Vehicle Technology Area

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Vehicle Technology Area

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Institute for ADVANCED Composites Manufacturing INNOVATION

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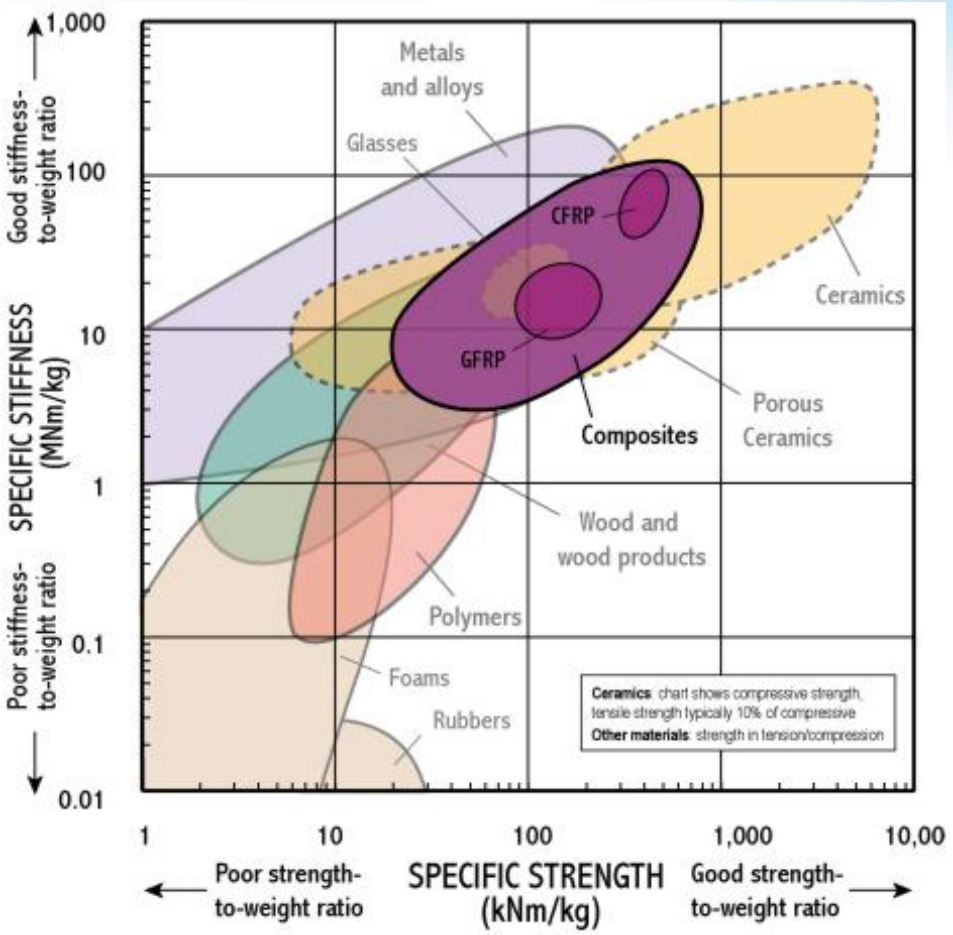
Vehicle Response to 54.5mpg challenge

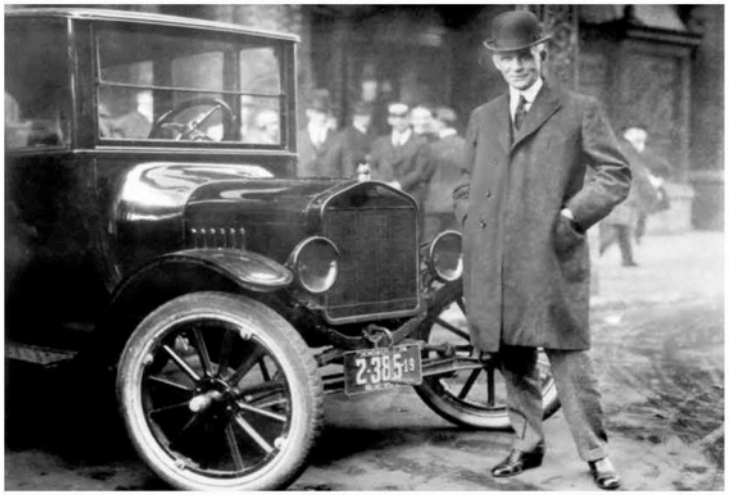
- Lightweighting is an important end-use energy efficiency strategy in transportation, for example a 10% reduction in vehicle weight can improve fuel efficiency by 6%–8% for conventional internal combustion engines, or increase the range of a battery-electric vehicle by up to 10%.
- Composites can offer a range of mass reductions over steel ranging from 25–30% (glass fiber systems) up to 60–70% (carbon fiber systems).



Specific stiffness and specific strength for various materials: Carbon Fiber Reinforced Polymer (CFRP) Composites and Glass Fiber Reinforced Polymer (GFRP) Composites.

University of Cambridge, http://wwwmaterials.eng.cam.ac.uk/mpsite/interactive_charts/spec-spec/basic.html

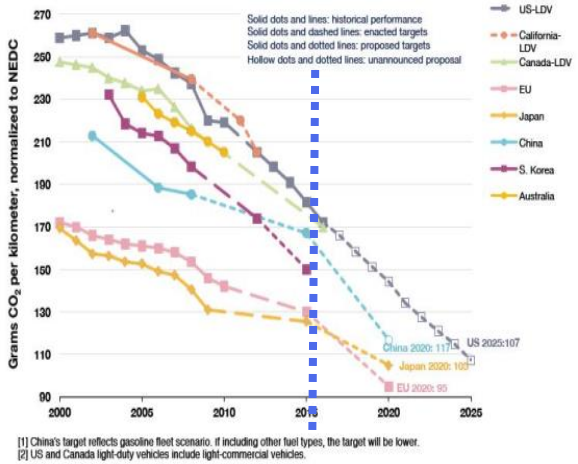
Why Lightweighting?



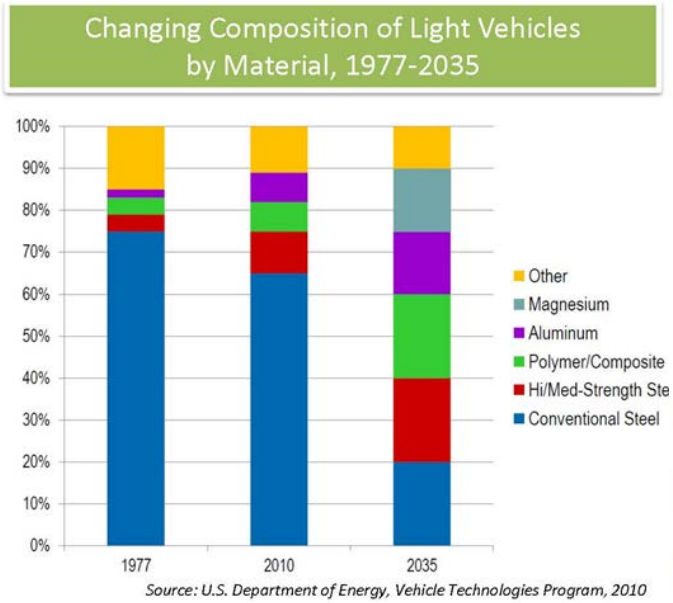
"Excess weight kills any self-propelled vehicle. There are a lot of fool ideas about weight … Whenever anyone suggests to me that I might increase weight or add a part, I look into decreasing weight and eliminating a part!" – Henry Ford, 1922

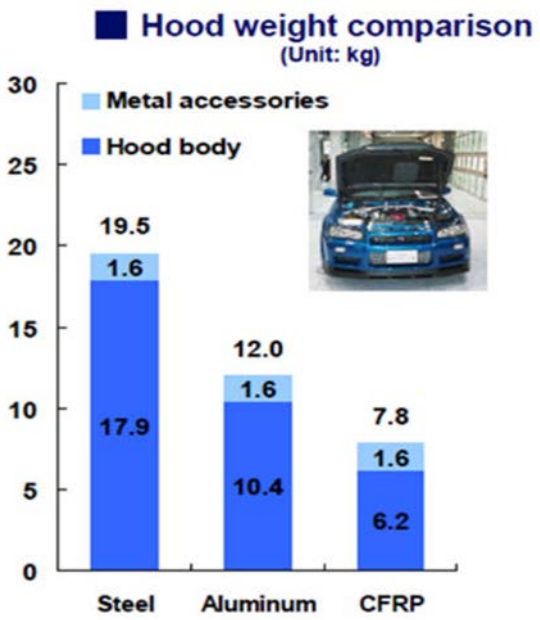
Every automotive manufacturer is pursuing light weighting as a key strategy to reduce fuel consumption—irrespective of the powertrain technology pathway.

Lightweighting Vehicles



Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards, International Council on Clean Transportation, August, 2011





Carbon Fiber Reinforced Polymer (CFRP) Composites have the greatest weight reduction potential if cost and manufacturing issues can be solved.

Rosato, D., "Automotive lightweighting trends drive plastics technology", MULTIBRIEFS, June 1, 2015, http://exclusive.multibriefs.com/content/automotive-lightweighting-trends-drive-plastics-technology/engineering

IACMI Goals Fiber Reinforced Polymer Composites for Vehicle Applications

Technical Goals

- 25% lower CFRP cost
- 50% reduction in CFRP embodied energy
- 80% composite recyclability into useful products

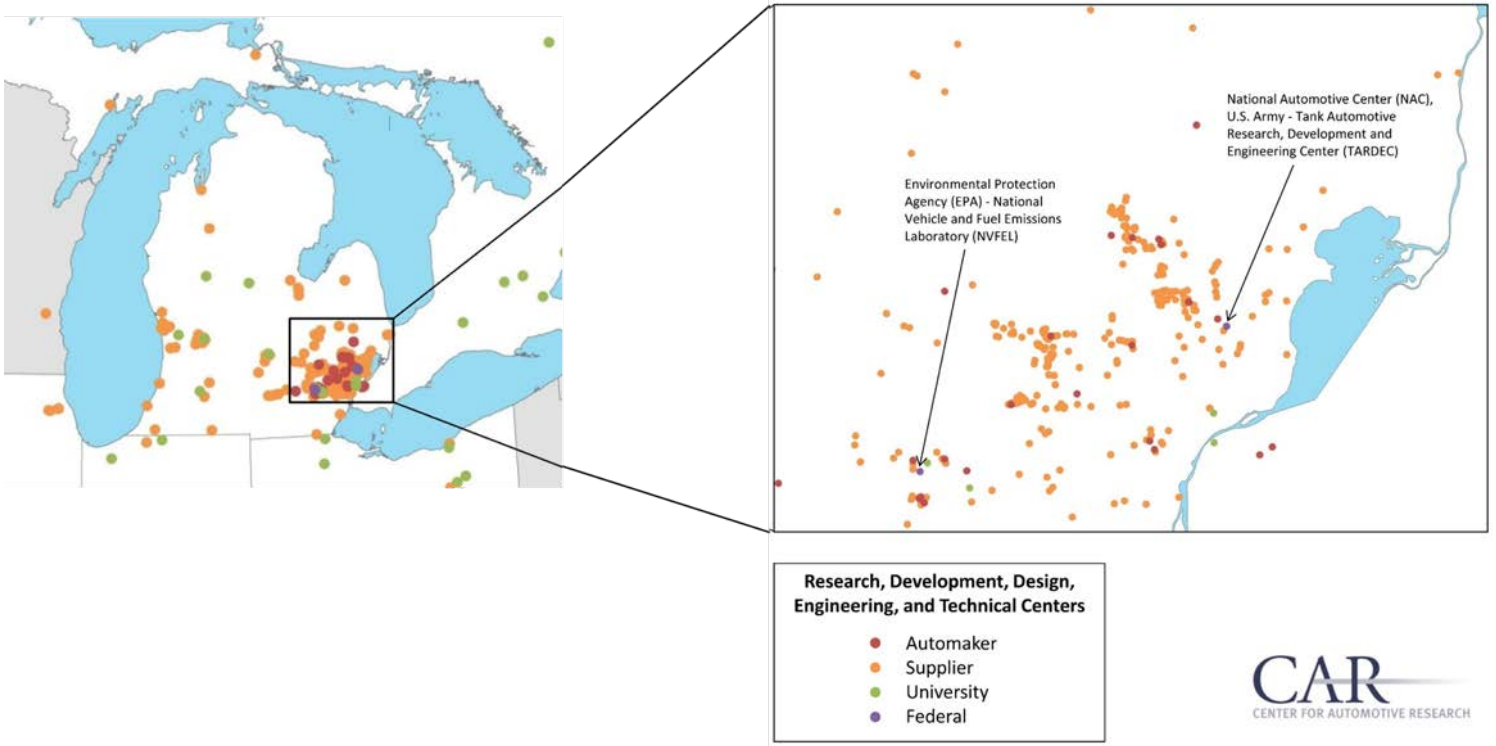
Specific Approach

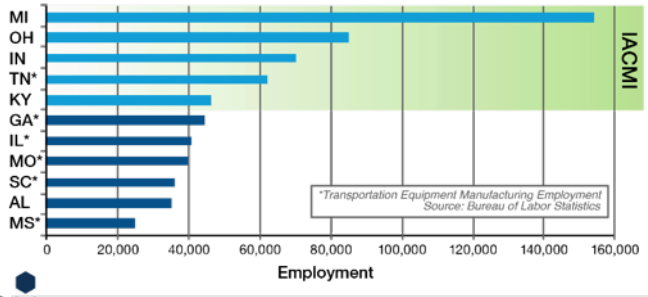
- Adoption of carbon fiber composites in mass-produced platforms (≥100,000 units/yr) by the end of Year 5.
- Advance multiple technologies incorporating continuous fiber reinforcement to achieve cycle times under three minutes within five years, with one or more technologies ***under 90 seconds***;
- Drive down the ***fabricated cost*** of continuous carbon fiber structural parts ***by 50% or more*** within five years, including reduction in material and process costs;
- Develop robust ***simulation and modeling tools that accurately and reliably predict*** the performance and costs of each major process and their resulting composite structures.

How will IACMI- Vehicle Technology Area (VTA) Achieve its Goals?

- Knowledgeable and Dedicated Professional Staff
- State-of-the Art Automotive Composite Process Facilities at Manufacturing Scale
- Integration of Participant Teams in the Vehicle Supply Chain
  - OEM, Tier 1, Material Suppliers, SMEs
- Identification and Support for Leading-edge Projects
- Access to Facilities for Proprietary Projects
- Workforce Development Opportunities

Michigan is strategically located and the leader in US auto production and R&D





>70% of US auto R&D in Michigan alone

State of Michigan Support

- Michigan Economic Development Corporation -MEDC
  - Automotive Strategic Plan
    - Demographics and Vehicle Market
    - Vehicle Design
    - Connected Vehicles
    - Powertrain and Propulsion Technologies
    - Manufacturing and Supply Chain
    - Material and Joining Technologies
  - Establish Collaboration Center across supply chain
    - OEM-Tiers-Suppliers-Tooling-Fabricators-Design-Testing
  - Leverage Expertise to attract Federal and Industry Investment
  - Develop Talent in Materials Engineering, Modeling, Simulation, Systems Engineering and Skilled Trades
    - Michigan State, Michigan, Michigan Tech, Wayne State
    - Community Colleges: Lansing CC, Macomb CC, Alpena CC
  - **$15M investment in IACMI-VTA 5 yrs**

PURE MICHIGAN
Michigan Economic Development Corporation

Automotive Strategic Plan

The design and engineering of tomorrow's vehicles will require the strategic use of advanced materials and joining technologies. Collaboration among suppliers and manufacturers is key to Michigan leading the transformation from mild-steel to lightweight, multi-material vehicles.

MICHIGAN STATE UNIVERSITY

Michigan Technological University

Macomb Community College
Education • Enrichment • Economic Development

MICHIGAN

LANSING COMMUNITY COLLEGE
Where Success Begins

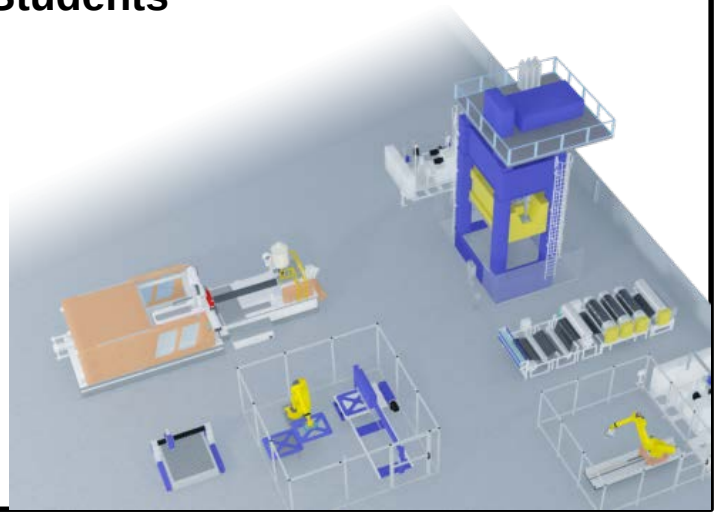
Focus: HOPE
Education • Opportunity • Community

ALPENA COMMUNITY COLLEGE

Vehicles Technology Area: RESOURCES

- **Michigan State University Resources (Lab Scale)**
  - **Composite Materials and Structures Center**
  - **Composite Vehicles Research Center**
  - **22,500 ft2 Facility for Analysis, Characterization, Processing and Testing**
  - **Faculty, Research Staff, PostDocs, Graduate Students**

- **Scale-Up Facility (MSU operated)**
  - **Located in 40,000 ft^2**
    Centrally located in Detroit Metro area
  - **Mi State-(MEDC) funded full-scale equipment and facilities**



CO
Automation processes
In situ thermoplastic infusion

IN
Models for preforming, infusion, cure kinetics, performance

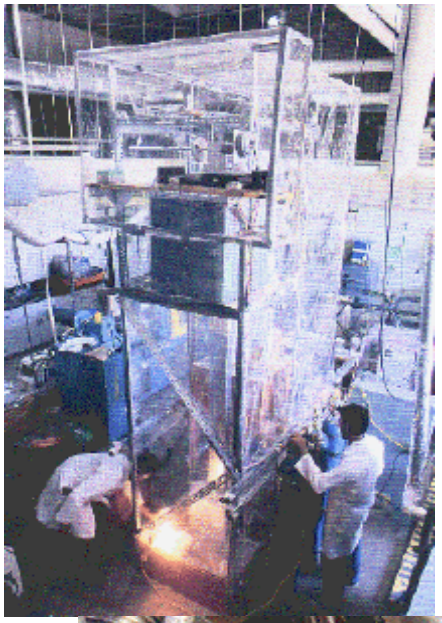
OH
High strain rate testing, NDE
Mesoscale molding
Netshape preforming
ICME processing and performance

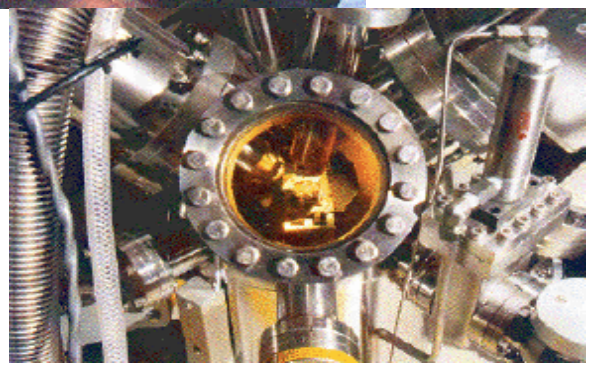
TN
Low-cost carbon fiber (LCCF)
Lab-scale intermediates and composites fabrication
NDE
Recycling

MI-Vehicles Technology Area: MSU Resources and Expertise

- ***Composite Materials and Structures Center***
- ***Composite Vehicles Research Center***
- ***MSU-Applied Research Laboratory, ITAR/EAR Compliant***
  - ***Research, Characterization, Testing, Development Facilities***
- ***Polymer Composite Processing and Modeling***
- ***Process Development , Modeling and Manufacturing-Liquid Systems***
- ***Additive Manufacturing of Thermoplastic Composites***
- ***Multifunctional Composites (Nano-particles)***
- ***Joining- Adhesive Bonding, Mechanical fastening, Bolt Design***
- ***Surface treatments and Sizing of Reinforcing Fibers and Adherends***
- ***Biobased Structural Composites***
- ***Modeling and Structural Analysis (Static, Crash, impact, Fire, Fatigue)***
- ***Dynamic Characterization and Design***
- ***NDI, NDE in-situ and Remote Sensing***

MSU-COMPOSITE MATERIALS and STRUCTURES CENTER





7,500 ft² Composite Characterization Laboratory and Processing Laboratory With Over $5M in Equipment for Polymer and Composites Fabrication and Testing

Full-time staff

- 3 professionals and 2 technicians

Education and Training of Engineers and Scientists 15+ Faculty and 25+ student researchers

Outreach to Industry and Government

- Fabrication, Testing and Characterization Capability
- Research Staff for Short -Term Contract and Applied Research
- Faculty and Students for Long-term Research

http://www.egr.msu.edu/CMSC/

MSU-COMPOSITE VEHICLE RESEARCH CENTER

Center of Excellence for the research, design, and implementation of composites for lightweight, durable, cost-effective, efficient, and safe vehicles

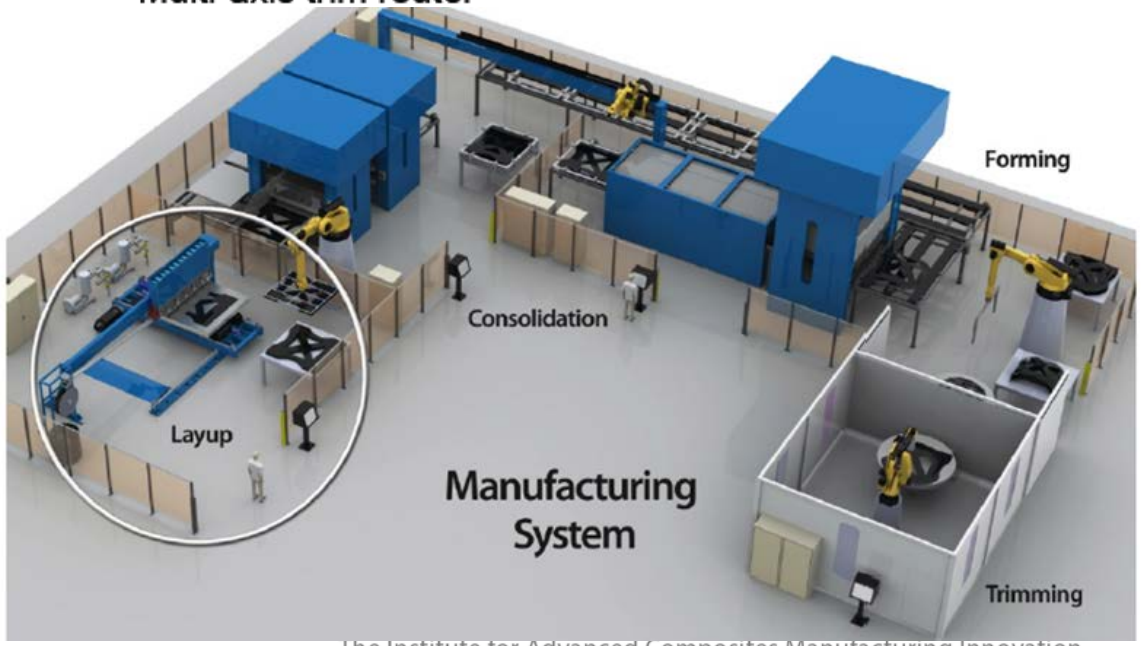
- Emphasis on composite vehicle systems, subsystems, and components
- Intersection of composites and vehicle technologies
- ITAR-compliant off-campus facility
- “Design validated by experiment”
- Integration of analytical, numerical, and experimental approaches
- Focal Areas:
- Impact and Crash Resistance
- Design and Manufacturing – Liquid Molding
- Multifunctional Composites
- Composites Joining – Bonded and Bolted
- Multi-scale Damage Modeling
- Wireless Health Monitoring
- Structural Optimization

Vehicle Scale-up Facility - Corktown

- ***OEMs and Tier 1 Industries met over a 24 month period to identify what was necessary to acieve large scale production of polymer composites for automotive applications***
- Shared facility located in epicenter of automotive R&D
  - Easy and flexible access
- Production-scale equipment to demonstrate production rates >100,000 parts/yr
- Automated pre-processing of composite constituents and post-processing of composites parts at scale
- Integrated in-situ recycling of offal

IACMI-VTA Process Capabilities

- Large part fabrication
  - Injection over-molding of structural inserts
  - HP-RTM (epoxy, PU) and variants
  - HP-RTM (thermoplastic)
  - Prepreg compression molding (thermoset & thermoplastic)
  - Thermoplastic and thermoset compression over-molding with structural inserts
- Material formulation
  - Hot-melt prepreg line
  - Thermoplastic recycling regrind/ re-compound
- Preforming
  - Automated cutting
  - Thermoplastic tape layup
  - Preforming press
  - Thermoplastic consolidation
- Finishing
  - Waterjet
  - Multi-axis trim router



Co-located with LIFT in Corktown (Detroit)

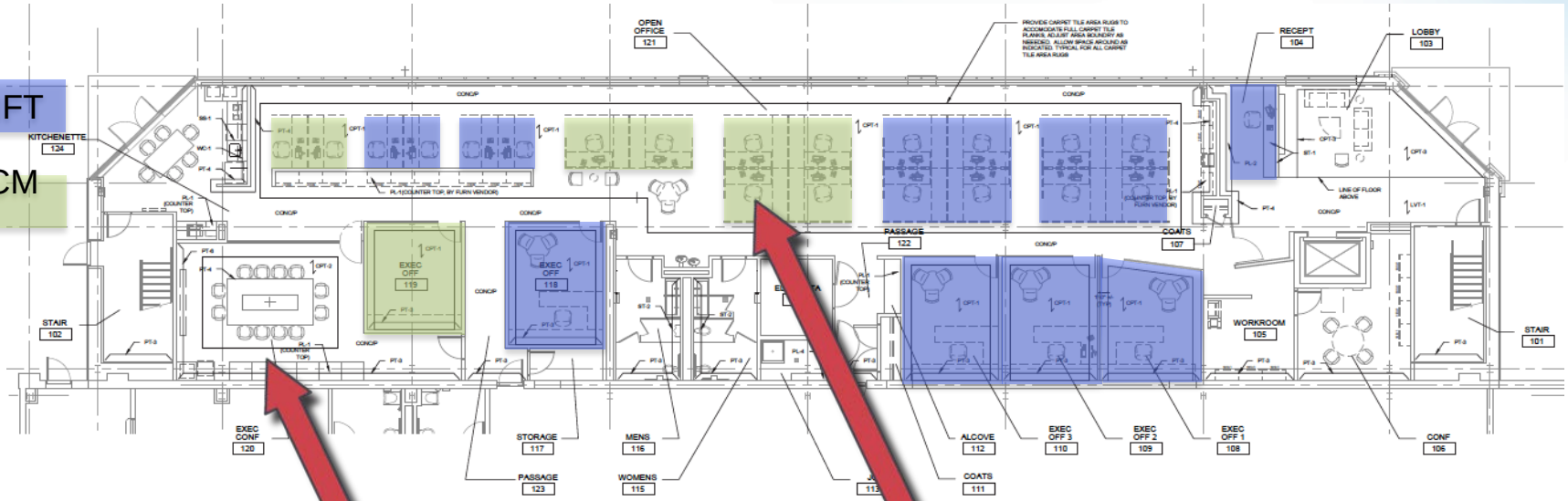
1400 Rosa Parks Blvd
Detroit, Michigan 48216

87,000 SF high-bay
13,000 SF office
43% dedicated to IACMI

Corktown Facility – First Floor Office

LIFT

IACM
I



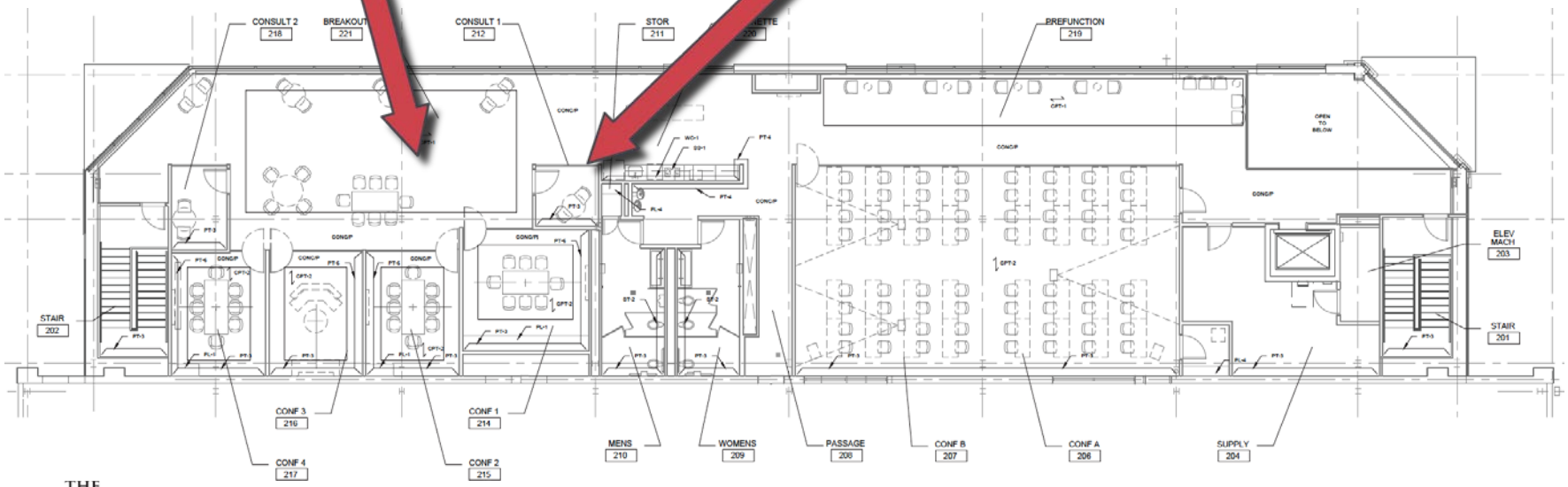
Executive Conference Room

Modular Office Space

Corktown Facility – Collaboration & Training

Open Collaboration

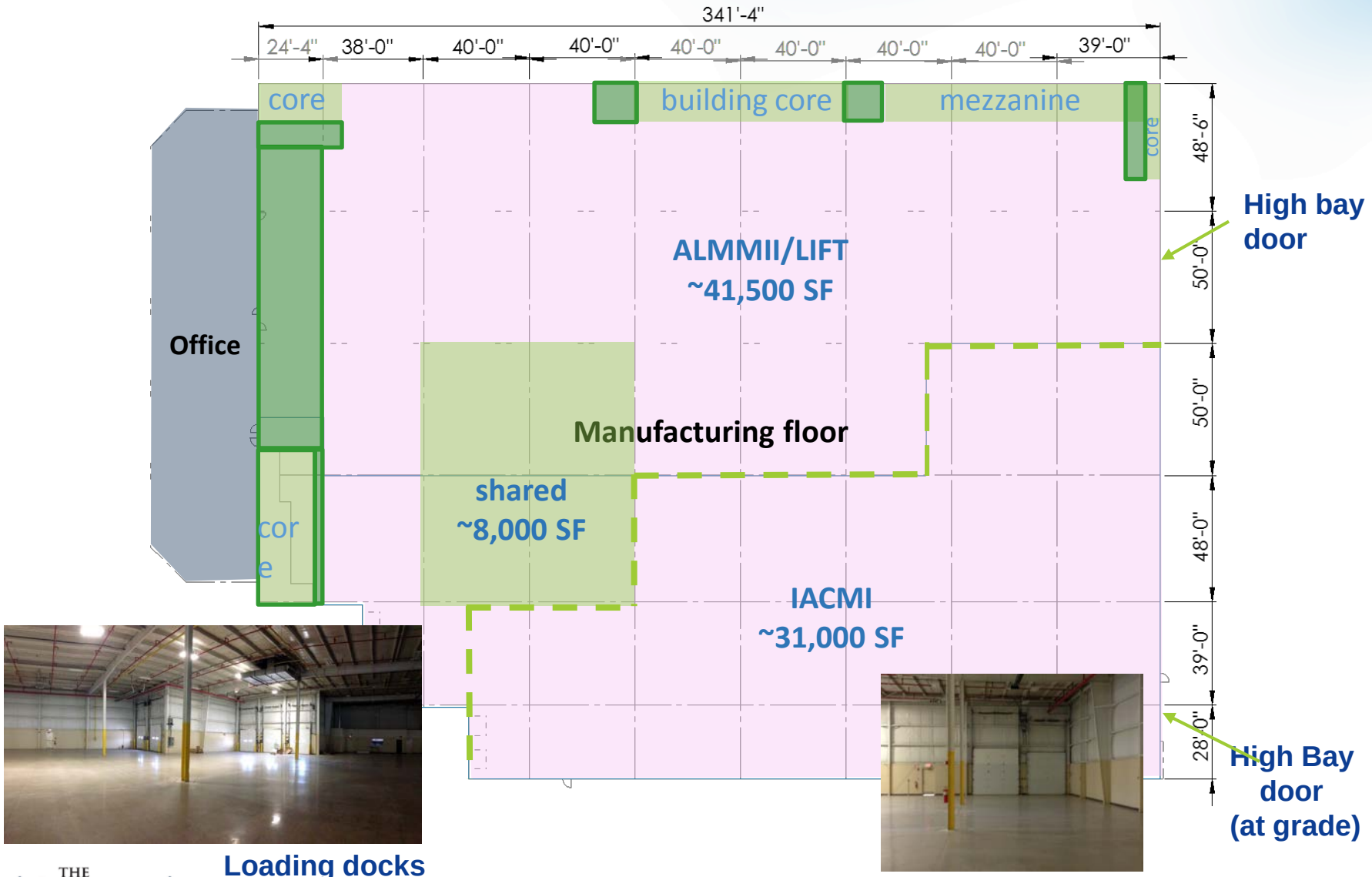
Conference Rooms



THE COMPOSITES iacmi INSTITUTE

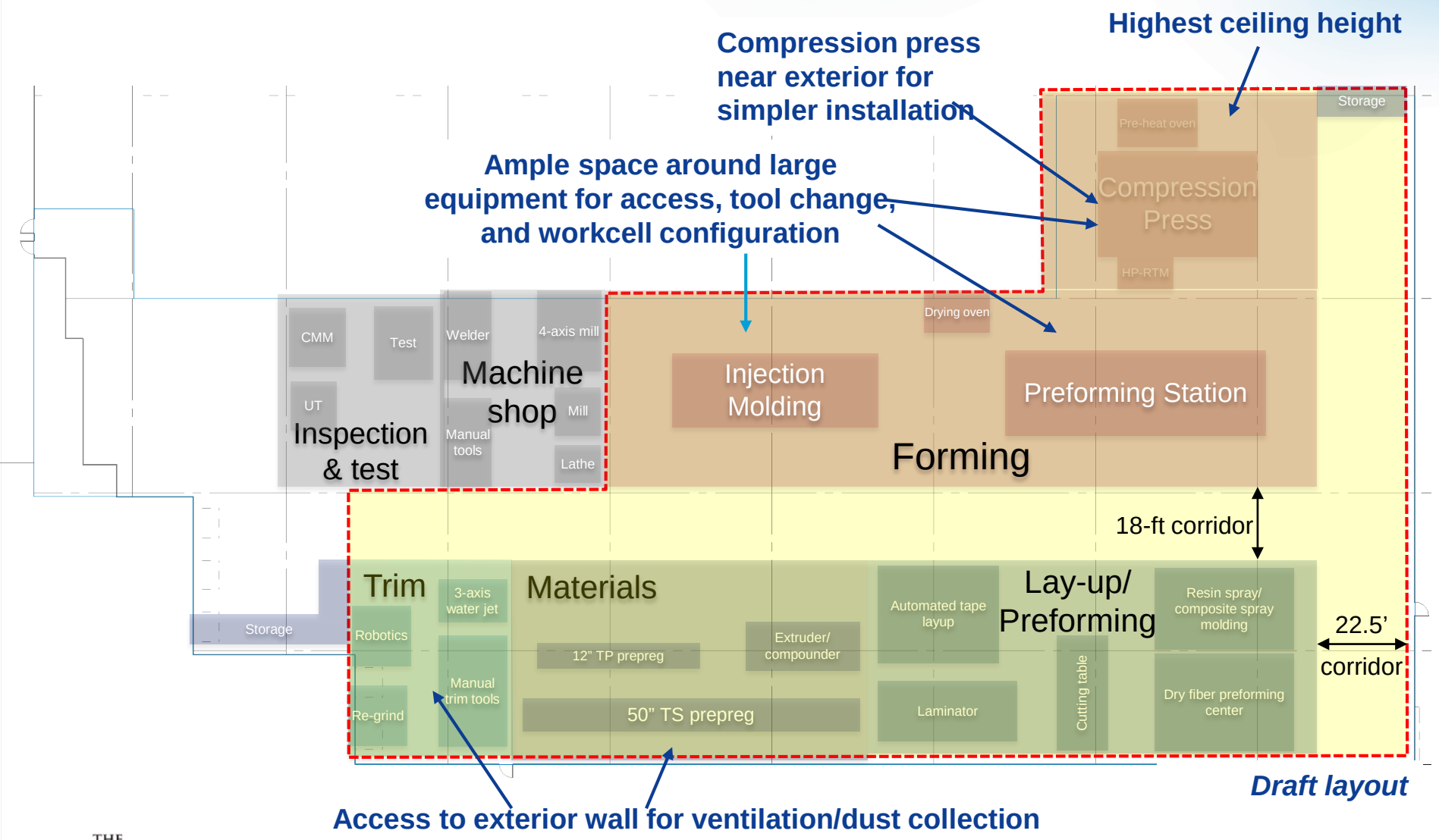
The Institute for Advanced Composites Manufacturing Innovation

Division of high-bay ~ 87,000 gross SF



Loading docks

IACMI lab – notional layout



Compression press ordered

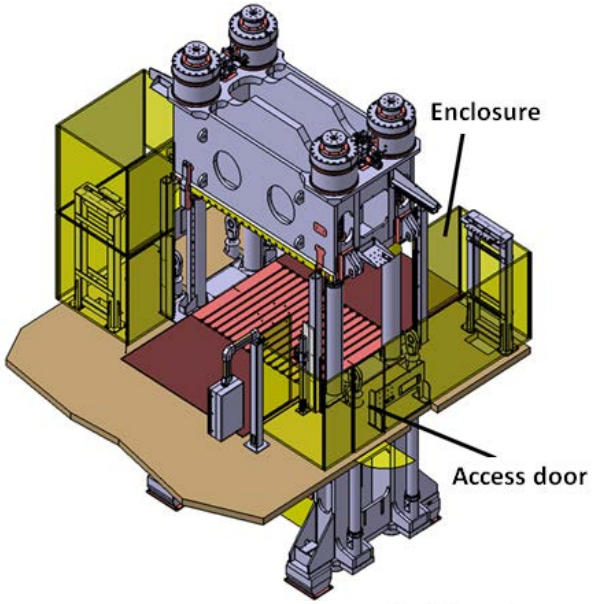
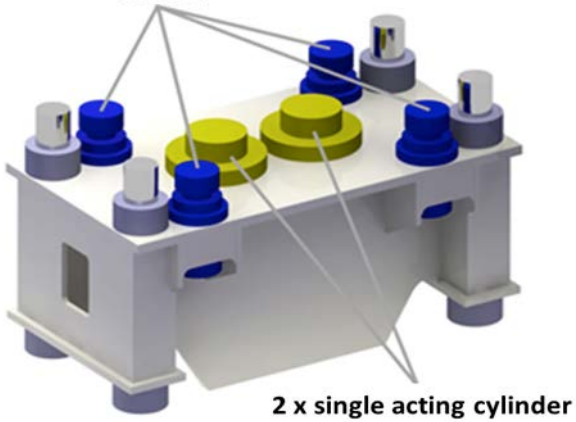
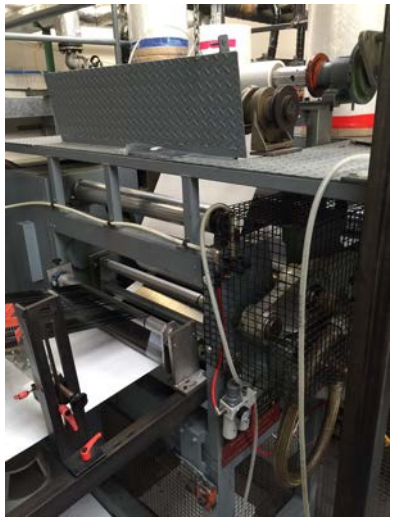


Image Source: Schuler



- 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 November 2016
- Operation status expected March 2017

Prepreg machine acquired



- Acquired from TenCate
- Produced commercial product through Dec 2015
- Specifications
  - 0.5m (20in) width
  - 120 - 600gsm
  - 2m/min
- Shipped from UK this week
- Operation status expected late spring/early summer

Injection molding press

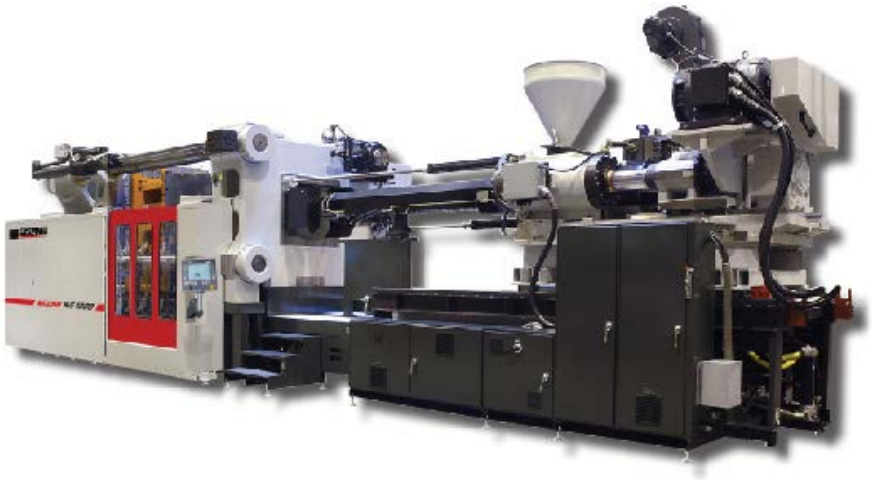


Photo Source: Milacron

- Purchase order anticipated within next few weeks
- Specifications
  - 29,500kN (3,315T)
  - Platen: 3m x 2.5m (~10ft x 8ft)
  - 413 oz. max shot size (multiple screw sizes)
- Operation status expected December 2016

HP-RTM/Liquid Compression Molding

Photos Source: KraussMaffei Technologies GmbH

- Request for proposals in coming months
- HP-RTM for “closed mold” infusion
- Liquid Compression with flat preforms (Wet Compression)
- Operation status to coincide with compression press

Preforming & lay-up technology

Photo Source: Cannon

Photo Source: Dieffenbacher

Photo Source: Dieffenbacher

Photo Source: Coriolis

Photo Source: Broetje

Photo Source: Compositence

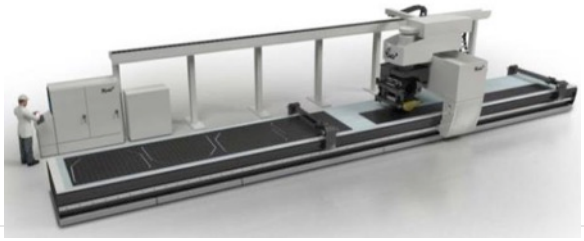
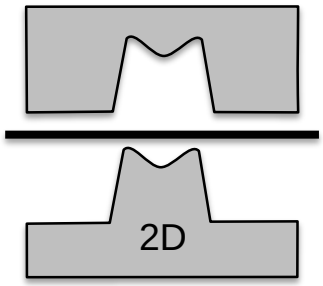


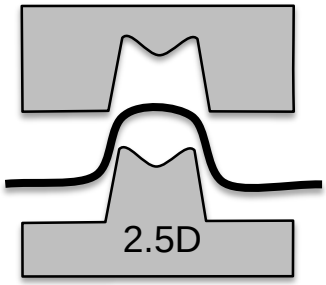
Photo Source: Fives

- Key challenge for low cycle times
- Key opportunity for scrap & cost reduction
- Many candidate technologies
  - Dry fiber
  - Thermoset prepreg
  - Thermoplastic prepreg
- May require significant financial and facility investments
- Need stakeholder involvement

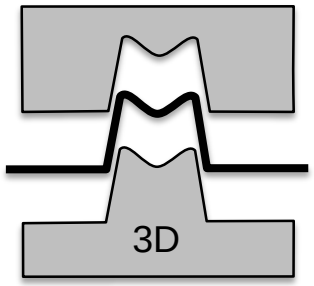
Preform complexity has trade-off



- Low part complexity
- No forming step or simplified lay-up (low capital, increased throughput)
- Lower control of fiber orientation
- Higher potential for defects (e.g., wrinkles)



- More part complexity
- Requires forming step or increased lay-up complexity (higher capital, decreased throughput)
- Better control of fiber orientation
- Lower potential for defects (e.g., wrinkles)



- Most part complexity
- Requires forming step or increased lay-up complexity (higher capital, lowest throughput)
- Best control of fiber orientation
- Lowest potential for defects (e.g., wrinkles)

Before establishing preform/lay-up capabilities

- Need to better understand your company's needs – proprietary projects
- Need better understanding and validation of competing technologies – potential pre-competitive project, e.g.,
  - Identify 2-4 candidate geometries of varying complexities
  - Provide materials and part data to equipment vendors for trials
  - Vendors fully document process and provide preforms for evaluation
  - Potentially collaborate with other institutes such as Fraunhofer ICT (Germany) and National Composites Centre (UK)

Please let us know your thoughts!

Scale-up facility summary

- Lease details finalized
- Equipment on order
- Facility manager is contracted, will become full-time in February
- Staff starts moving in this month
  - Ray Boeman, Associate Director of VTA
  - Laraine Owens, Office Manager
  - TBD technical staff (hiring expected to begin this quarter)
- Additional support
  - MSU CMSC staff (e.g.,Michael Rich)
  - Jim deVries, JdV Lightweight Strategies
  - MSU faculty, students
- Forming working groups from interested companies – Please let us know your interest to help shape the scale-up facility

IACMI-Vehicle Technology Area Personnel

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We welcome the opportunity to answer your questions, provide operational, facility and technical information!

Ron Averill - Design Optimization: Structures, Manufacturing, CrashDesign, Optimization

Jay Jayaraman – Polymer composite molding, extrusion of thermoplastics, nanocomposites and thermoplastic elastomers; solid state forming; polymer foams and foamed composite

Mahmood Haq - Computational Design: Tailorable Materials / Multi-scale Materials Adhesively Bonded and Bolted Hybrid Composite Joints, NDE

Al Loos - Manufacture of composites by RTM, VARTM, and RFI. Expertise in resin infusion process simulation models, mechanics of composite materials

Sharon Xiao - Composite damage -Crashworthiness simulation, Progressive composite fatigue model, Residual properties of damaged composites

Michael Rich – CMSC and CVRC facility operation, research, testing, fabrication