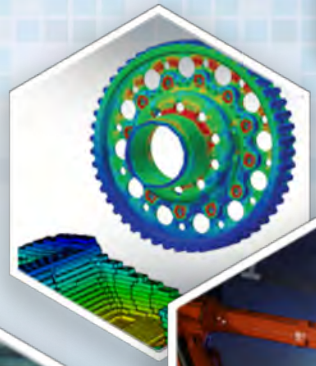


IACMI Facilities and Capabilities Update

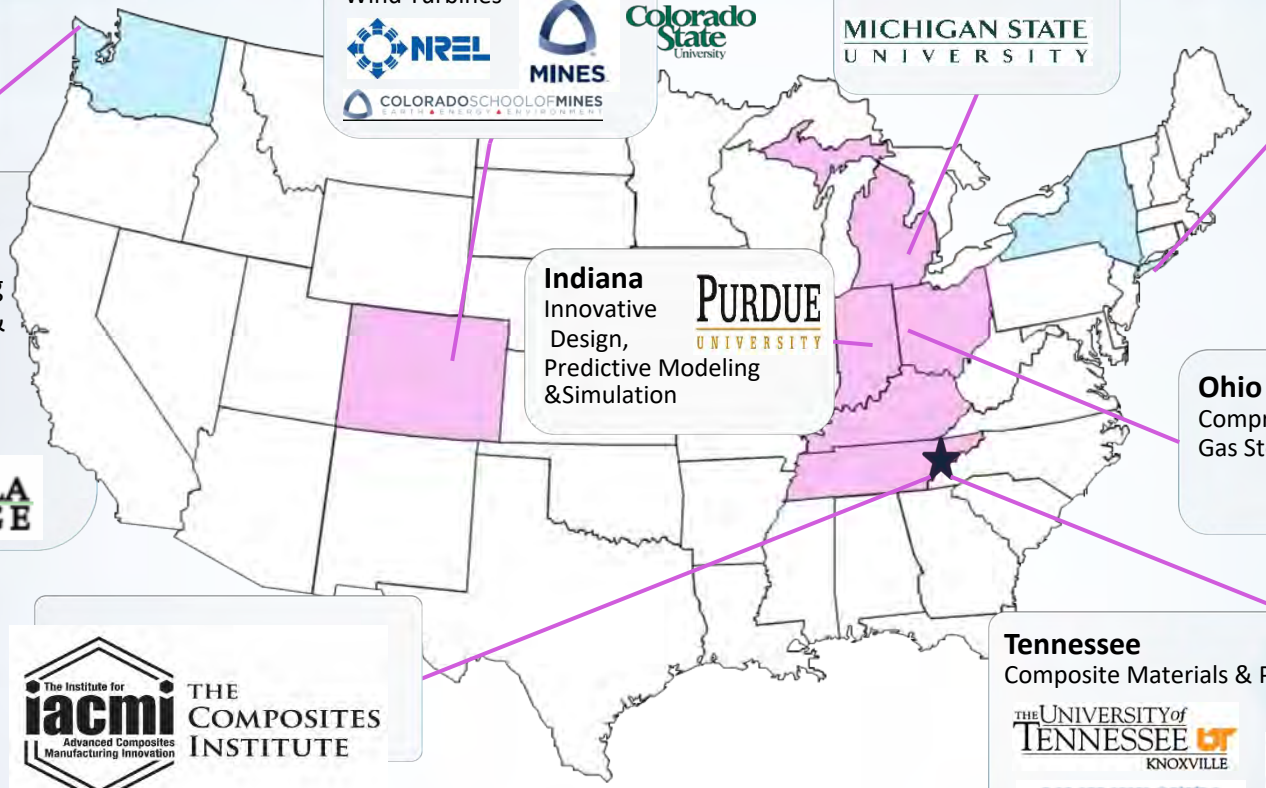
Dale Brosius

Chief Commercialization Officer

January 30, 2019

THE COMPOSITES iacmi INSTITUTE

IACMI – A National Institute for Advanced Composites



Colorado
Wind Turbines
NREL
MINES
Colorado State University
COLORADOSCHOOLOFMINES

Michigan
Vehicles
MICHIGAN STATE UNIVERSITY

New York
Composite Prototyping Center
CPC Composite Prototyping Center

Washington
Composite Recycling Technology Center & Peninsula College
CRTC COMPOSITE RECYCLING TECHNOLOGY CENTER
PENINSULA COLLEGE

Indiana
Innovative Design, Predictive Modeling &Simulation
PURDUE UNIVERSITY

Ohio
Compressed Gas Storage
UDRI UNIVERSITY of DAYTON RESEARCH INSTITUTE

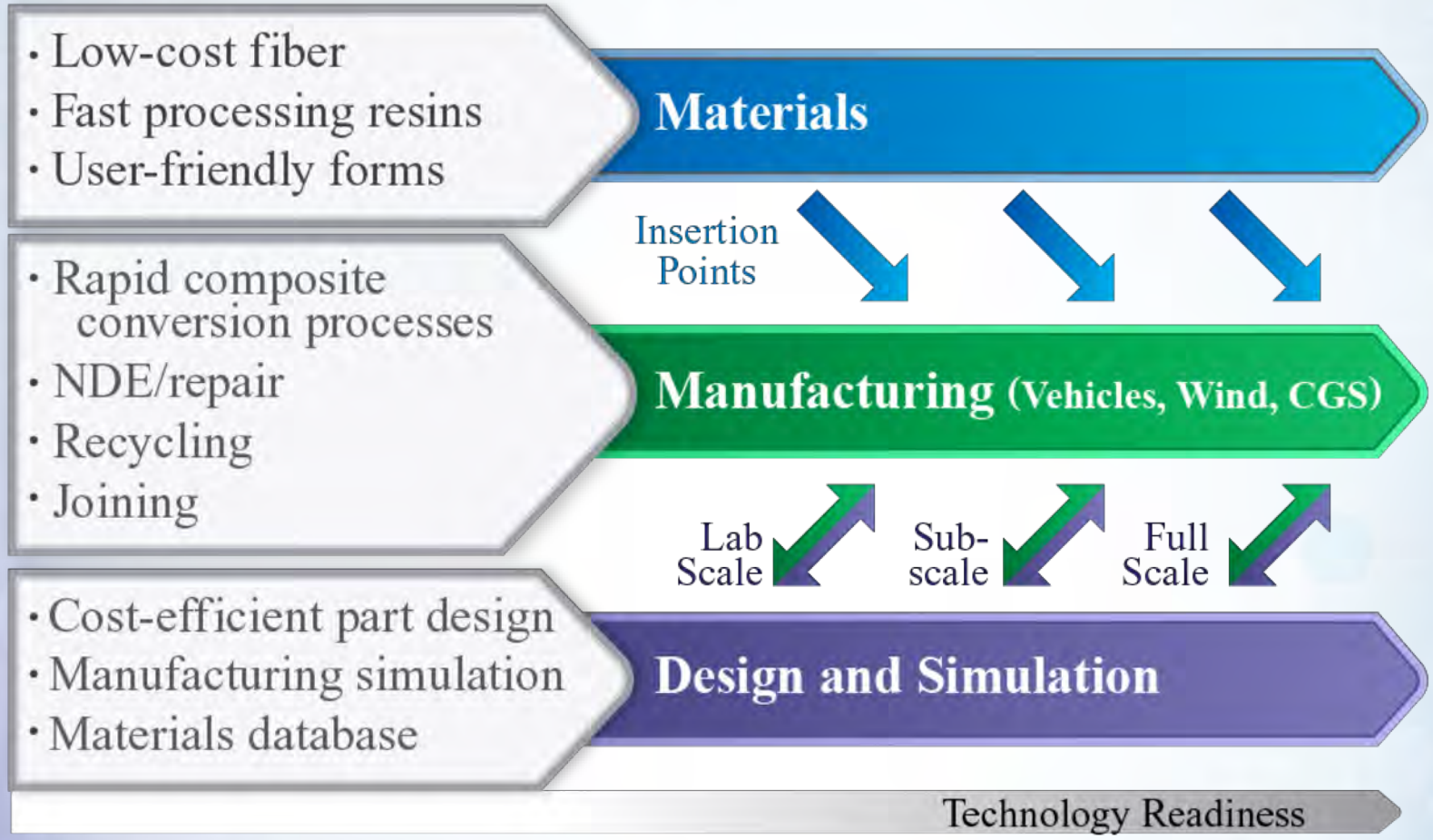
The Institute for iacmi Advanced Composites Manufacturing Innovation
THE COMPOSITES INSTITUTE

Tennessee
Composite Materials & Process Technology
THE UNIVERSITY of TENNESSEE KNOXVILLE
UNIVERSITY OF KENTUCKY
OAK RIDGE National Laboratory
VANDERBILT UNIVERSITY

Technical Goals:

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

Capabilities across multiple competencies



Unparalleled Capabilities Worldwide

Solution spinning line

KY

Carbon Fiber Technology Facility

TN

Pre-preg production pilot/full scale

OH MI

Pilot-scale PCM
750 ton press

TN

Full Scale PCM
4,000 ton press

MI

IN

THE COMPOSITES iacmi INSTITUTE

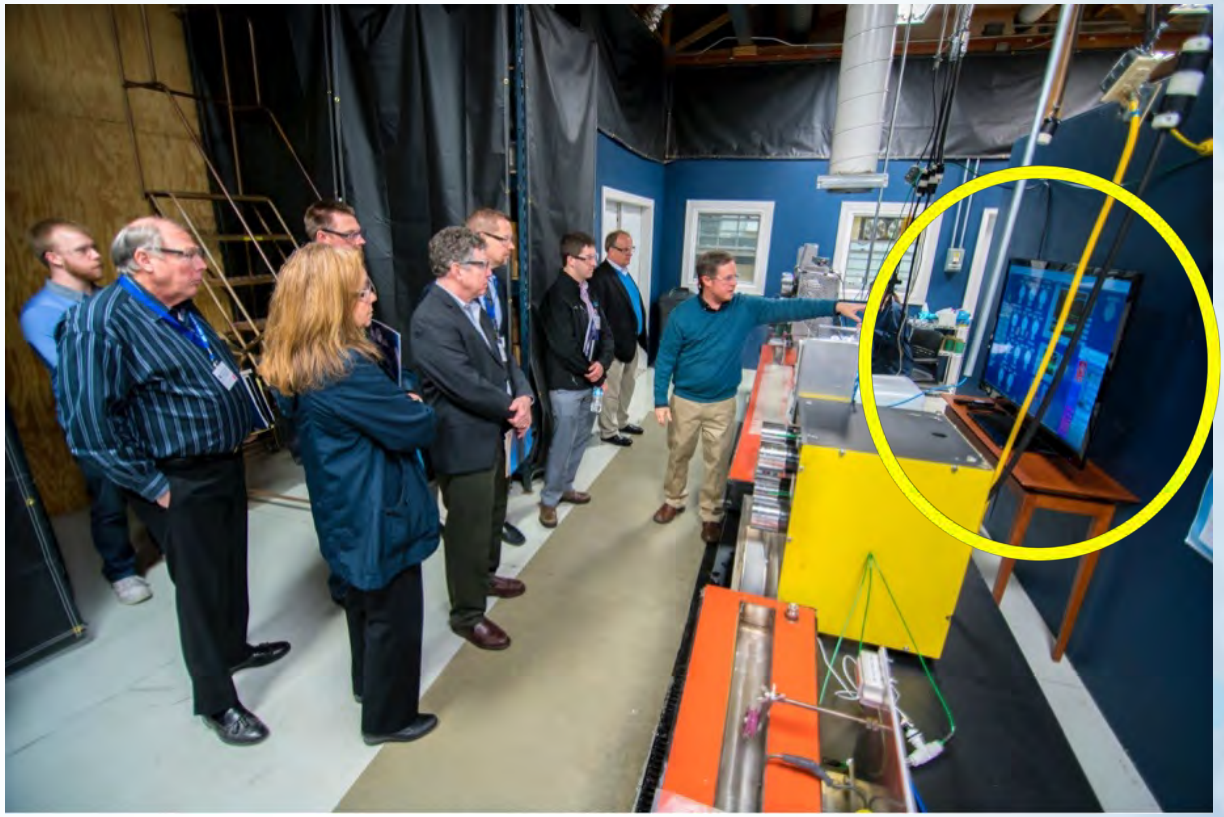
Composite Materials

UKY CAER solution spinning line for multifilament continuous tow

University of Kentucky

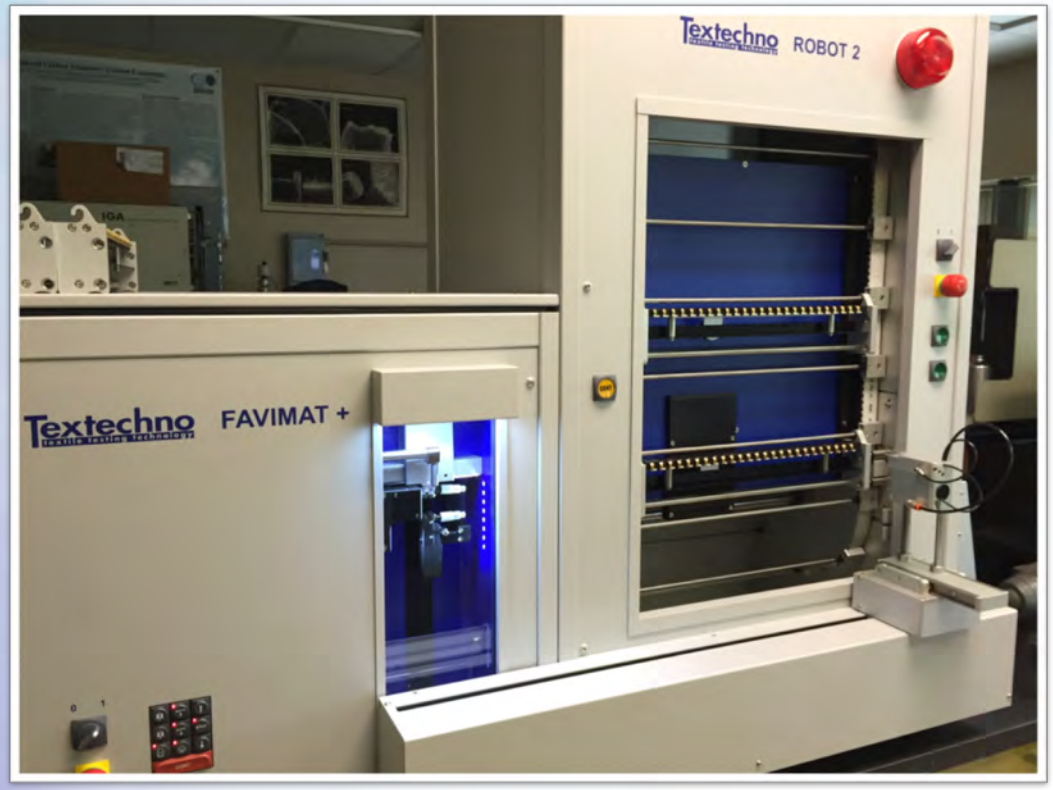
Heads UP, Real-Time Spinning Data Acquisition and Logging

- 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



University of Kentucky

Robotic Single Filament Tensile Testing and Linear Density



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

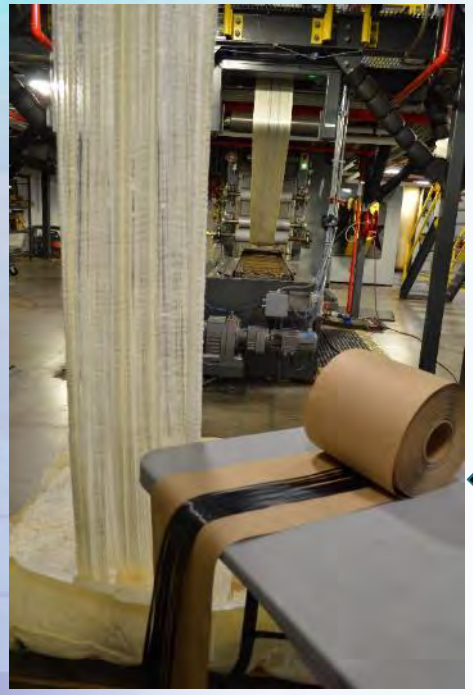
Unique open-access carbon fiber processing capabilities

Melt spinning

Bench and pilot scale heat treatment equipment

World's most flexible carbon fiber semi-production facility

Textile PAN based CF



IACMI partner, Oak Ridge National Laboratory, has demonstrated a production method estimated to reduce the cost of carbon fiber as much as 50% and the energy used in production by more than 60%.

IACMI generating properties on composites produced with textile PAN carbon fiber

UTK : Lab Scale Flexible Automated Infused Tow and Pre-Preg Manufacturing

Manual Method

Automated Method

Sheet molding compound (SMC) line - UTK

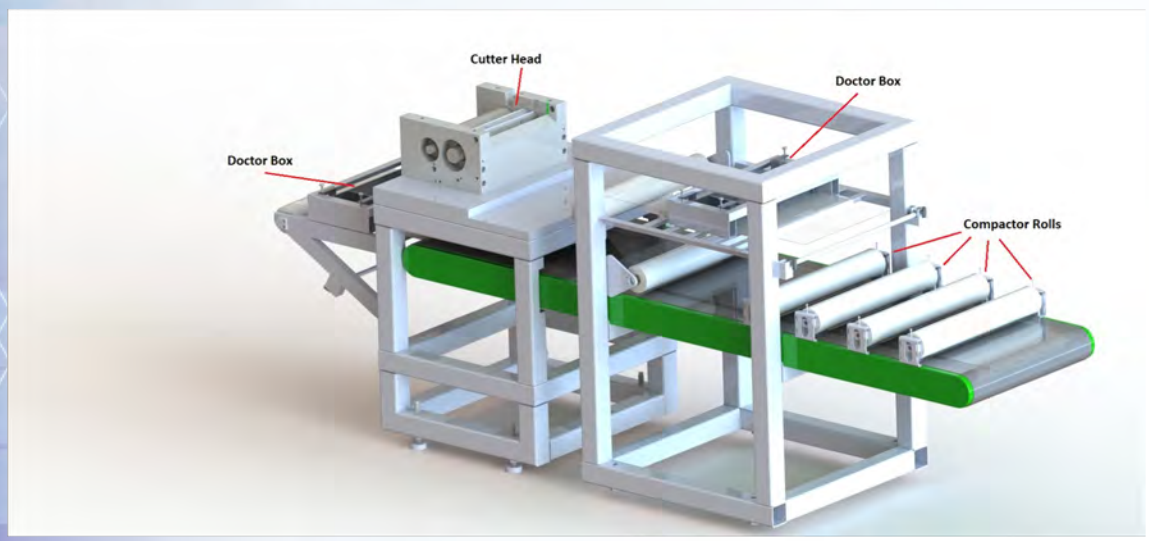
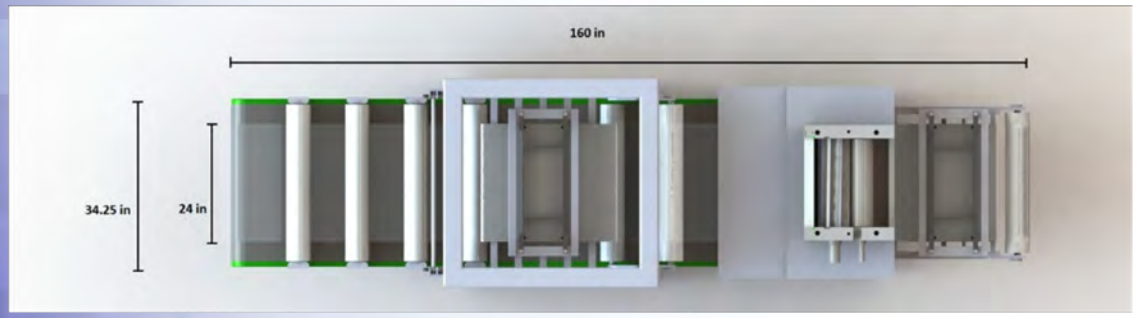


Illustration of cutting head of the SMC line

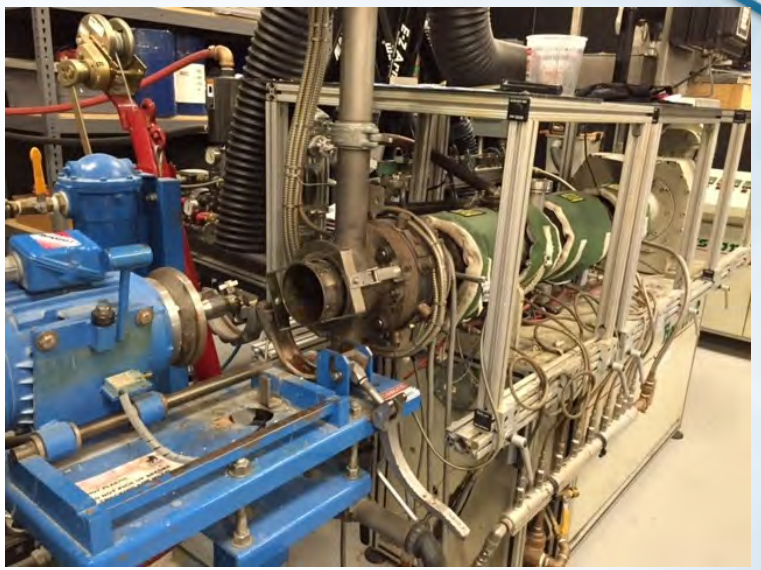


- Custom line
- Produce up to 18” wide SMC
- Glass, carbon, basalt SMC
- For use in multiple IACMI projects
- Materials collaboration with industry partners

Multiphase Compounding – Pelletizing Line (UTK)

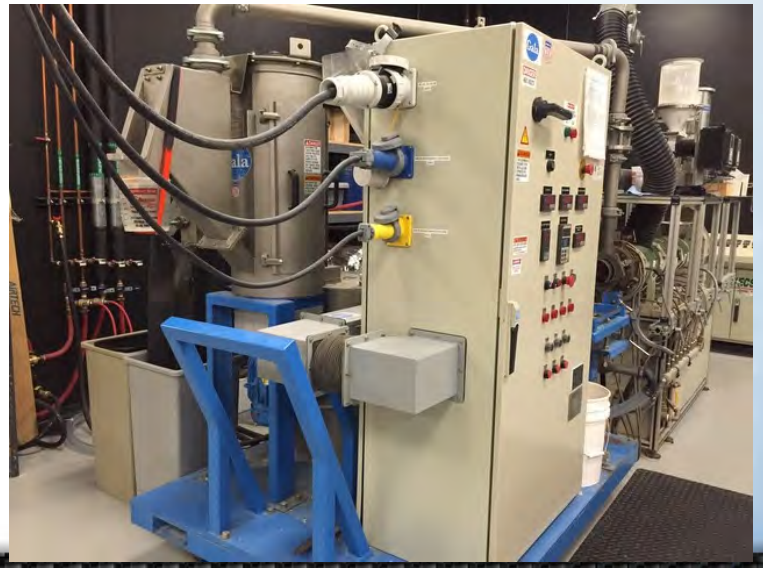
Specifications

- 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



12” prepreg line – SURF facility in Detroit

LITZLER
DRIVEN BY RIGHT

Net shape preforming – Laystitch at UDI

Complex shaped CFRP parts:

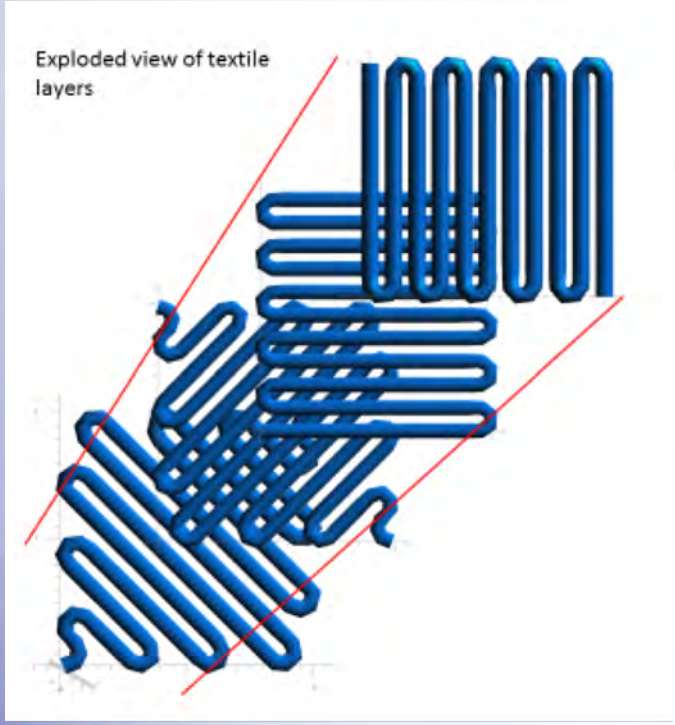
- load detour
- load introduction
- stiffening function

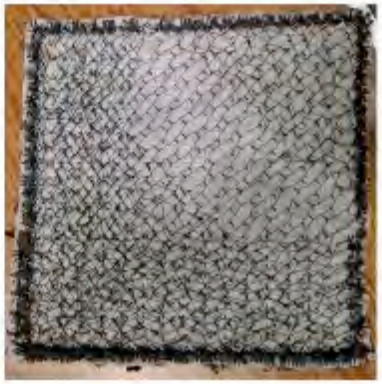
Potential applications:

- Cleats, clips, brackets
- Window frames
- Frame elements

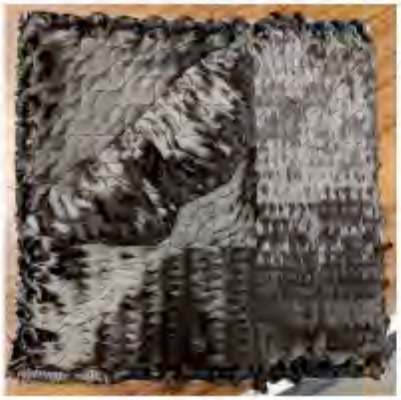
Net Shape Preforming - Laystitch

Simulation and fabrication of quasi-isotropic preform

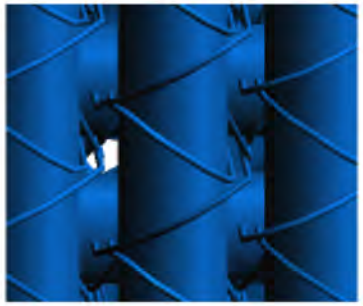




Back Side – Quasi-Isotropic Laystitch preform.
Differential amount of stitching is an artifact of the number of layers printed to show the quasi-isotropic nature of the preform.



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



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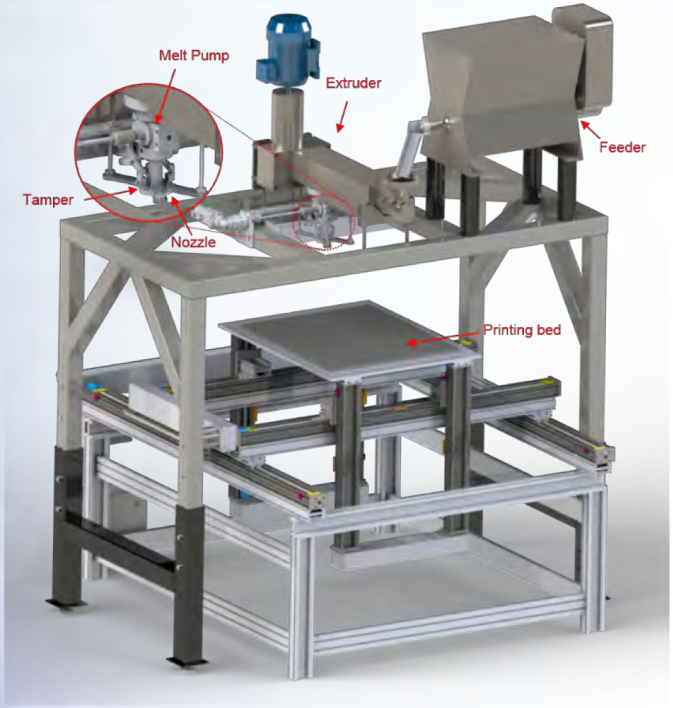
Component Manufacturing

Additive Manufacturing - Purdue



Composites Molding Tools Printed

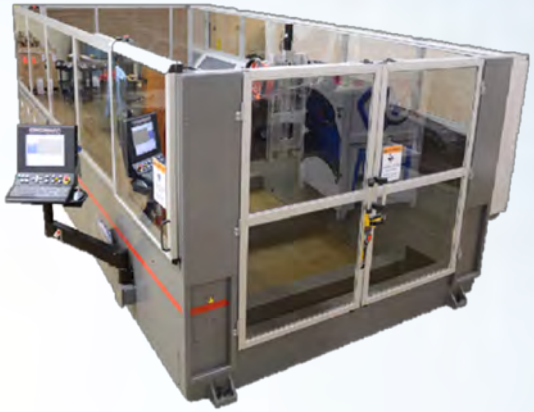
50% Carbon Fiber/PPS

Thermoforming Tool

Compression Molding Pin Bracket Tool

High Temperature Tooling by Additive Manufacturing - UDRI

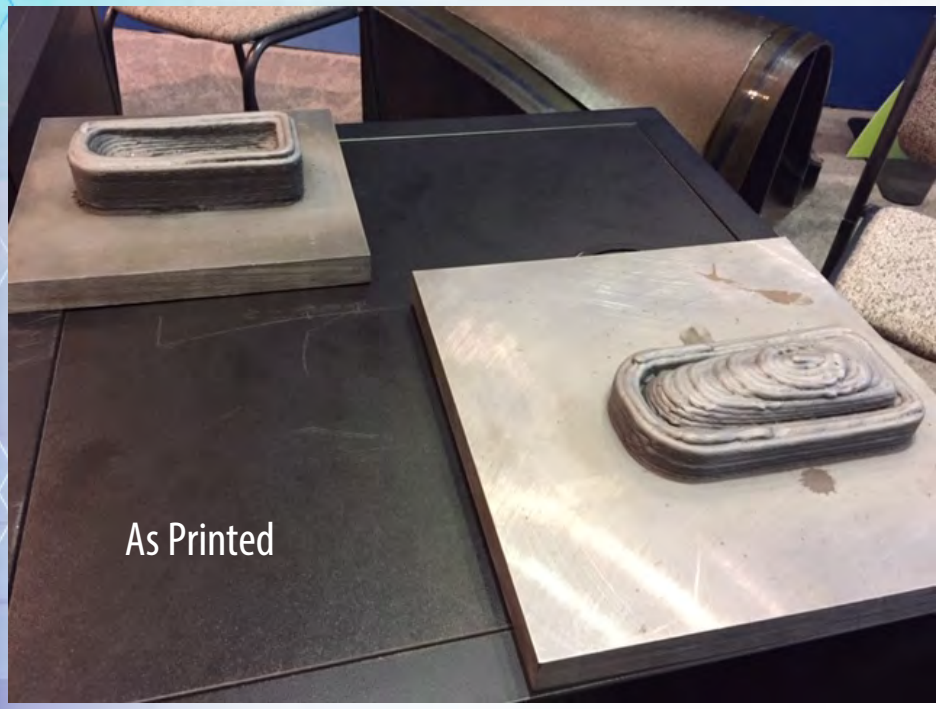
- Collaborative effort with Cincinnati, Inc (1 hour from UDRI)
- Focus on single sided tooling capable of 350F and 100 psi cure (autoclave, Rapidclave, e.g.)
- Focus material is specially formulated carbon fiber filled polysulfone. Other materials, such as PPS and PEI have also been trialed.



Big Area Additive Manufacturing - ORNL

Recent enhancements in physical scale, speed of production, and work in high temperature polymer composites, e.g. PPS/CF

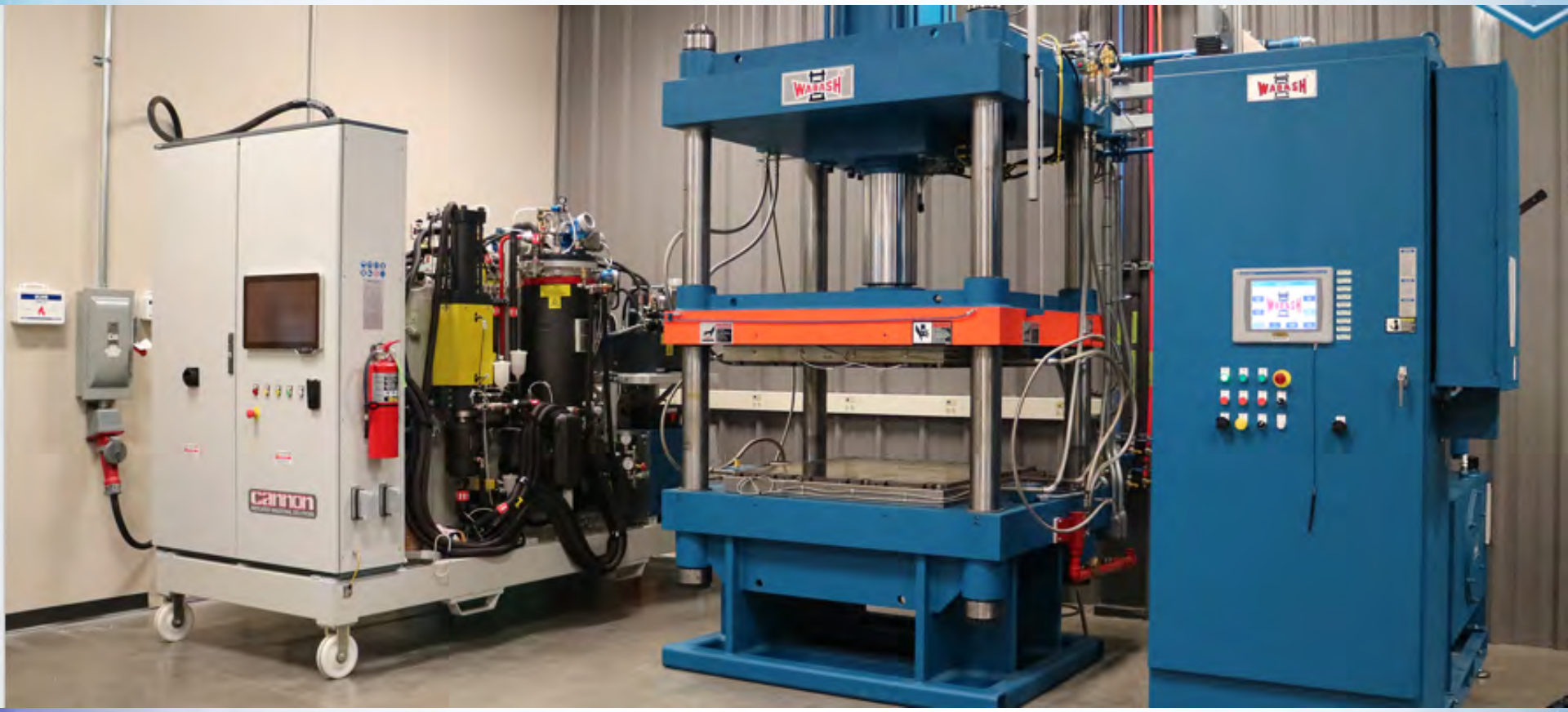
3D printed steel tooling - ORNL



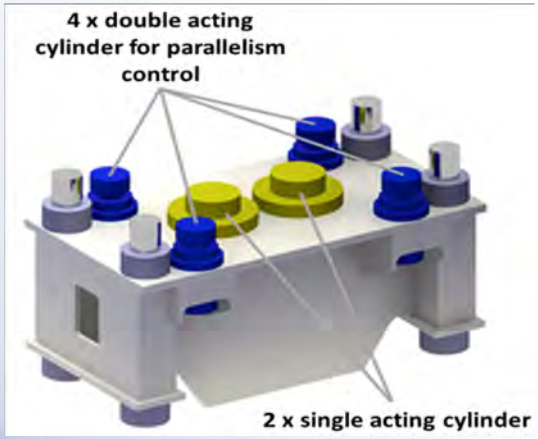
Parts molded from 3D printed steel tooling - ORNL

Compression presses - UDRI

Compression Molding and HPRTM - Purdue



Compression press – SURF



- Manufactured by 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)
- Operational since October 2017

SCHULER
FORMING THE FUTURE

Compression press - SURF

Tools currently available for project use

Saturn Fender

Tonneau cover (inner & outer)
Ford Sport Trac

Chevy Volt Battery Box

Resin mixing unit for HPRTM and wet pressing (SURF)

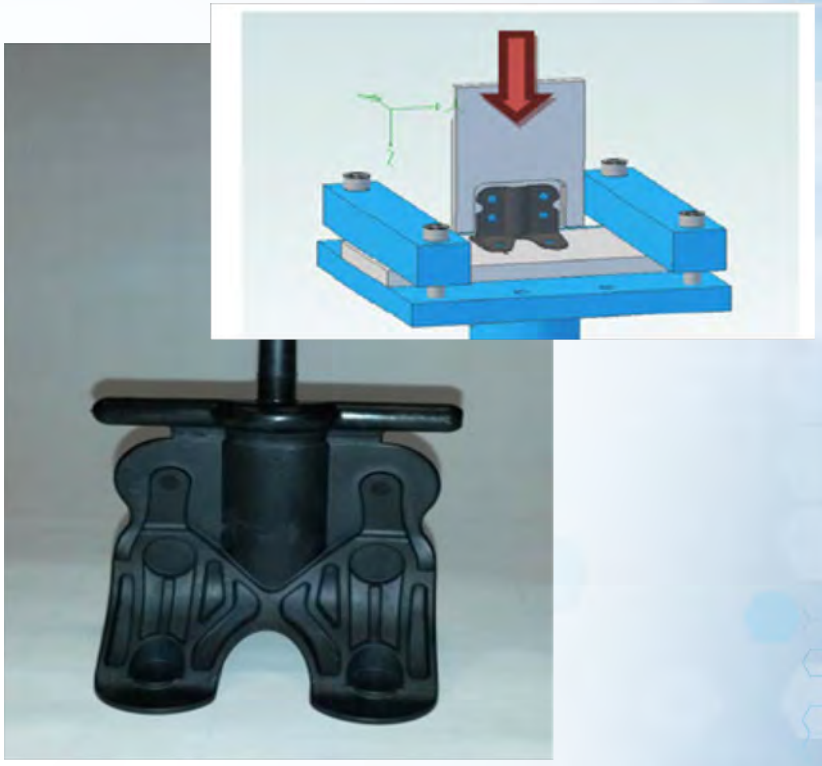
- Capable of processing epoxies and polyurethane systems
- High pressure (120 bar) capability
-

Hennecke
Polyurethane Technology

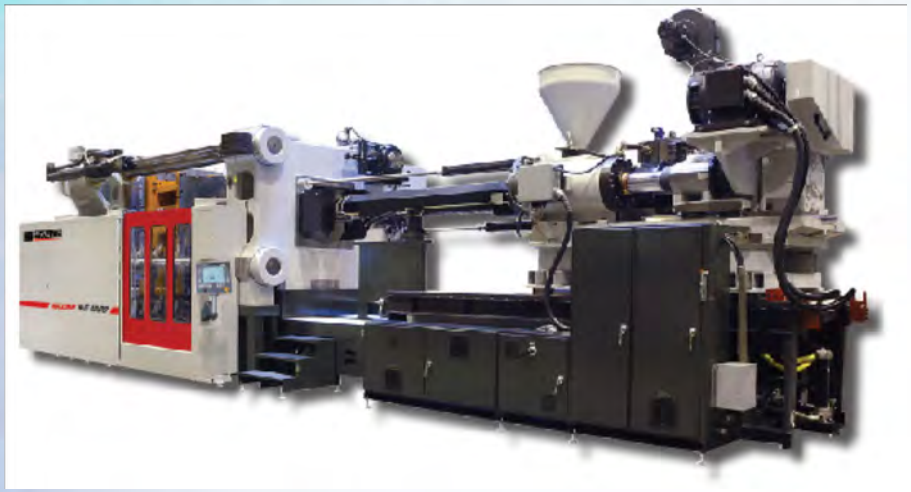
Purdue – Injection Over Molding (330 ton)

Purdue – Injection Over Molding w/preform line

UDRI Facility – Injection Over Molding (440 ton)

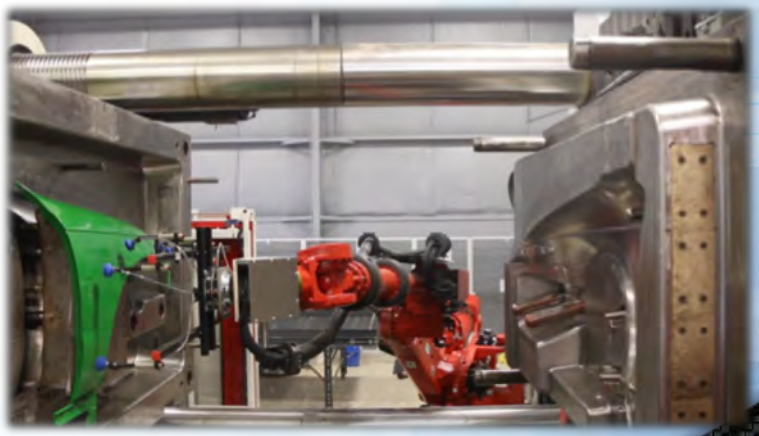


Injection molding press – SURF (3300 ton)



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

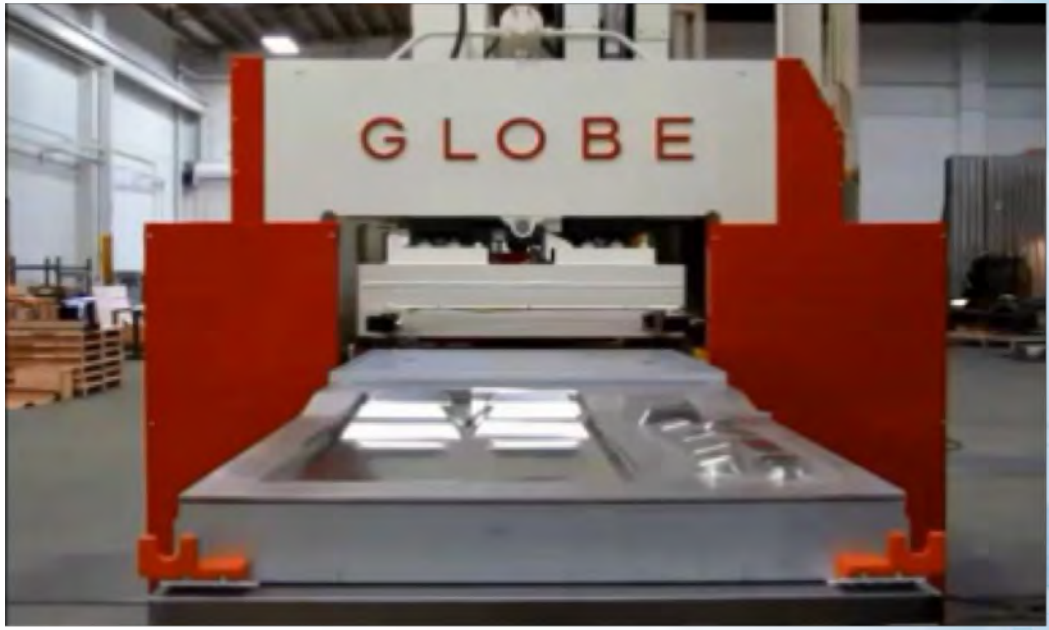
MILACRON®



Autoclave - UDRI

Rapidclave® curing - UDRI

- Globe Machine Rapidclave® equipment at former National Composite Center site
- Provides heating and cooling capabailities 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

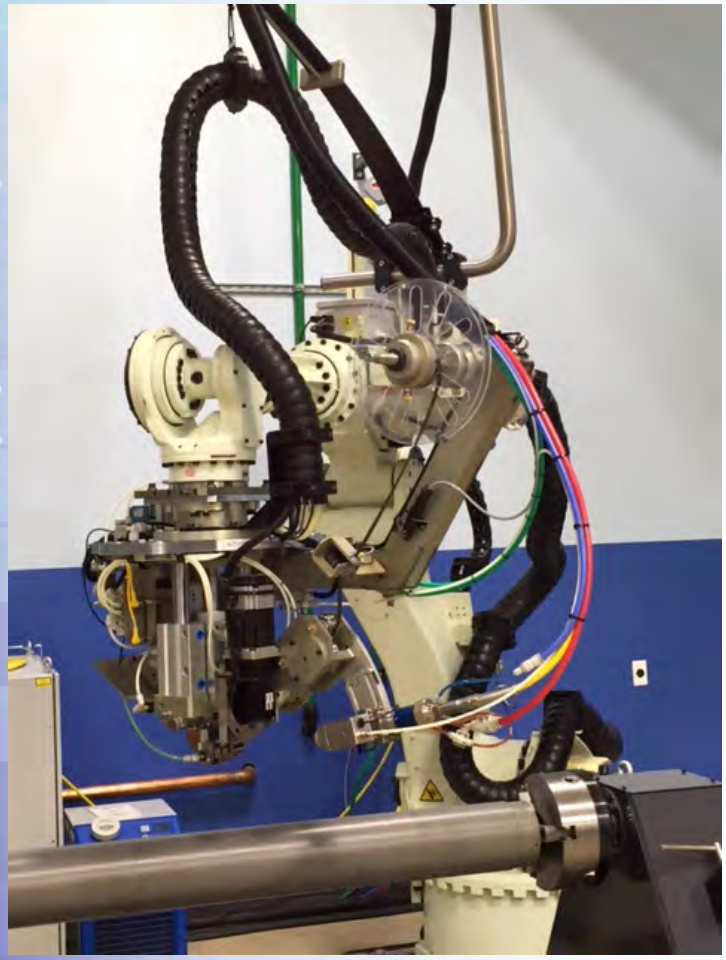


CPC Manufacturing Floor

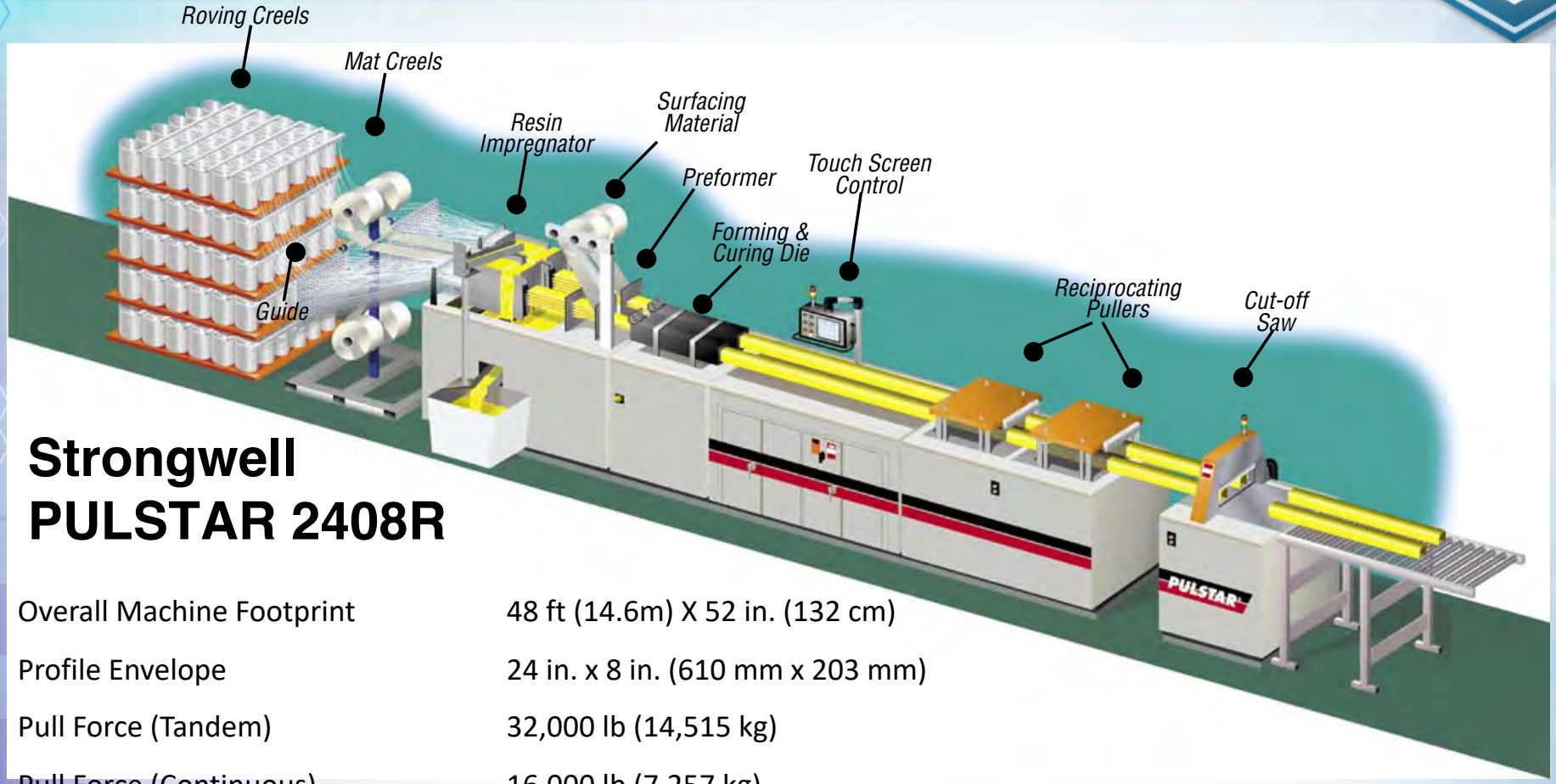
CPC supports the following processes & functions:

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 -CPC



IACMI Pultrusion Machine – ORNL CFTF



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 – ORNL CFTF

Large scale infusion equipment - NREL

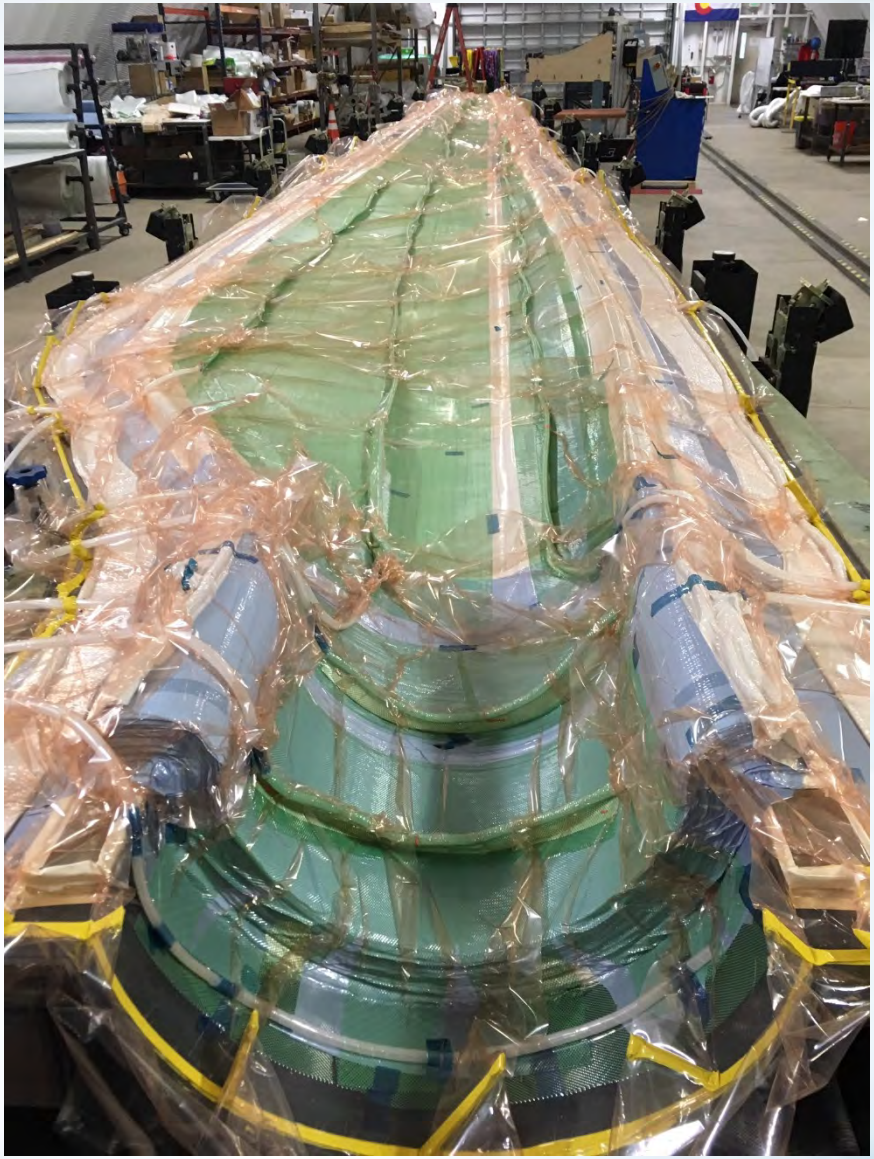
- Multiple station valves enable up to eight individual vacuum sources for larger infusions

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

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

Large part infusion - NREL

13m blade shell
At CoMET facility



Wind Blade Tooling

48.7m blade tip mold
Courtesy GE

48.7m shear web mold
Courtesy GE

Wind Blade Tooling

9m BSDS blade components
Courtesy TPI Composites

Portion of 45m spar cap infusion mold
Courtesy DowAksa

RocTool Induction Heating / Fast cycle processing of thermoplastic composites (MDF) installed July 2017

Equipment specifications

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

IACMI projects

Compression molding

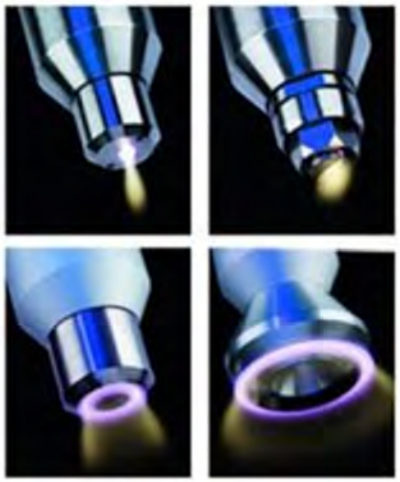
Class A surface finish

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

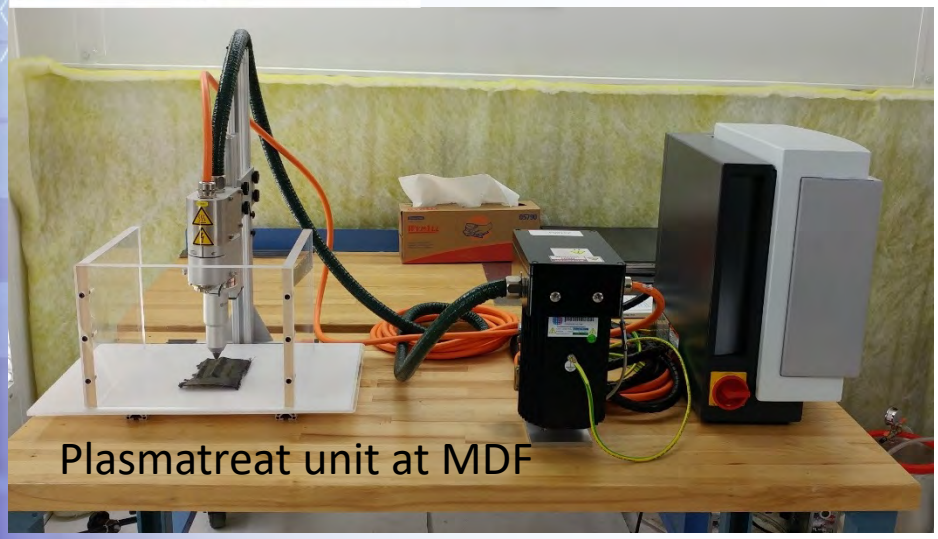
Plasmatreat unit at MDF (Jet - RD1004 / Generator - FG5001 / Transformer - HTR1233) - MDF



Resource Member

Enabling plasma treatment for surface enhancement

Tennessee (in place) and Michigan (planned)



Plasmatreat unit at MDF

- 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

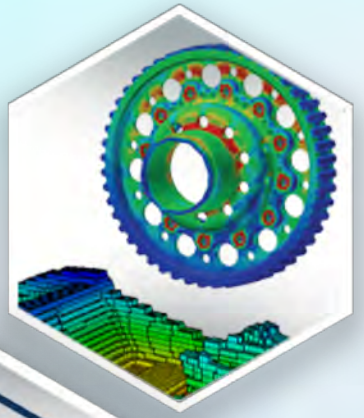
Plasmatreat and RocTool at SURF

plasmatreat
solutions on top

Plasma cleaning & coating
(2 systems via LIFT)

ROCTOOL
MOLDING MATTERS.

Systems for rapid (induction) heat-cool for injection & compression molding

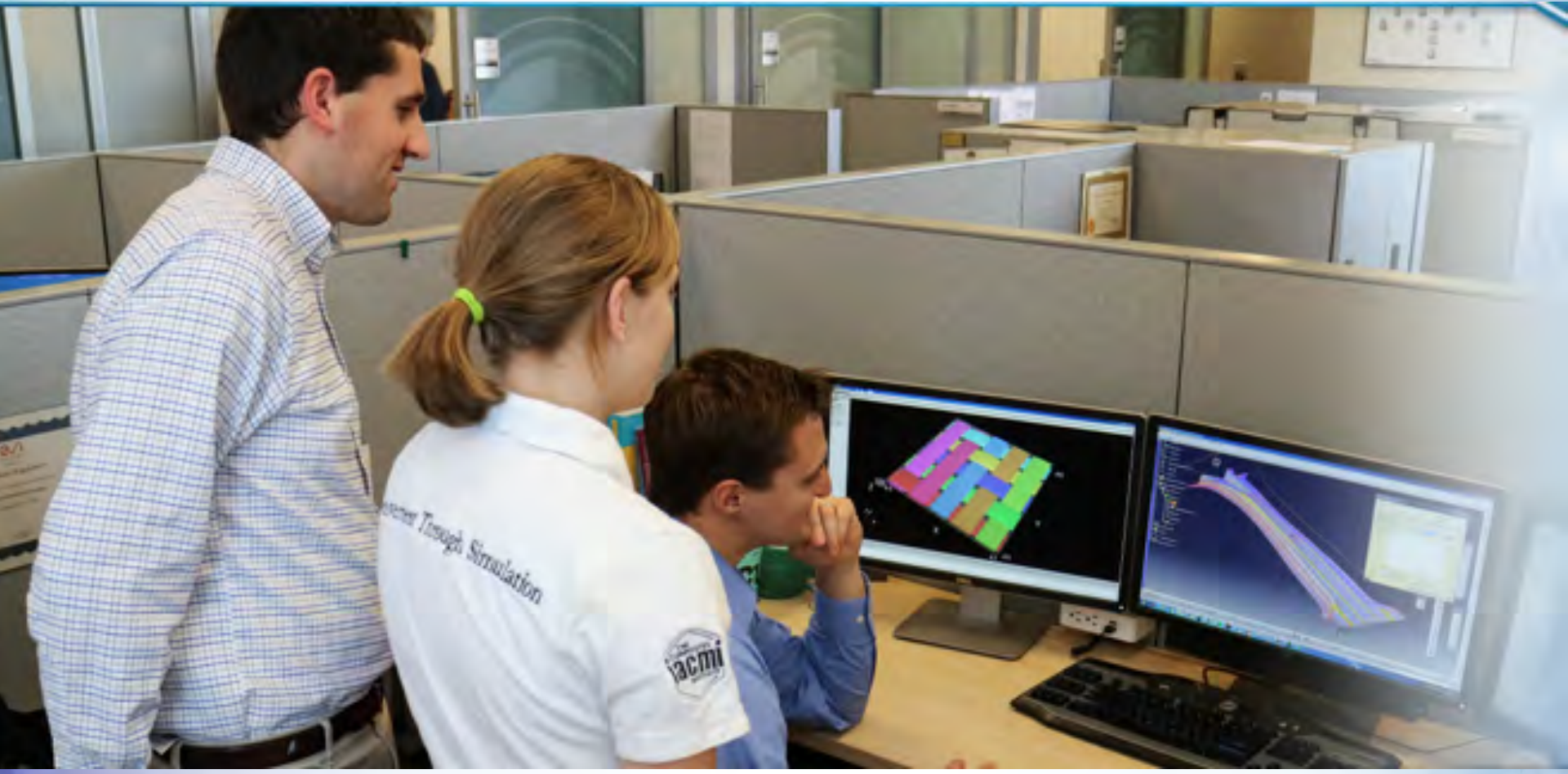


THE COMPOSITES iacmi INSTITUTE

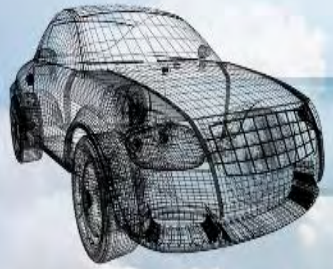
Design Modeling and Simulation

Indiana Manufacturing Institute

Composites Virtual Factory



Manufacturing Informed Design



PAMFORM

PAM-RTM

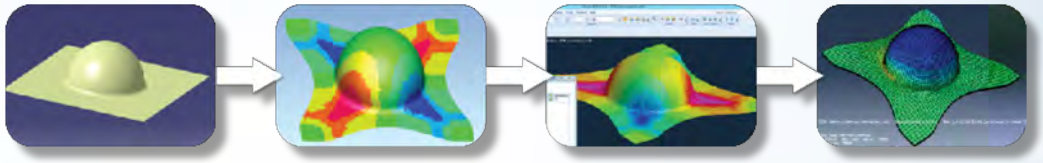
COMPRO

Expertise

Collaboration

Composites Virtual Factory Vision

End-to-end composites simulation.



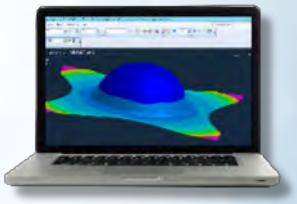
Powered by **integrated** and **validated** commercial software.

Design

Manufacturing

Performance

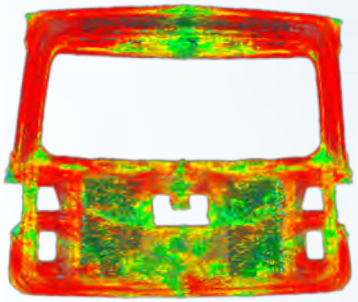
In a **secure**, **collaborative**, **cloud-based** environment.



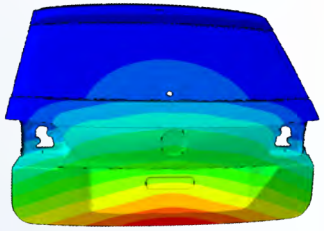
Driven by End-to-End Simulation

Current Metal Design

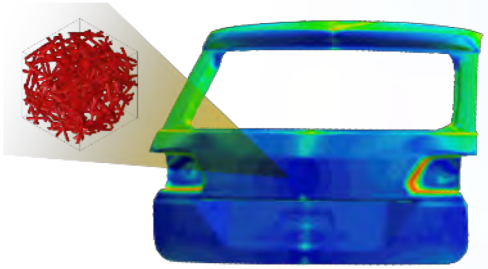
Redesign in CATIA



Predict fiber orientation with Moldex3D



Design for manufacturing informed performance with Abaqus



Integrate material properties with Digimat

Delivering Composites Simulation Tools

COMPRO | RAVEN

CATIA | ABAQUS | ACCELRYS | ENOVIA | DELMIA

SWIFTCOMP | VABS

DIGIMAT

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

MOLDEX3D

A single platform - with major composites software.

Integrated Workflow Apps

Additive Manufacturing

CATIA | SIMPLIFY3D | Stream Engineering (MSC Software Company) | SIMULIA

Injection Overmolding

CATIA | LS-DYNA | Moldex3D Molding Innovation | Stream Engineering (MSC Software Company) | LS-DYNA

HP-RTM

CATIA | PAM-RTM | PAM-FORM | CONVERGENT Manufacturing Technologies | SIMULIA

Compression Molding

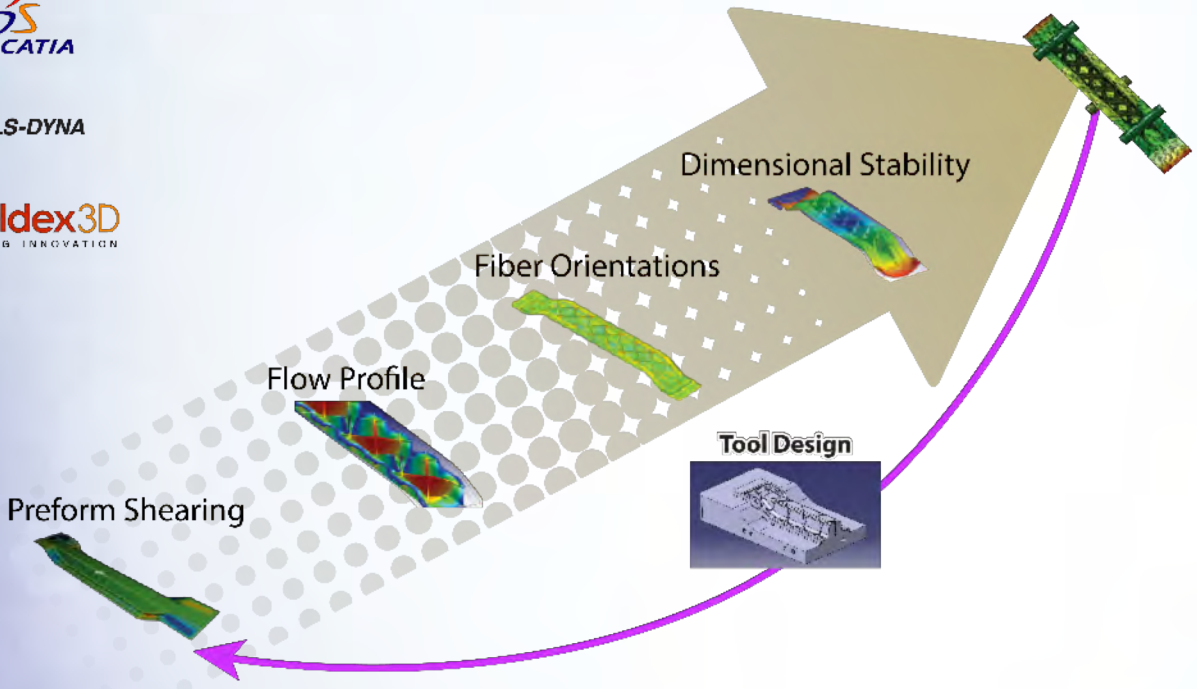
CATIA | PAM-FORM | Moldex3D Molding Innovation | Stream Engineering (MSC Software Company) | PAM-CRASH

Code Integration Makes Possible

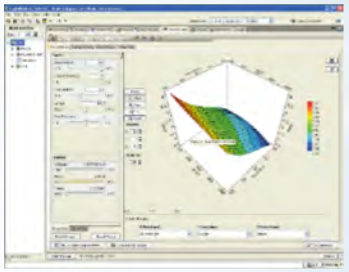
CATIA

LS-DYNA

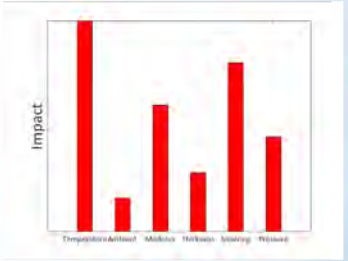
Moldex3D
MOLDING INNOVATION



Optimization



Sensitivity Studies



Delivering Simulation Tools in the Cloud

amazon web services

COMPOSITES VIRTUAL FACTORY HUB

A secure cloud services platform, offering compute power, file storage, content delivery, and other functionality to help businesses scale and grow.

Testing

Materials and Mechanical Testing

The IACMI network includes numerous labs capable of testing fiber and resin properties, as well as mechanical properties on molded components and structural testing of assemblies

- All ASTM/ISO test methods for numerous specimen geometries
- Hot/wet, cold, fatigue, chemical exposure, creep, etc.
- Panel fabrication and specimen preparation
- Resin rheology, fabric drapability/formability and permeabilty
- Larger scale structural tests at UDRI, Vanderbilt, NREL

Just ask your IACMI contact and we can direct your enquiry to the right location(s) to meet your needs

Validation Labs - Purdue

UDRI Facility

Analytical Lab

Environmental Conditioning Lab

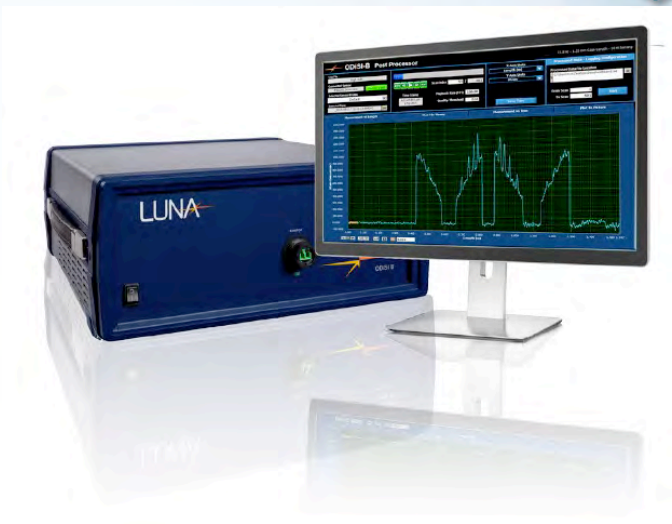
Laboratories - SURF

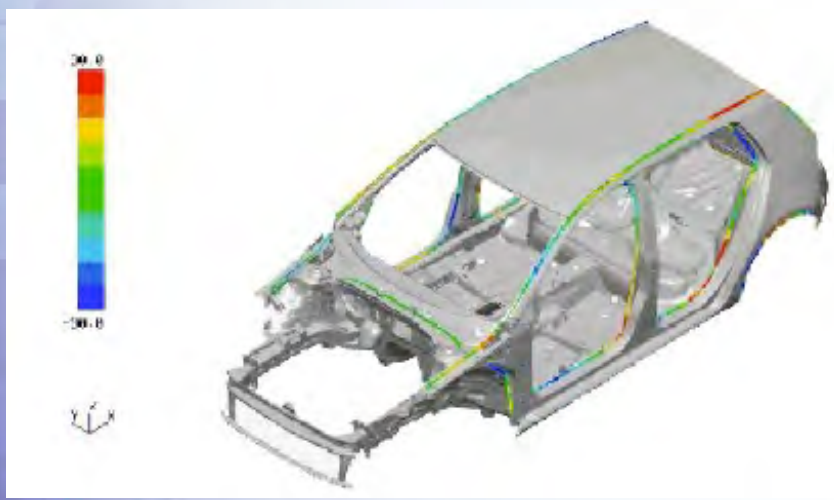
- Analytical-wet lab & sample prep (340 m^2)
  - Material preparation (e.g., mixing)
  - Materials Characterization
    - FTIR, DSC/DMA, Microscopy, etc
  - Trimming, cutting, grinding, etc.

- Controlled process lab (450 m^2)
  - Temperature & humidity controlled
  - Negative pressure & filtered return (carbon containment)
  - Space for pre-preg & tape lay-up lines

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**





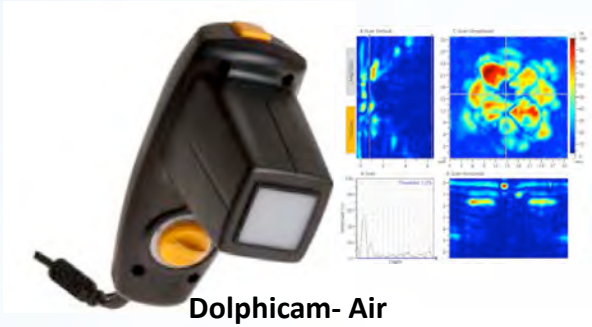
ODiSI - Key Benefits

- 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 - Vanderbilt

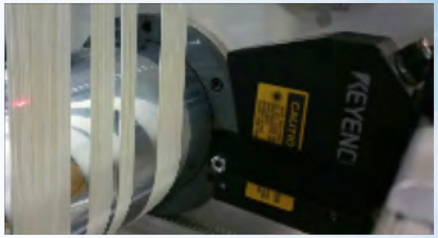
Flaw detection in composites

Mistras Acoustic Emission System 01/2017



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

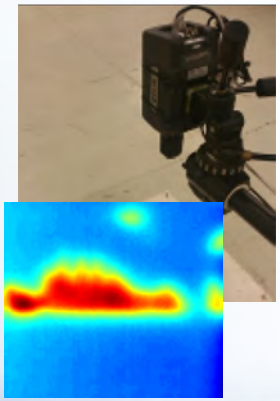
Keyence Laser Profilometer 08/2015



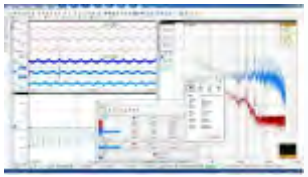
Keyence Laser-Displacement Sensors 08/2015

Cure Monitoring for Composites

Olympus EPOCH 650 Portable Ultrasonic NDE Systems 01/2017



FLIR High Resolution IR Camera 03/2016



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

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

Recycling

Recycling Shredder (UTK)

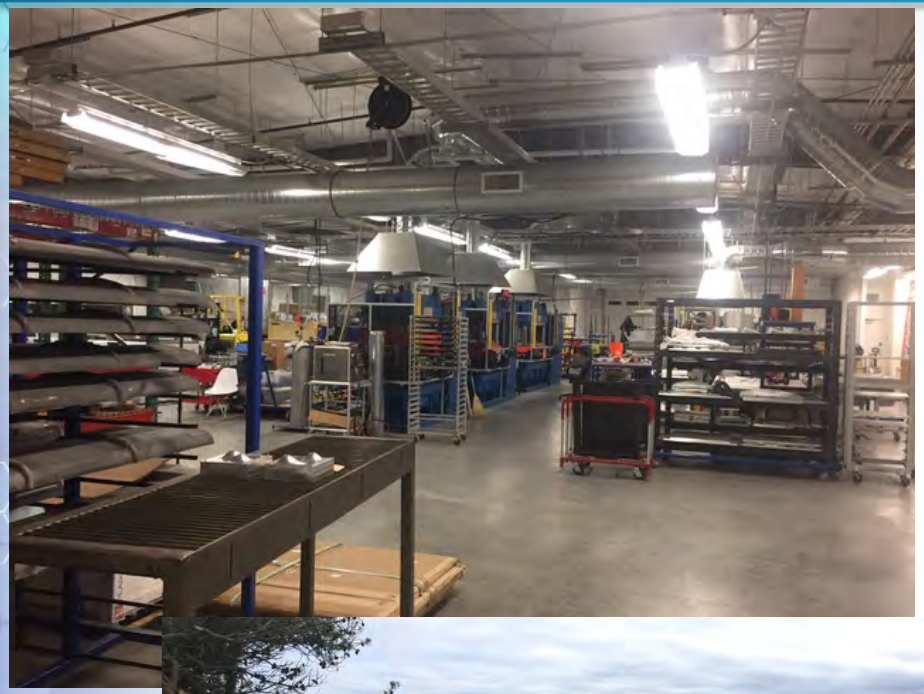
MS-1714 Dual Shaft Shear Shredder

- 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

Composites Recycling Technology Center



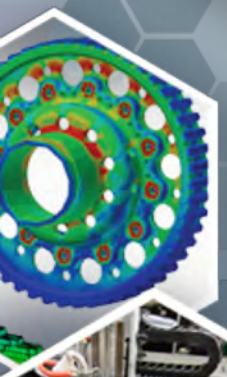
- CRTC, located in Port Angeles, Washington
- Objective to recycle scrap prepreg into useful parts
- Initial products developed and shipping

CRTC COMPOSITE RECYCLING TECHNOLOGY CENTER

PENINSULA COLLEGE

Working Relationships - Recycling

- Composite Recycling Technology Center
- Carbon Conversions
- Vartega
- ELG Carbon Fiber
- GreenTex Solutions
- CHZ Technolgies
- Adherent Technologies



Questions?

Dale Brosius

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