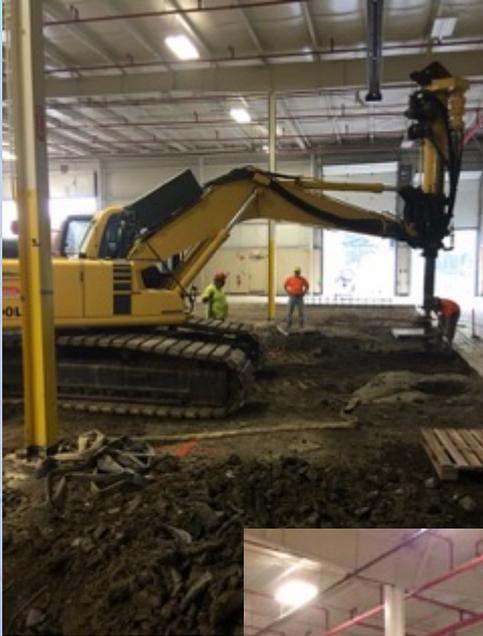
Open Collaboration



Conference Rooms



Floor and Utilities



Floor and Utilities



Injection molding press



- ◆ Received from Milacron
- ◆ Specifications
 - ◆ 29,500kN (3,315T)
 - ◆ Platen: 3m x 2.5m (~10ft x 8ft)
 - ◆ 413 oz. max shot size (multiple screw sizes)
- ◆ Operational February 2017

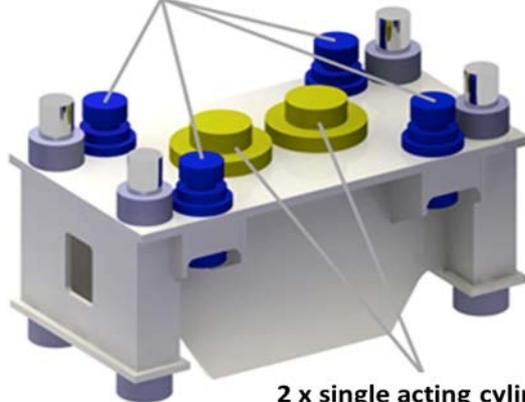
Injection molding press



Compression press



4 x double acting
cylinder for parallelism
control

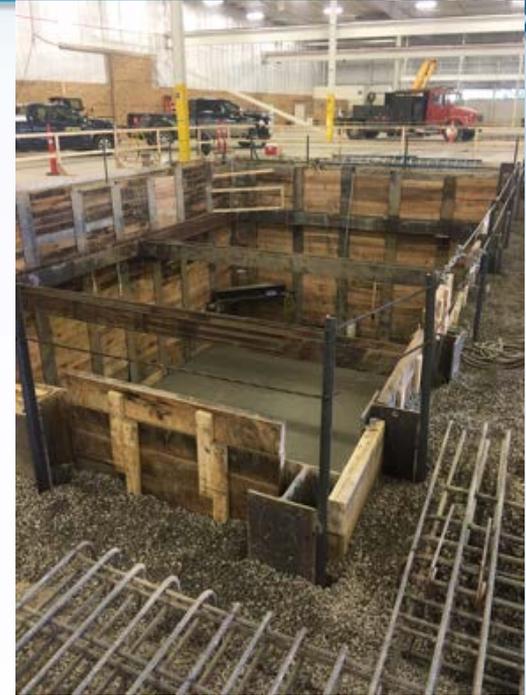


2 x single acting cylinder

Image Source: Schuler

- ◆ Ordered from Schuler
- ◆ Short-stroke design
- ◆ Multi-process capable
 - ◆ “Closed mold” infusion
 - ◆ Compression molding
 - ◆ Thermoplastic forming, etc.
- ◆ Specifications
 - ◆ 36,000kN (4,000T)
 - ◆ Platen: 3.6m x 2.4m (~12ft x 8ft)
- ◆ Installation begins February 2017
- ◆ Operation status expected April 2017

Compression Press Pit



Compression Press



Press bed and columns

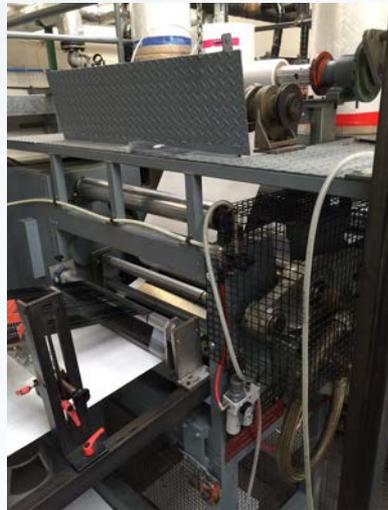


Upper slide
(platen
)



Mold transfer cart

Prepreg machine



- ◆ Specifications
 - ◆ 0.5m (20in) width
 - ◆ 120 - 600gsm
 - ◆ 2m/min
- ◆ Received at facility
- ◆ Operation status expected mid-2017

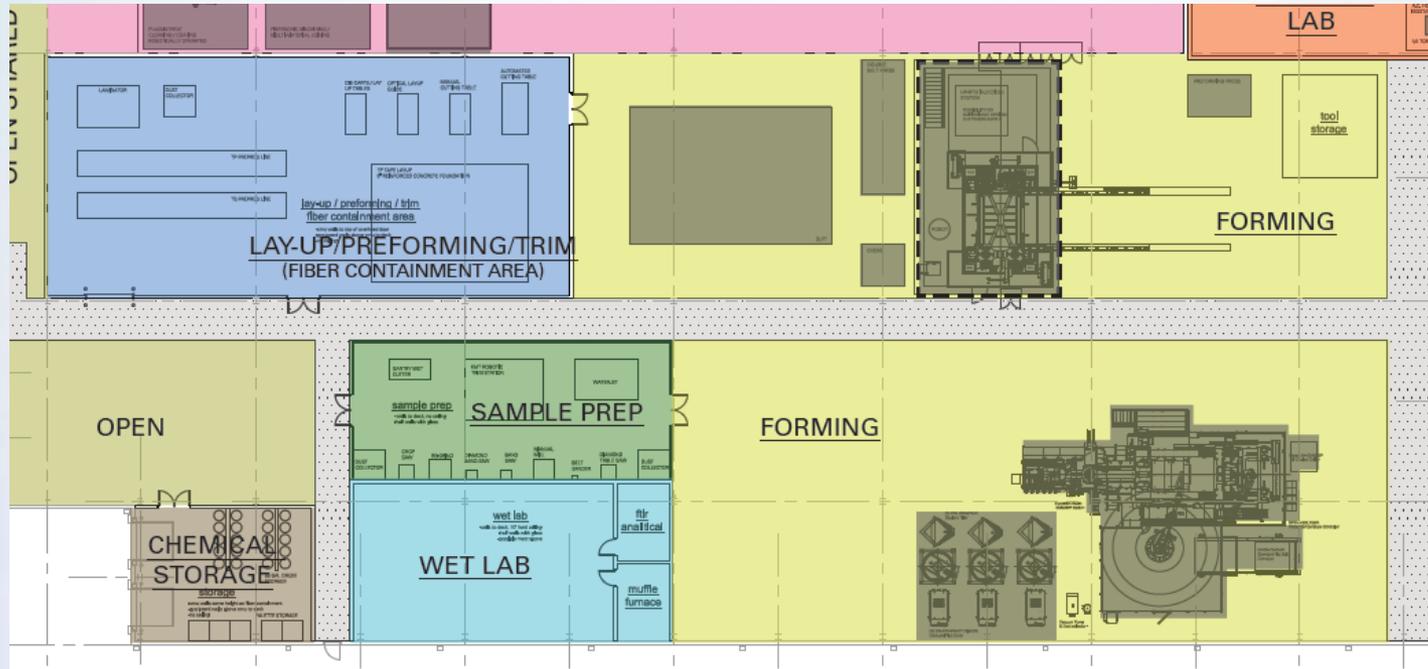
HP-RTM/Liquid Compression Molding



- ◆ HP-RTM for “closed mold” infusion
- ◆ Liquid Compression with flat preforms (Wet Compression)
- ◆ Finalizing decision on supplier soon
- ◆ Operation status to coincide with compression press mid-2017

Photos Source: KraussMaffei Technologies GmbH

IACMI Scale Up Facility Completion Timeline



- 2/16 Caratsch Pre-Preg Machine Delivered
- 7/16 Engineering and Architectural Drawings Finalized
- 8/16 Phase 0 Construction Begins (Infrastructure – Structural, Mechanical, Electrical etc.)
- 9/16 Installation of Milacron Inj. Machine Begins
- 4Q/16 Phase 1 Construction Begins (Sample Prep, Wet Lab, Analysis, Chemical Storage area)
- 2Q/17 Installation of Schuler Compression Molding Press
- 3Q/17 Phase 2 Construction Begins (Carbon Fiber Containment Area – Lay-up, Pre-Preg, Trim)
- 1Q/18 IACMI Scale-up Facility Completely Functional



Technology Partner Facilities

Composite Prototyping Center

Composite Recycling Technology Center

Composite Prototyping Center



- ◆ Composite Prototyping Center
- ◆ Plainfield, NY (Long Island)





CPC supports the following processes & functions:

Automated Fiber Placement

RTM / VaRTM

5 Axis CNC Routing Cell

Autoclaves , Ovens

Compression Molding, Heated Press

Hand Lay-Up with Laser projection assisted templates and kitting capabilities

Clean Room (Class 100,000)

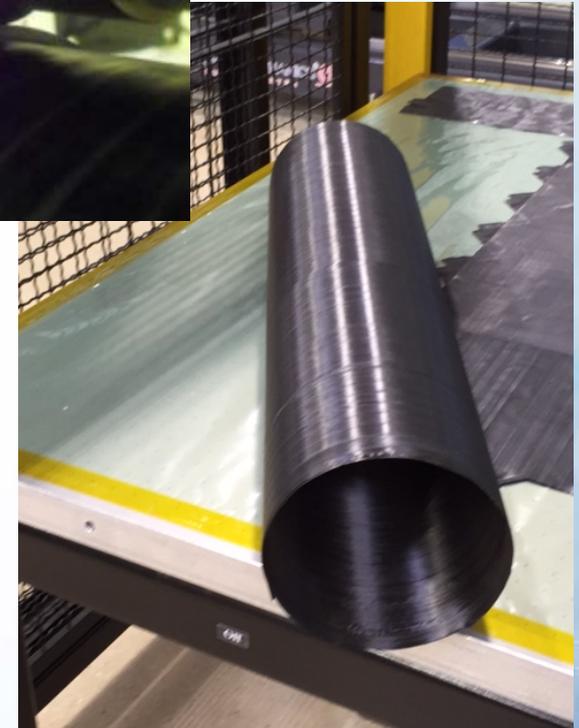
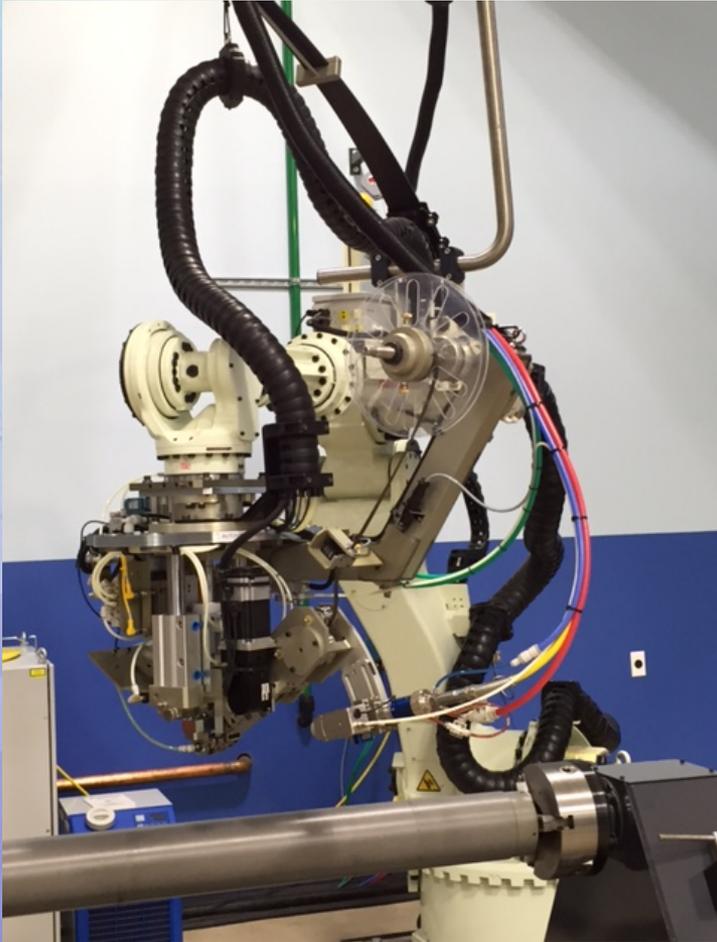
Single Ply Cutting System with nesting s/w

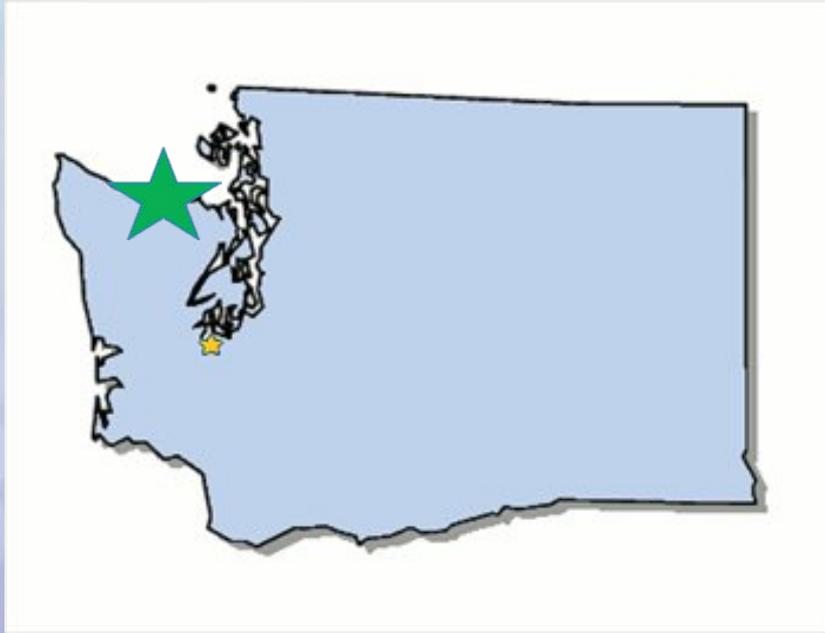
Test and inspection – NDT and CMM tools and instruments

3D Printer

Walk-in Freezer

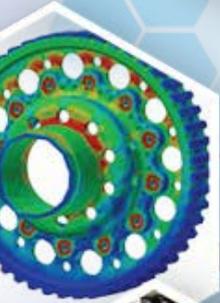
Laser Consolidation Fiber Placement





- ◆ CRTC, located in Port Angeles, Washington
- ◆ Objective to recycle scrap prepreg into useful parts
- ◆ Initial operations commenced
- ◆ Member of Toray project team





Questions?

Dale Brosius

Chief Commercialization Officer

dbrosius@iacmi.org