University of Dayton Research Institute
Composites Capabilities

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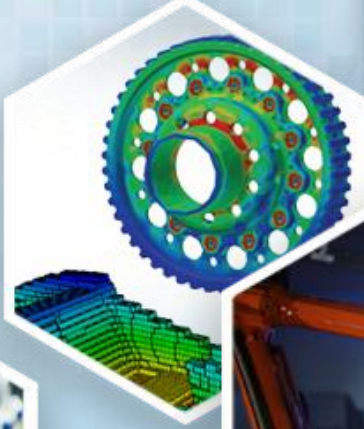


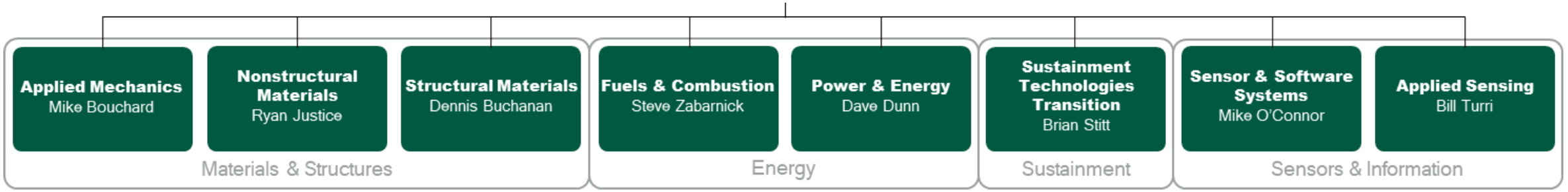

University of Dayton Research Institute

Among all colleges and universities:

- 1st in the U.S. for materials R&D
- 1st in Ohio for R&D in industrial & manufacturing engineering
- 1st in Ohio for research sponsored by DOD (15th in the nation)
- 2nd in Ohio for engineering R&D (18th in the nation)

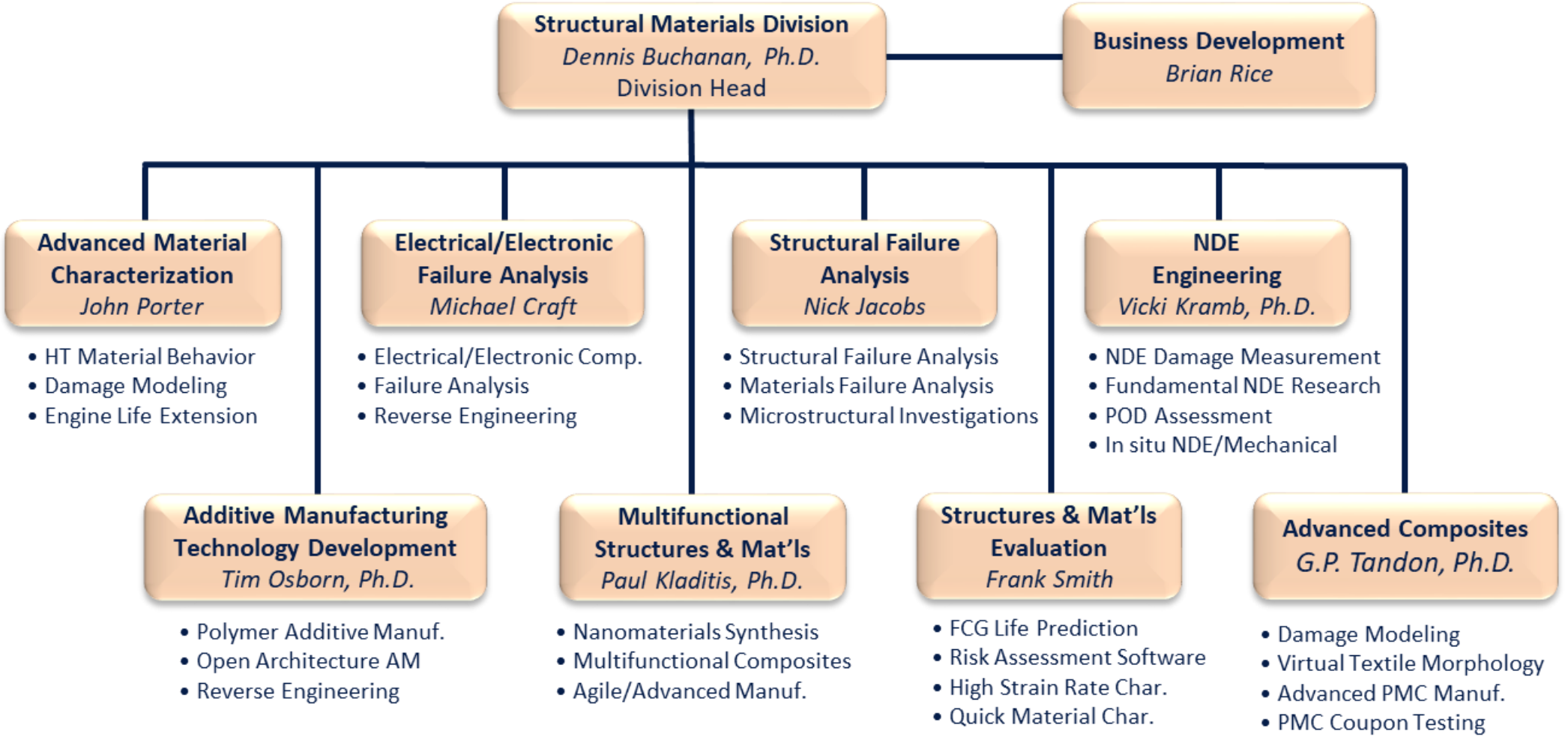
Winner of three R&D 100 Awards

Organization



- Over 737 research staff (250+ at WPAFB)
- Supported by 280+ students
- In collaboration with roughly 90 faculty
- 440,600 SF of facilities
- FY20 annual revenues: $170M
- Currently under contract for more than $1.6B of research

Structural Materials Division Organization by Group



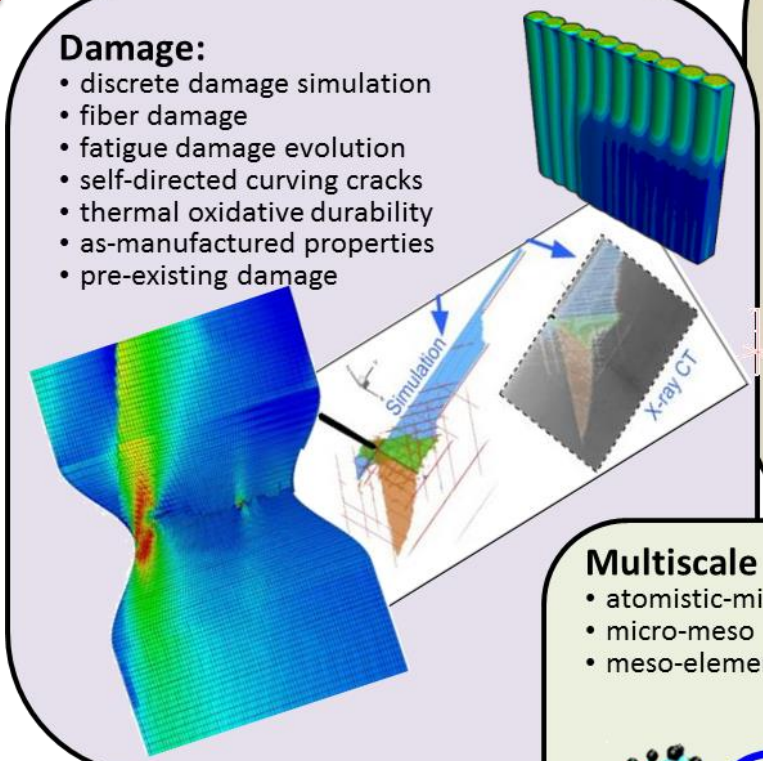
UDRI Advanced Composite Comprehensive Approach

1) ICMSE model development for processing an performance
2) Topology optimization and technical origami
3) Rapid preforming on flat surface, designed for tool draping
4) Low cost agile tooling
5) Rapid consolidation and cure
6) Nano-enhanced multifunctional composites
7) Performance testing

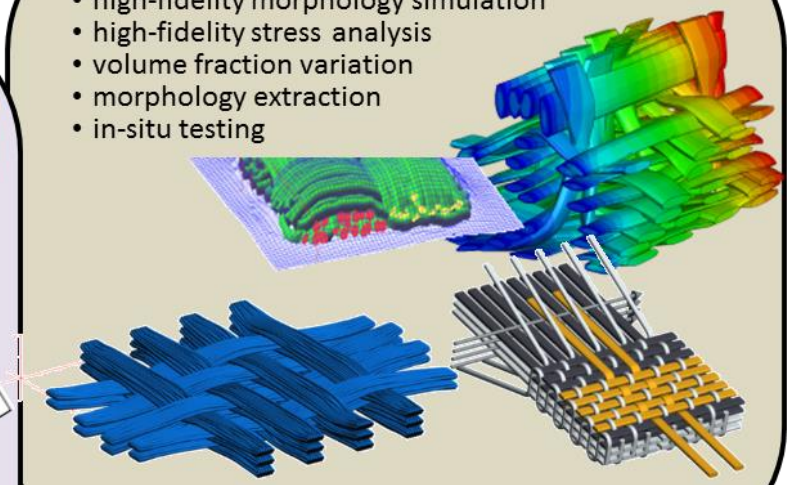
1) ICMSE Model Development

BSAM

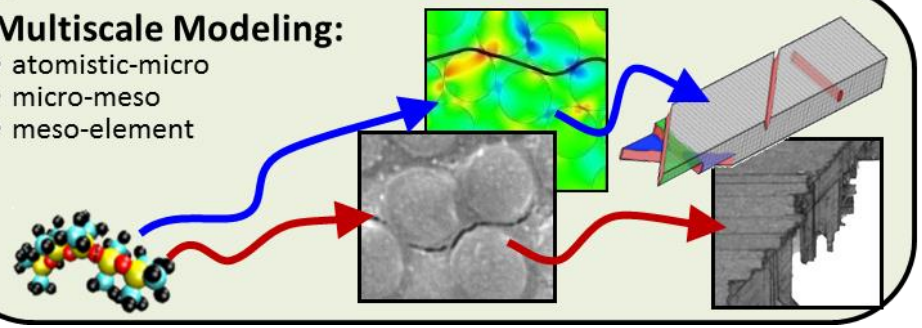
Damage:
- discrete damage simulation
- fiber damage
- fatigue damage evolution
- self-directed curving cracks
- thermal oxidative durability
- as-manufactured properties
- pre-existing damage



Textile Analysis:
- high-fidelity morphology simulation
- high-fidelity stress analysis
- volume fraction variation
- morphology extraction
- in-situ testing



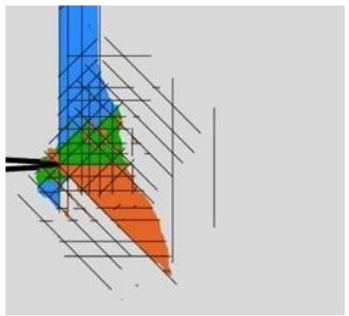
Multiscale Modeling:
- atomistic-micro
- micro-meso
- meso-element

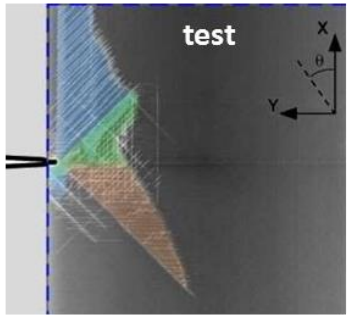


VTMS

BSAM: 3D Stress Analysis Software System

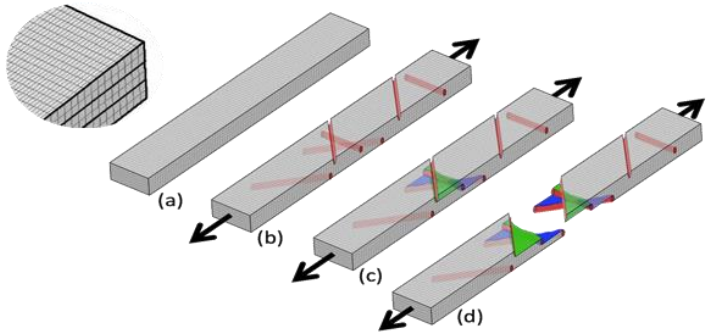
- Crack insertion via:
  - Regularized X-FEM → "Rx-FEM"
    - Displacement discontinuity represented by step-function enrichment
- Integration schema is preserved
  - Cracks and delams behave well numerically!
- Initiation of crack via LaRC-04 *(NASA) failure criterion*
- Propagation: cohesive zone method (CZM)
- Delamination: propagation via CZM
- Fiber failure via Critical Failure Volume *(RXCC)* and progression via CDM *(NASA)*

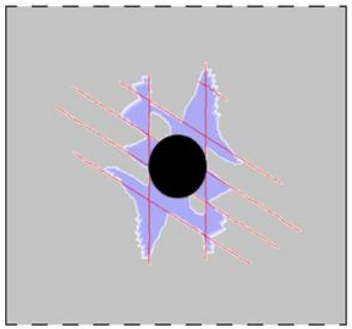


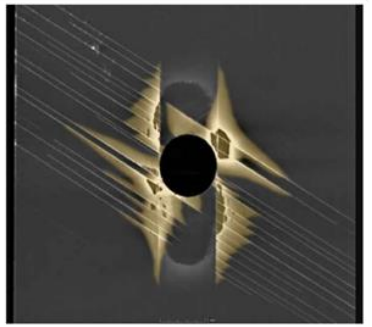


Fracture Mechanics Framework for Composites

Matrix Cracking and Delamination







Tension-tension fatigue, 200,000 cycles
$[60 / 0 / -60 / 60 / 0 / -60 / 60 / 0 / -60]_s$

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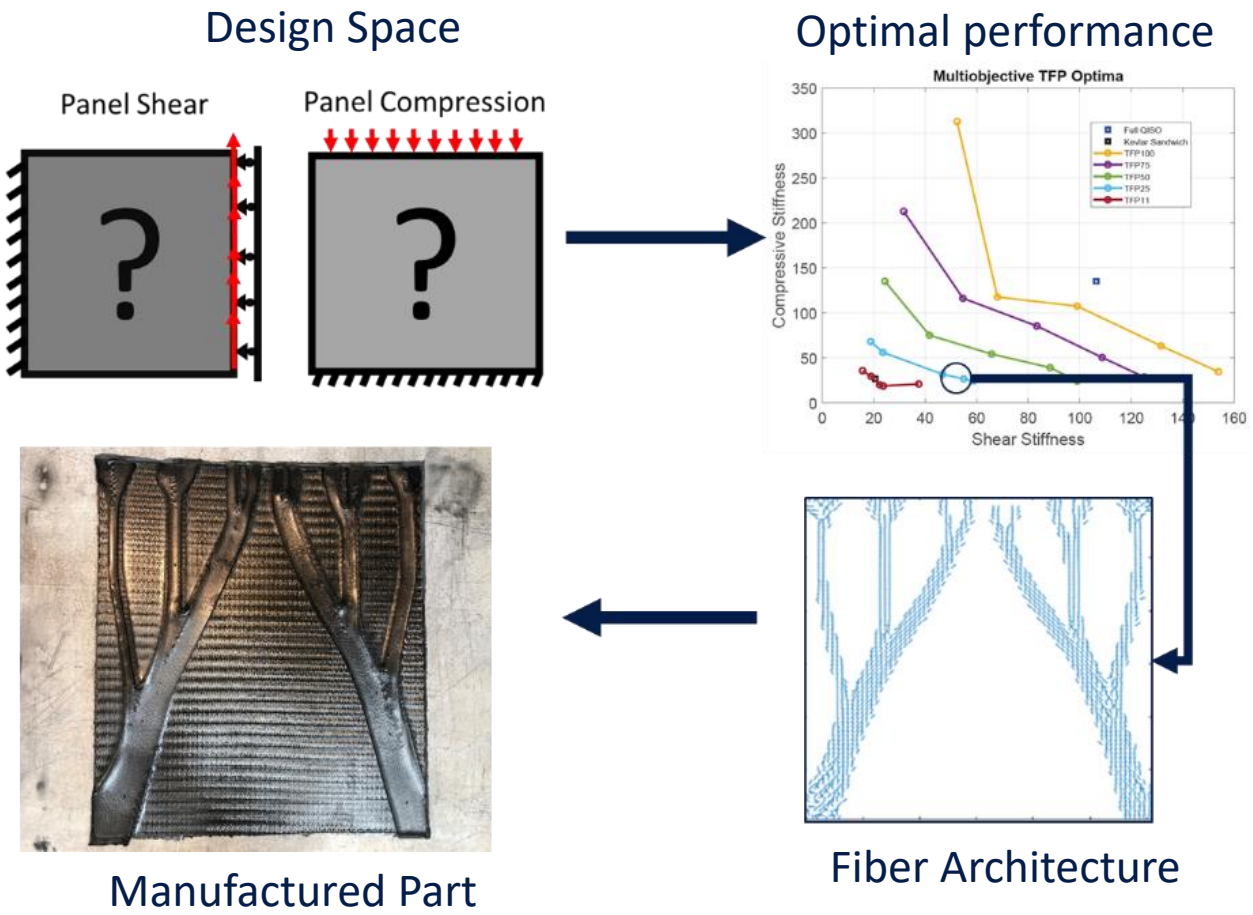
2)Topology + Fiber Alignment Optimization

- Topology and Fiber Alignment Optimization of TFP-Reinforced thin-wall structures.
  - Main benefit of TFP: can create highly tailored reinforcement topologies.
    - Most continuous fiber composites are an order of magnitude stiffer in the tow-axial direction.
  - **Less material + pointed in the right direction = lighter, stiffer structures**

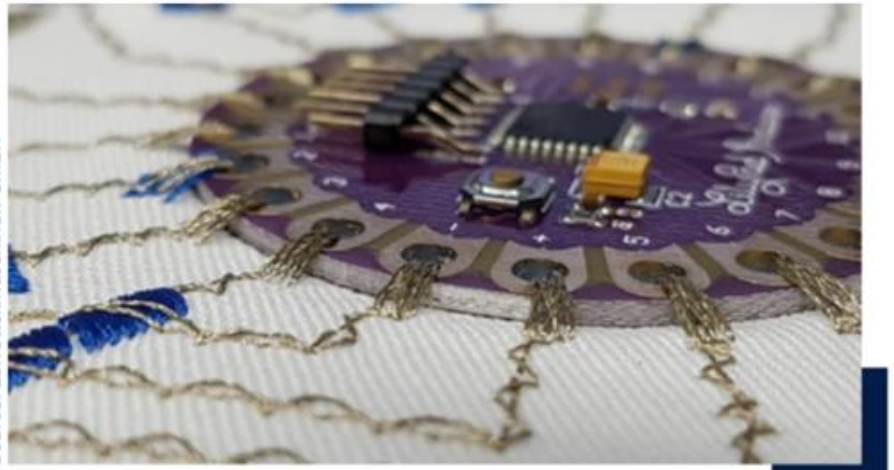


3) Tailored Fiber Placement - Preforming

Tailored fiber placement (TFP) is a fiber steering process that builds fiber architecture at the tow level.

- Originated in Germany 25 years ago
- Well vetted and in use by Airbus, Adidas, and multiple automakers
- Allows complete control over fiber orientation in an automated, cost-conscious process

Tailored Fiber Placement: Scaling Up
UDRI Has ZK and LayStitch machines with 1m x 2m layfield



- Fast Lay + HV-TFP
  - Two, 50k tows simultaneously
  - Stitching removed from straight runs
  - ~13m (43’) tow length per minute
- Multi-head
  - 7’ lay field width per head
  - 30’ width allows multiple heads
- Smart Structures
  - Embedded electronics
  - Embedded actuators

iCOMAT FibreSteer Tape Placment (planned 2023)

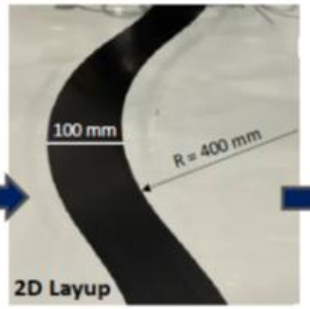
High-rate complex aerostructures

Steering Necessary for doubly curved shapes

3D hemisphere geometry

Developed pattern needs fibre steering

Forming Trial



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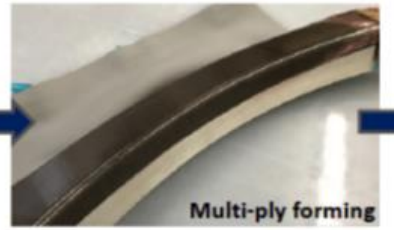
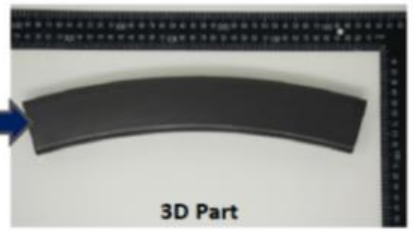
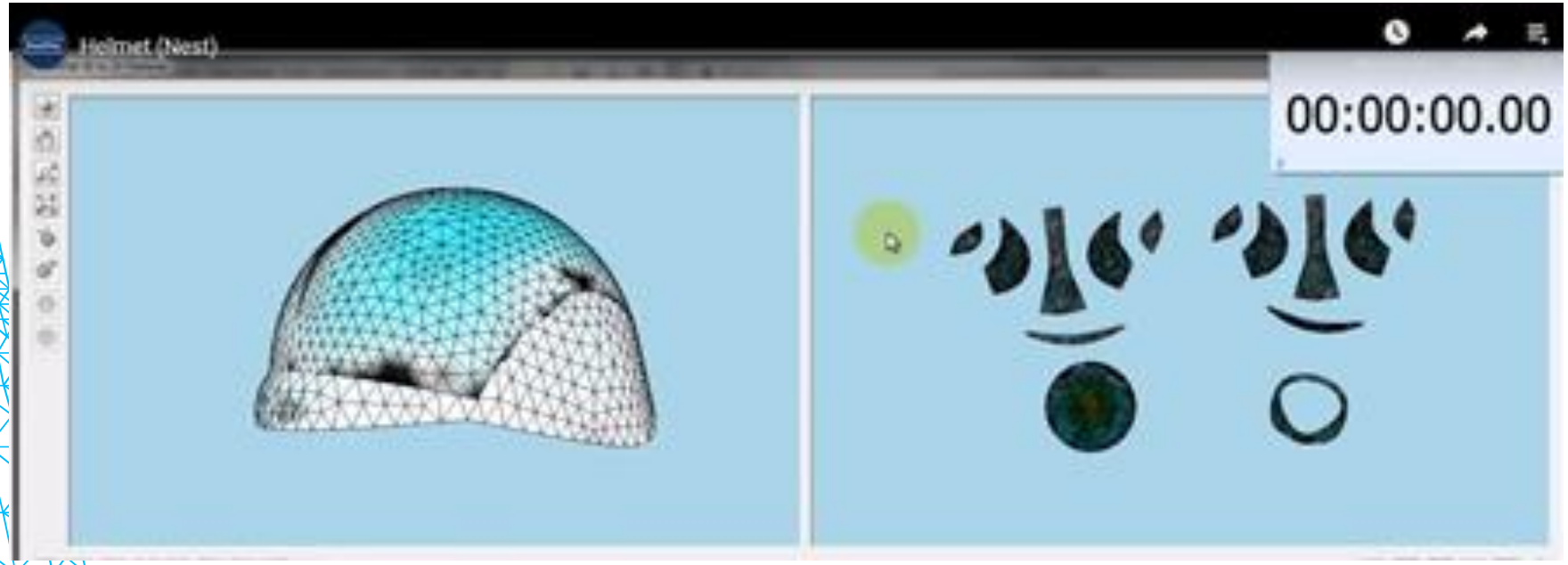
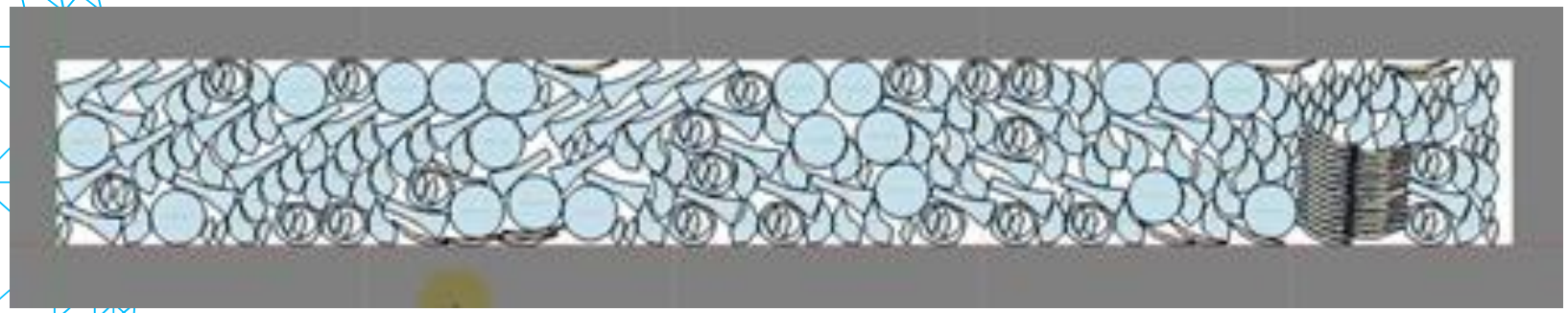




ExactFlat – 3D to 2D Digital Pattern Making



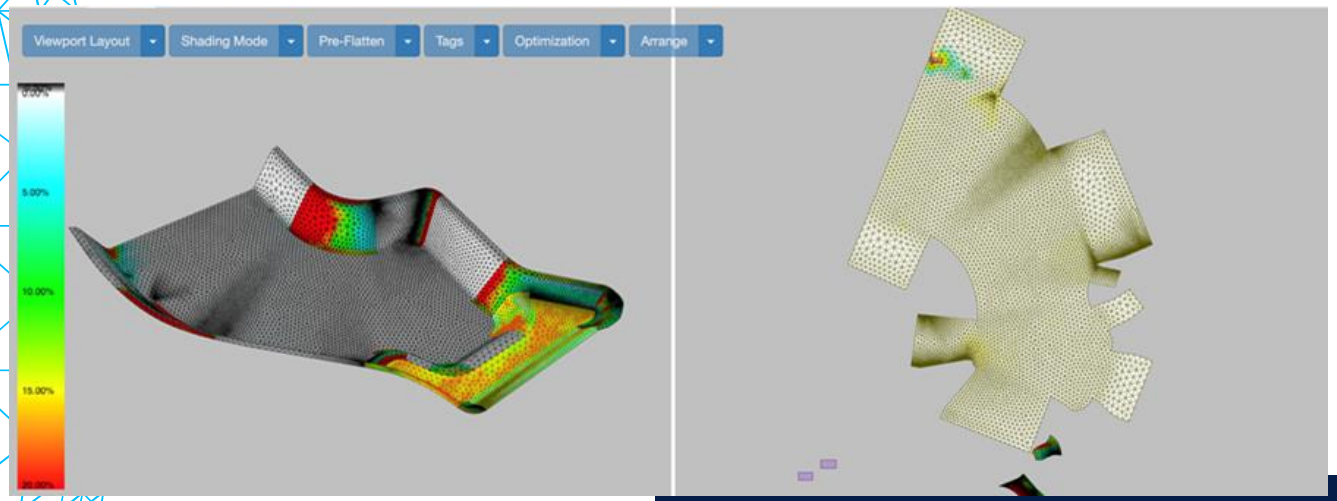


Software automates and optimizes flat patterns for 3D shapes based on material forming characteristics.

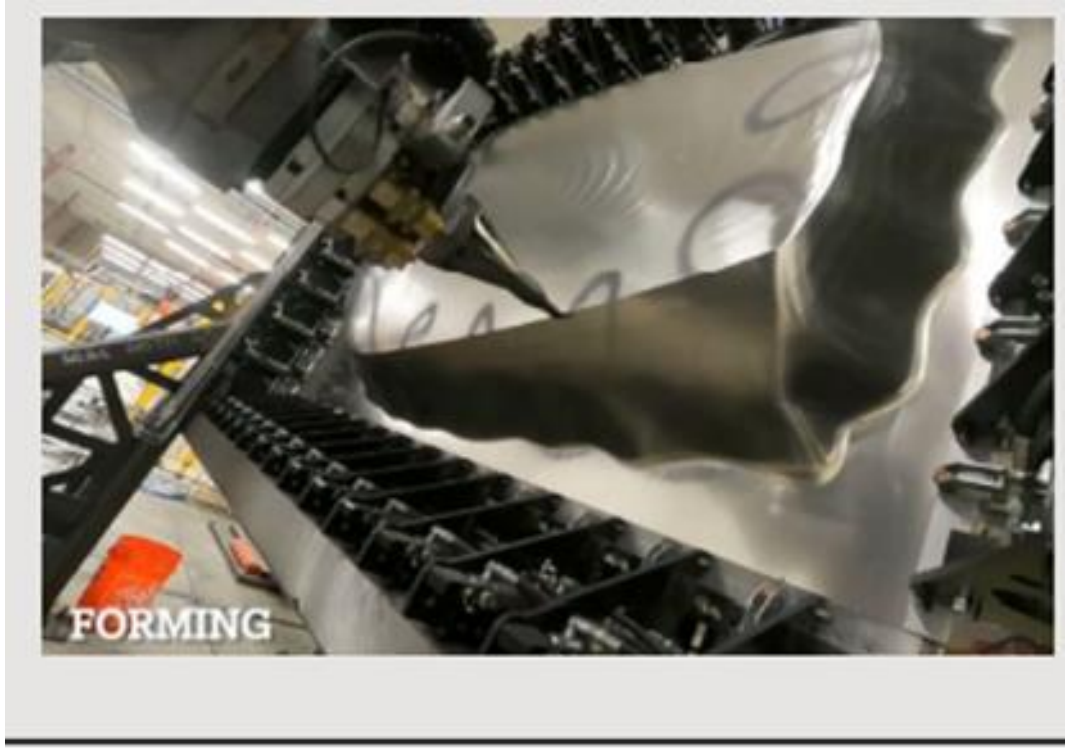
Optimizes nesting for minimal waste

Preform Development for Rapid Tool Lay-up

Gerber DCS 2500 Cutter
6ft x 24ft table

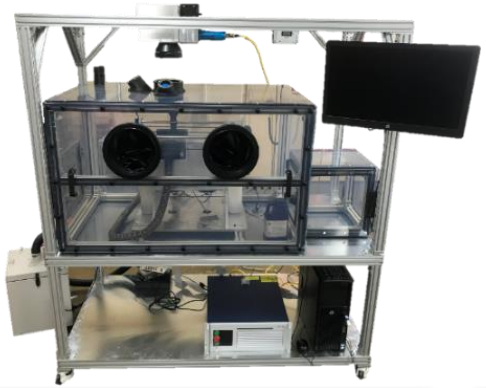


4) Low Cost “Responsive” Tooling – Machina Labs

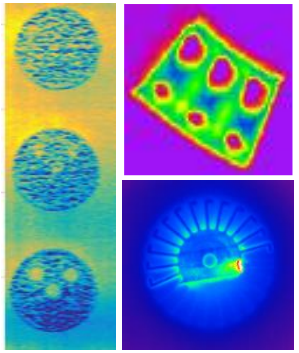


Tooling formed from sheet metal is highly responsive to changing thermal environment – ideal for rapid cure

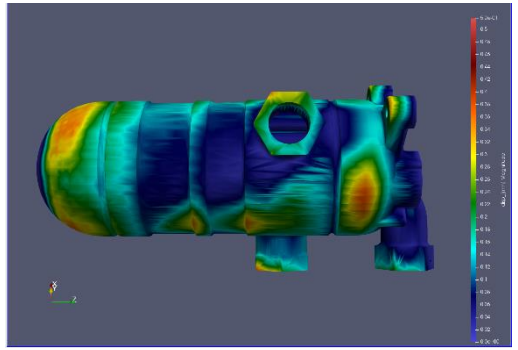
4) Additive Manufacturing Technology for Tooling, Aids



Laser Powder Bed Fusion (LPBF)

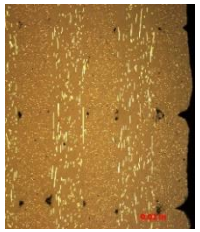


In-Situ Process Monitoring



Design and Analysis for Additive

Reverse Engineering

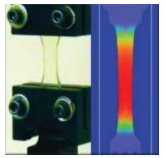


AM Characterization

Digital Light Processing (DLP) and SLA

Fused Filament Fabrication (FFF)

Large Format Pellet to Part (October 18')



Materials/Component Testing

5) RapidClave® Processing

Hot tool base keeps tool heated
Position preform, apply vac bag
Cure and repeat – similar to press forming

New RapidClave® with enhanced thermal control, energy saving features, and 5’ x 10’ size to be installed at UDRI spring 2023.
Sponsored by Air Force under TARMACS program. Equipment available for industrial projects.

6) Multifunctional Structures & Materials

Mission: Optimized systems and new applications through synthesizing and integrating new materials into multifunctional composites

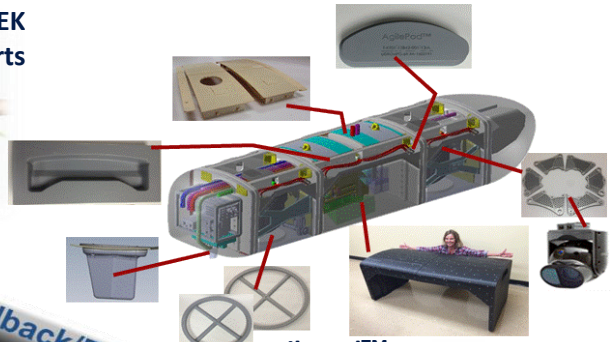
- 14 Personnel
  - Multidisciplinary: Mech, Elect, Chem, Matls, Phys
- 60+ Projects & $5.2M Business Yearly
- Capabilities
  - **0** High risk R&D
  - **1** Advanced Material Synthesis
    - World leader in nanomaterials synthesis & innovations
    - Polymer synthesis, compounding, forming: matrices, films, coatings, joining, printing
    - Material evaluation, testing, conditioning
  - **2** Structure Fabrication
    - Novel/Conventional
    - Composite fab/repair: PMC, CMC, C/C
  - **3** Advanced/Agile Manufacturing
    - AM, AM Tooling, RapidClave
    - Engineering Textiles (Fiber Placement, Embroidery, 3-D Weaving)

60inch NAHF-X

AM MQ-9 Deicing

FDM CNT Satellite Bus Harness

CNT/PEEK Parts



AgilePod™

Advanced Materials

Feedback/Focus

Feedback/Focus

Reduced size, weight, energy consumption, peripheral complexity

Increased capability, ruggedness, and survivability

Advanced Manufacturing

Feedback/Focus/Pull

Multifunctional Application w/Transition

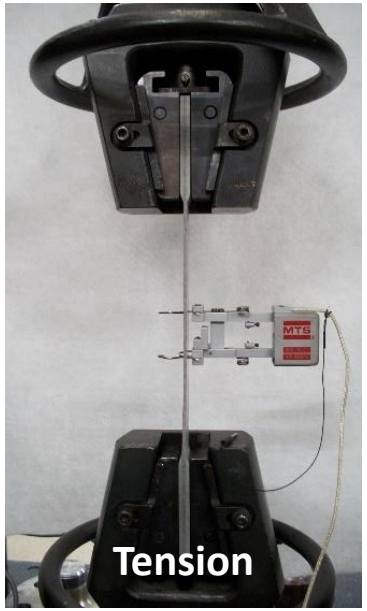
LCAAT

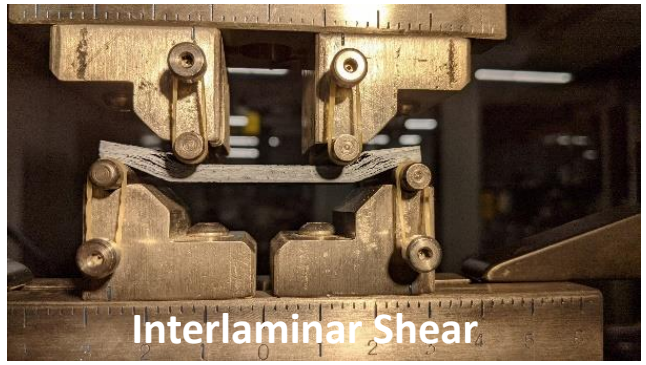
TFP

AM Tooling

7) Composites, Polymers, Ceramics Testing

- **ISO 9001-2015 certified**
- Coupon testing & evaluation
  - Qualified to perform over **240 ASTM & ISO test standards**
  - Loads ranging from 0.5lbf (250g) to 66,000 lbf. (293 kN)
  - -320°F (-195°C) to 600°F (315°C) temperature range
  - Tension, shear, flex, fracture toughness, compression, open hole, bearing, bolt pull thru, impact, peel
  - Strain measurement via strain gage or extensometry
- Subcomponent Testing
- Custom test design
- DOE expertise





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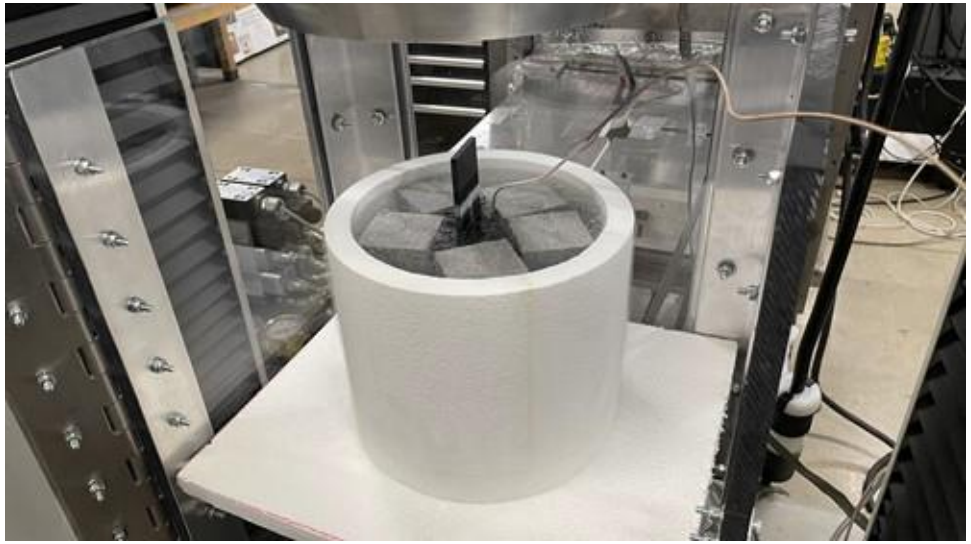
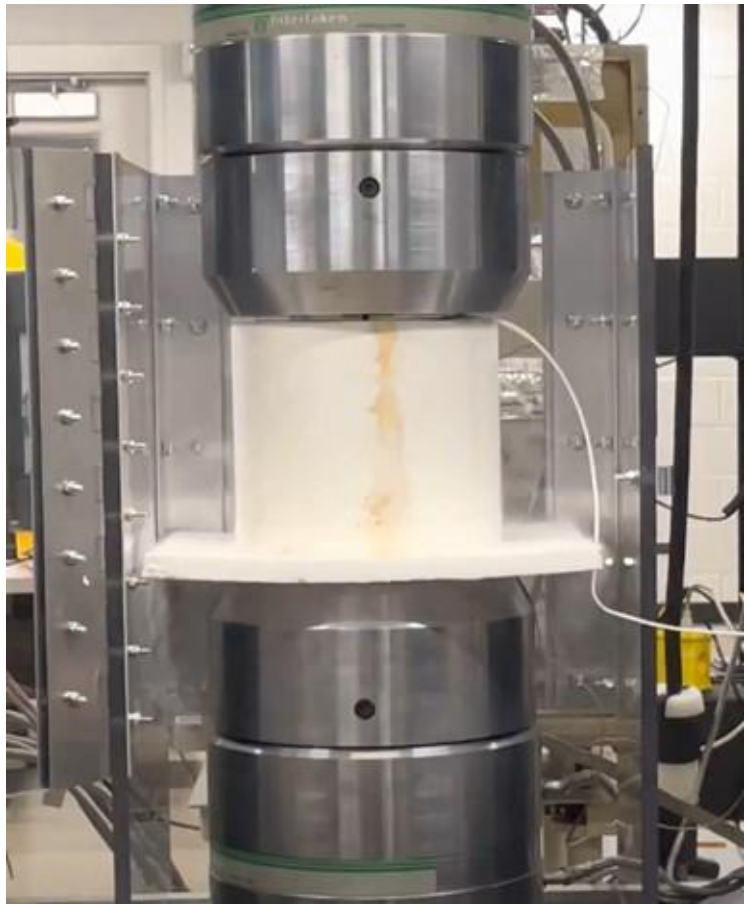
Cryo Testing Setup - Hydrogen Storage Composite Tanks

- Foam Test Chamber was filled with LN2
  - Aluminum Blocks were added to increase thermal mass and displace some liquid
- Tests were completed with minimal loss of LN2
- Evaluate microcracks at strain allowable



Test Set Up



Specimen In Chamber during Test

We Are…

Flexible

Solution Driven

Responsive

Agile

Research & Engineering Leaders

Innovative

Customer Focused

Objective

Value Oriented

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