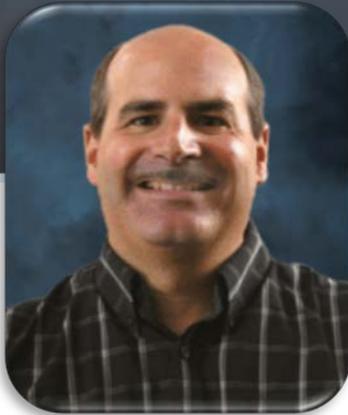




# Compressed Gas Storage Technology Area



**Brian Rice**

Director, CGS Technology Area  
UDRI



**Jared Stonecash**

Group Leader  
UDRI



# Compressed Gas Storage Technology Area and Intermediate Scale Manufacturing

Institute for **ADVANCED**  
**Composites Manufacturing**  
INNOVATION

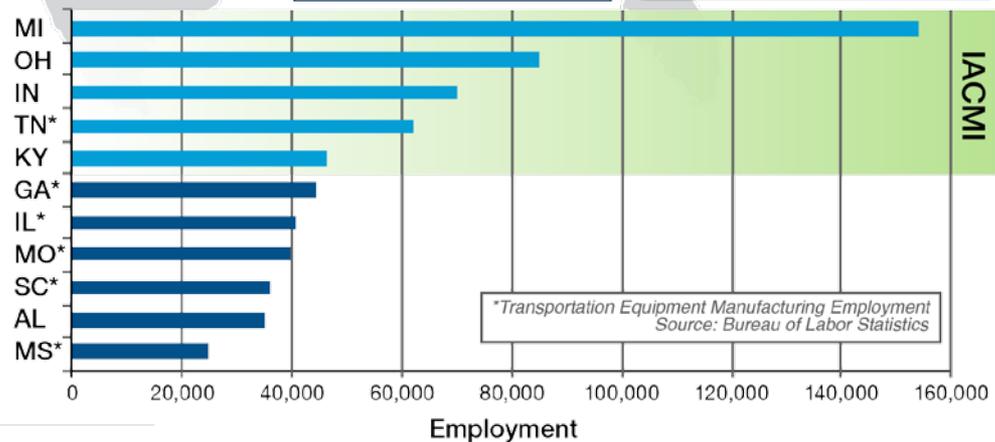
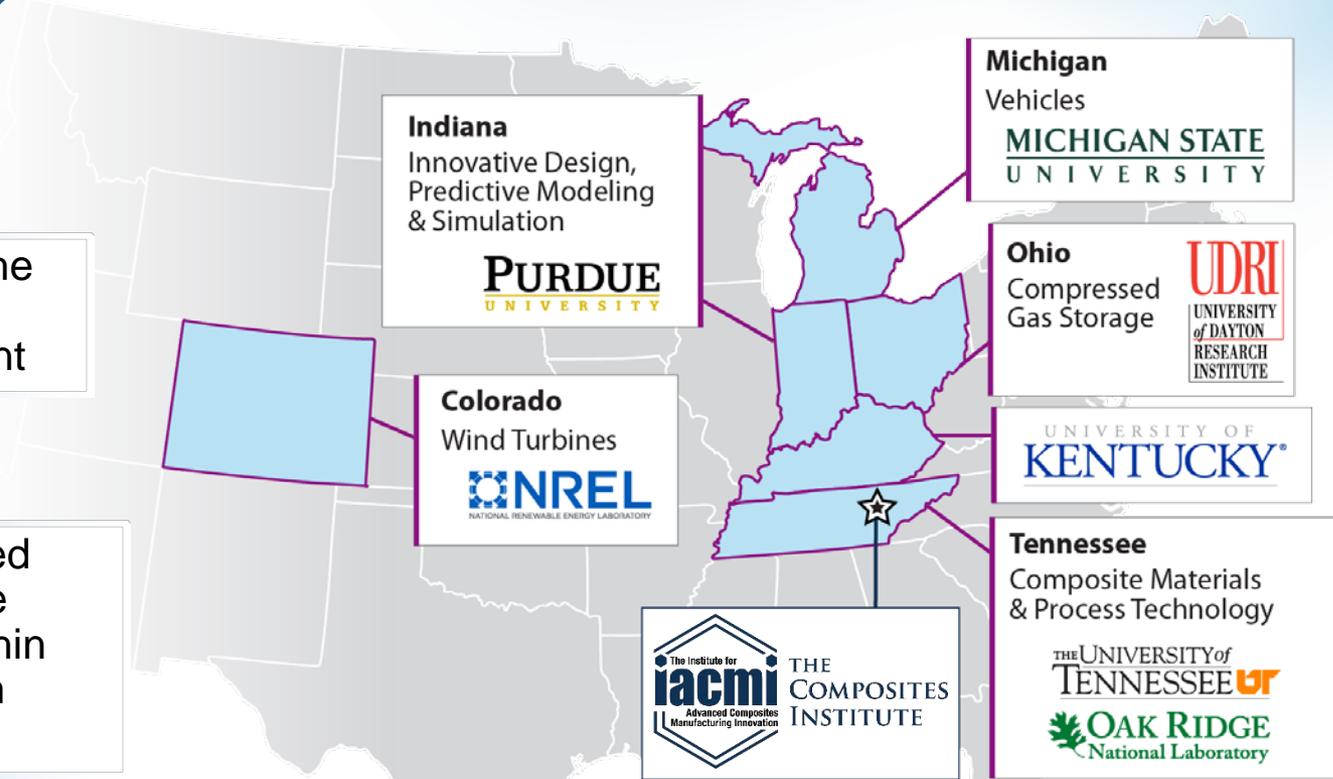
Jared Stonecash  
Group Leader  
Univ. of Dayton Research Center

January 14, 2016

# Why Ohio?

Ohio ranks #2 in the US in automotive-related employment

60% of compressed gas-fueled vehicle manufacturers within half-day drive from IACMI centers

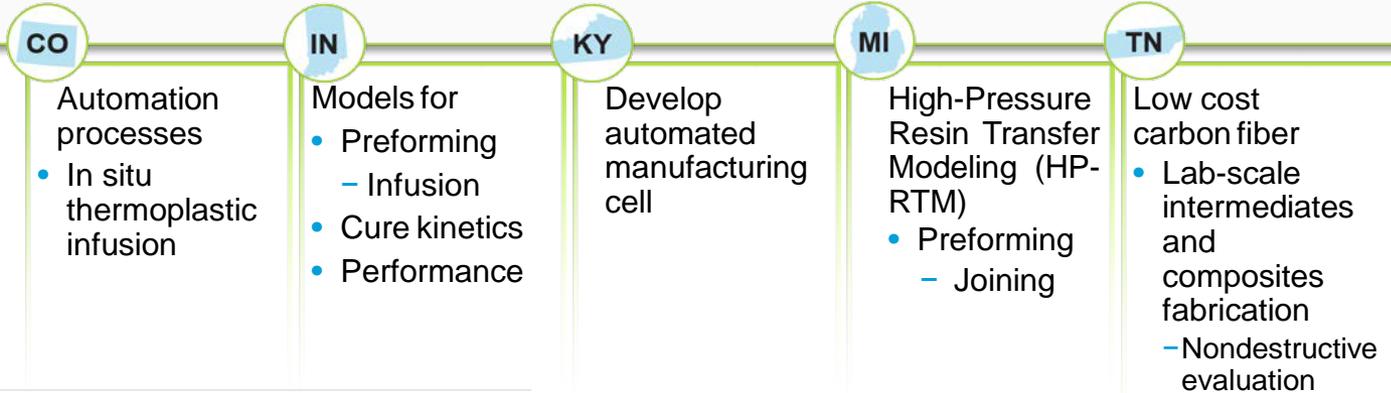


# Ohio Technology Area



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- >40 years' experience in applied, advanced composites RD&D, over 50 staff
- 200,000 ft<sup>2</sup>, fully equipped and industrially focused
- ISO-9000 Certified
  - 440 ton co-injection molder
  - 10 x 5 ft, 800 °F, 200 psi autoclave
  - 1000 ton press, 28" x28", 1000F
  - 12" wide prepregger, 18" film line
  - 60" fabric tackifier line
  - Custom compounding TS, TP
  - Comprehensive testing
  - AM low cost tooling
  - Reverse engineering, design



# DOE Compressed Gas Storage (CGS) Tank Targets

**Reduce the cost of a type IV hydrogen storage tank by 30% (2018) and 50% (2024) with a capacity of 500,000 units/year**

**Type IV:** An all-composite construction featuring a polymer (typically high-density polyethylene, or HDPE) liner with carbon fiber or hybrid carbon/glass fiber composite. The composite materials carry all of the structural loads.

Fabrication method: Filament winding, a mature industry, 40+ years

**The markets: Pressure vessels (2015)\***

High-pressure gas storage vessels represent one of the biggest and fastest-growing markets for advanced composites, as transportation markets demand alternative fuels (Compressed natural gas [CNG] and hydrogen) for motive power systems.

# CGS Manufacture SOA



# CGS Potential Project Areas

- **High technology readiness level (TRL):** Increase efficiency of filament winding and foster integration of hybrid reinforcements. Improve performance and reduce processing time with new matrix resins.
- **Mid TRL:** Dramatically decrease fiber placement time/cost by wrapping with custom braid. Also expected to increase safety and damage tolerance while reducing mass. Application area focus is for Class 6–8 trucks.
- **Low TRL:** Support manufacture of conformal/novel tank design for automotive market designed to preserve trunk space. Recognize adsorption technology could significantly reduce pressure requirements and alter optimal tank design.

IACMI to foster improved safety as well as cost reduction

# CGS Project #1

## ***Braid Offers Potential for Rapid Manufacture, Enhanced Safety, and Reduced Mass***

Braided Tank After Burst Test



Filament Wound Tank After Burst Test



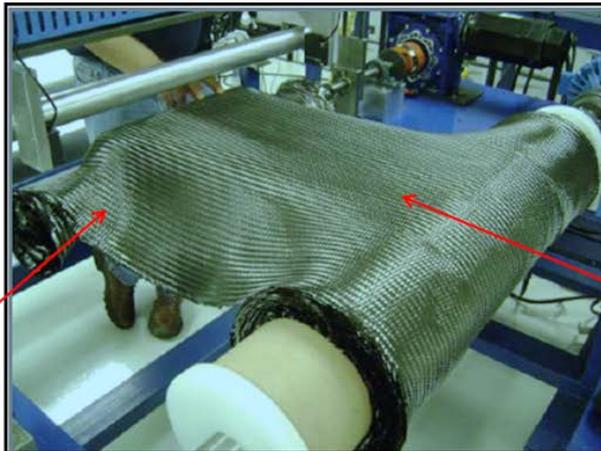
## xperion Energy & Environment

- ▶ **Leading manufacturer of type IV CNG cylinders**
  - 25 years of composite experience - entered the CNG business in 2006
  - More than 60k cylinders in the field.
  - Supplier to key Automotive OEM programs
- ▶ **Fuel tank solutions for all vehicle classes**
  - Product range from Passenger cars to Class 8 trucks – including hydrogen
- ▶ **Bulk storage and transport applications**
  - X-STORE trailer module offers the highest natural gas storage capacity in the world





Leverage unique properties of engineered braid to develop next generation CGS tanks



Biaxial region of braided fabric provides sufficient drape for end-dome geometry

Triaxial region of fabric reinforces major diameter of pressure vessel



# UDRI Overview

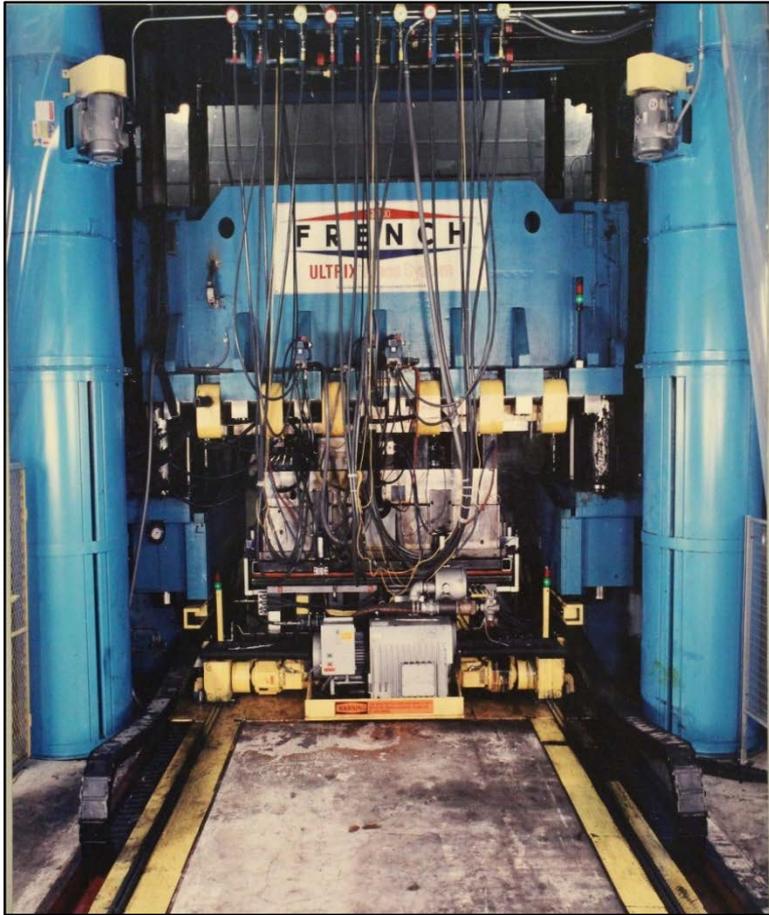


- Established in 1956 in Dayton, OH
- Performs basic and applied research, engineering services, and testing
- Fully supported by external sponsors
- Third in the U.S. in funded materials research
- More than 460 professional research staff
- 218,000 ft<sup>2</sup> of facilities
- Average annual revenues (last 3 years): \$90 million
- Currently under contract for more than \$550 million of research



# Ohio IACMI Automotive Work Cell

1000 ton press for HP-RTM and prepreg compression molding



# Thermoplastic Injection Overmolding



“One of a kind” all-electric Cincinnati Milacron injection molding machine. Ability to use 440 tons of clamping force and two barrels, our machine is ideal to conduct developmental work and short production runs for automotive insert/overmolding applications.

## Injection Molding Specifications

- Cincinnati Milacron NT440 S Powerline model
- Horizontal injection shot capacity: 40 oz (1135 g)
- Vertical injection shot capacity: 10 oz (284 g)
- Maximum injection rate (horizontal): 20.8 oz/s (590 g/sec)
- Peak injection pressure: 30,000 psi (206 MPa)

## Mold and Clamp Unit

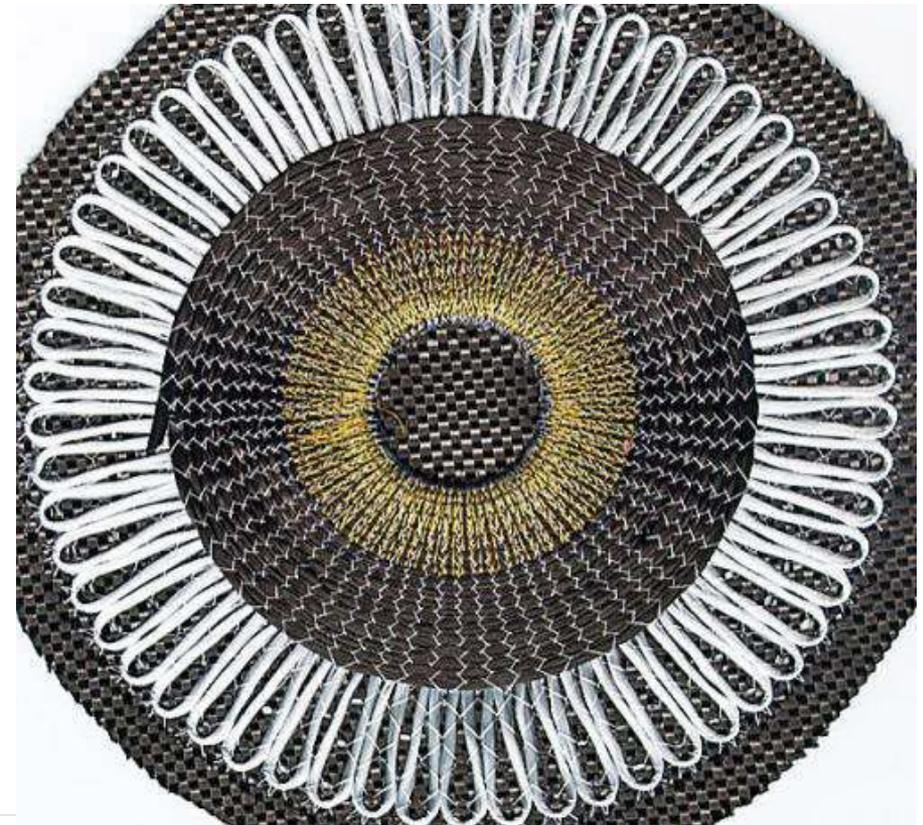
- Daylight: 56.1 in. (1425 mm)
- Minimum mold height: 9.8 in. (250 mm)
- Maximum mold height: 29.5 in. (750 mm)



Dry insert; reinforcing fabric

# Unique Net Shape Preforming

**LAYSTITCH**  
TECHNOLOGIES



# Additive Fabricated Rapid Tooling

Carbon Fiber/Polymeric Tooling for 350F Cures

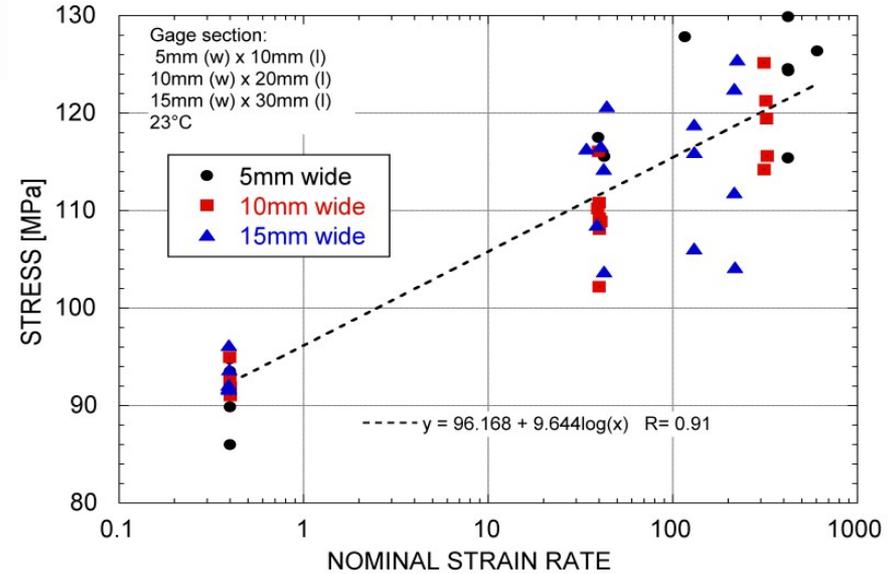
“Art to Part” in 3-4 days



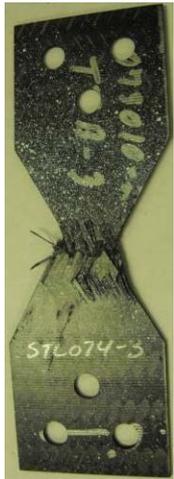
# High-Rate Test Capabilities

- National/international expertise
- Rates up to ~1000 in./s [25.2 m/s] (800 s<sup>-1</sup>)
- Standard specimens as well as structures/ components
- Non contact digital image correlation (DIC) system for strain measurement

**LGFP\***  
**tensile**  
**strength**

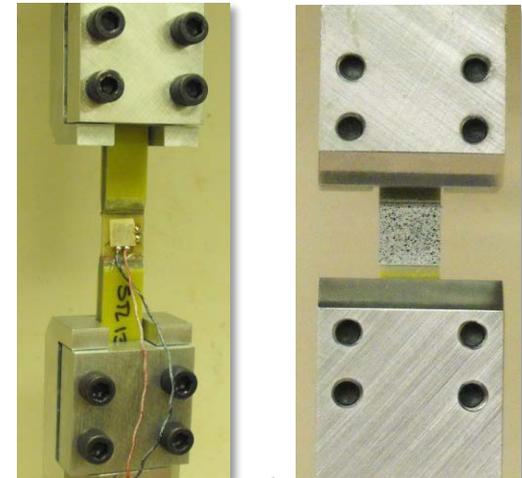


\*Long glass fiber-filled polypropylene

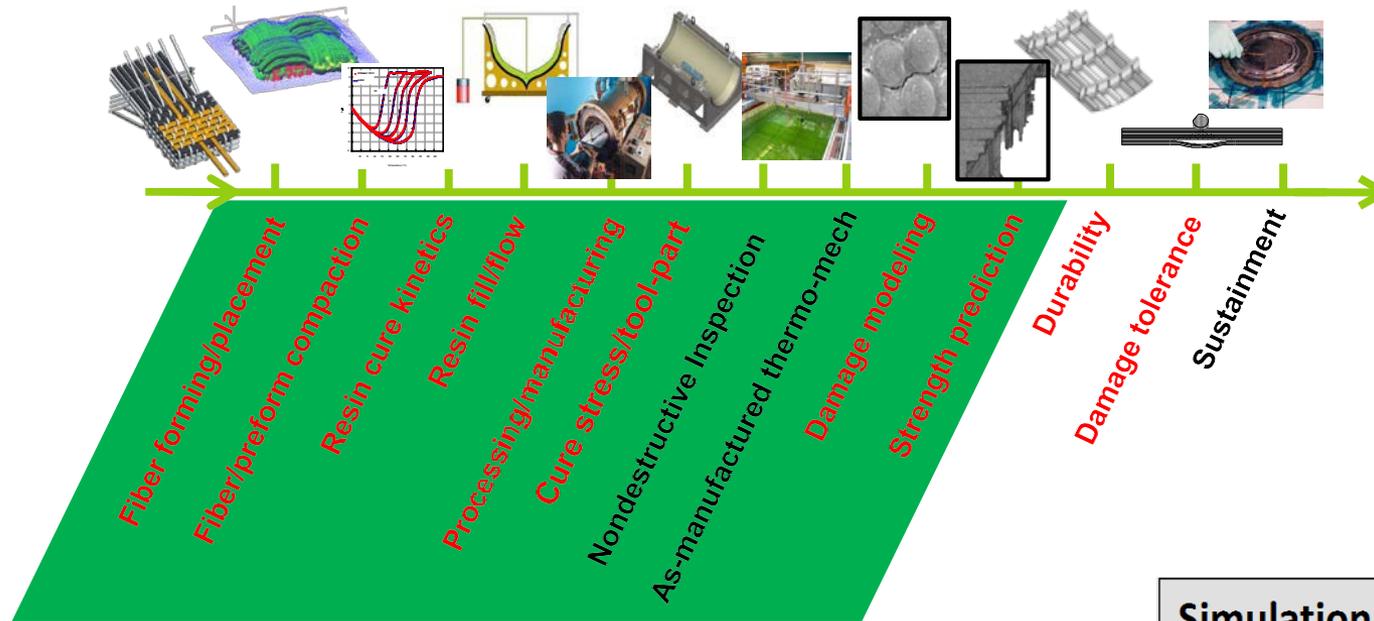


**Carbon/Epoxy**  
**Braid**

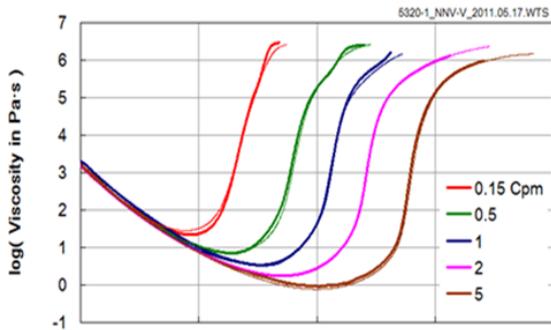
**Vinyl ester/epoxy**  
**weave**  
**Gaged and DIC**



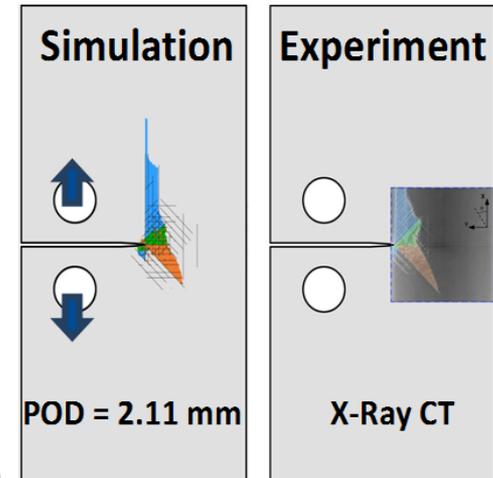
# Integrated Computational Materials Engineering (ICME)



FEP integration activity



Demonstrate linking of engineering disciplines and tools to design and manufacture key feature articles



# UDRI Contact Information

Contact UDRI personnel to network and discuss potential IACMI projects:

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