

# AM<sup>2</sup> Virginia's Additive Manufacturing and Applied Materials Tech Hub

Agile, Affordable, and Resilient Solutions for Advanced Manufacturing



Christopher B. Williams L. S. Randolph Professor Department of Mechanical Engineering <u>cbwill@vt.edu</u>





# **VIT Calls for "Reshoring Manufacturing" aren't going away**

- Digital manufacturing technologies hold promise for addressing national needs due to their increased automation and their ability to be digitally networked to enable rapid response and reconfiguration.
- SME adoption of digital manufacturing has stymied by slow industrial adoption due to the uncertainty and unproven reliability inherent in these emerging technologies.
- Adoption is hindered by a lack of a workforce prepared with the interdisciplinary skills required to implement and integrate these digital technologies.

# **EDA Tech Hubs Strategy Development Grant: AM<sup>2</sup>**



https://www.eda.gov/news/pressrelease/2023/10/23/biden-harrisadministration-designates-31-techhubs-across-america



**NRVRC** 

new river valley regional commission













**The goal** of *VA's Additive Manufacturing and Applied Materials Tech Hub Consortium* is to establish this region as a <u>global</u> destination and home for heavy <u>industry</u> <u>AM</u> and <u>advanced</u> <u>materials</u> <u>solutions</u>, where manufacturers can benefit from the expertise and collaboration present in the region.</u>



# **AM<sup>2</sup>TechHub Goals**

- 1. increase SME knowledge and capabilities,
- 2. reduce their risk prior to adoption and implementation,
- 3. establish a regional eco-system and knowledge base that links SMEs directly with manufacturing facilities and prime contractors.



# **About the Region**

### SW, Central, Eastern Virginia

Manufacturing, Coal, Textiles, Tobacco, DoD

### Manufacturing makes up

- > 11.7% of total regional employment
- 15.4% of GRP

## > Historically underserved communities

> persistent poverty rates at least 5 percentage points above the national average

### Manufacturing Heritage

Focus on distributed digital manufacturing technologies enable the integration of SME manufacturing shops into the U.S. supply chain, its outcomes have clear potential to expand far beyond any defined region.

#### **Industry Partners**

- 2C Innovation Commons
- Boeing
- FasTech
- Hollingsworth & Vose
- MELD
- Metalsa
- Printworks
- Virginia Manufacturers Association
- Virginia Tech Corporate Research Center
- Volvo Trucks

#### Education and Workforce Partners

- · Goodwill Industries of the Valleys
- Institute for Advanced Learning and Research
- Montgomery County CTE
- New River Community College
- New River Mount Rogers Workforce Development Board
- Pulaski County CTE
- Radford CTE
- Radford University
- Virginia Tech

#### Business and Economic Development Partners

- Bridging Virginia
- GenEdge
- · Floyd County
- Giles County
- Manufactory
- Montgomery County
- New River Valley Regional Commission
- Onward NRV
- Pulaski County
- · Radford (City of)
- Southern Virginia Regional Alliance
- Tech Opp Consulting
- VERGE
- Virginia Economic Development Partnership
- Virginia Innovation Partnership Corporation
- Virginia Tech Corporate Research Center
- VTC Innovation Fund



#### **Ecosystem Resources**

- Lab-to-Market
   Commercialization &
   Entrepreneurship
- Business Scale-Up & Technology Adoption
- Talent Development



### Materials Companies

- Sustainable Materials Acquisition & Synthesis
- Characterization and Inspection
- Design Services
- Advanced Manufacturing of Applied Sustainable

#### Materials



### Machinery

- Additive Manufacturing OEMs
- AM Parts Manufacturers and Machine Shops
- Post-Processing



### Manufacturing Users

- Transportation
- Heavy Machinery
- Construction
- Packaging
- Biotech
- Energetics

#### Along this supply spectrum, where are your interests?



Year 1

Year 2

January – March 2024:	Project leads will coordinate coalition members, begin ecosystem mapping, and plan for work sessions.
April – June 2024:	The coalition will host 5 or more NRV work sessions to strategize, develop, and prioritize implementation steps (i.e. projects).
July – September 2024:	The coalition will finalize the ecosystem mapping, develop scopes of work, identify funding sources for at least 2-3 cluster projects, and develop a plan for continued collaboration in the future.
October – December 2024:	Coalition members will convene for a celebratory event and kick-off next implementation steps.
January – December 2025:	Pursue project(s) funding and implementation.



- > MELD Manufacturing & PrintWorks
- > Virginia Tech Advanced Manufacturing Team
- > Virginia Tech Macromolecules Innovation Institute
- > Navy AM Center of Excellence @ IALR
- FasTech LLC



## > MELD Manufacturing & PrintWorks

- Virginia Tech Advanced Manufacturing Team
- Virginia Tech Macromolecules Innovation Institute
- > Navy AM Center of Excellence @ IALR
- FasTech LLC

# MELD Manufacturing Background

### WOMAN-OWNED SMALL BUSINESS



Our experienced, passionate team has successfully developed MELD from concept to a mature process that is well positioned to bring an immediate and impactful benefit to manufacturing industry. We can enable the use of advanced materials, improve logistics, and bring revolutionary technology to the production floor.

Visit us in Christiansburg, Virginia!



### MADE IN AMERICA



# MELD Process and How it Works

MELD is a solid-state additive manufacturing method that can achieve fully dense parts with isotropic, forged equivalent, strength properties in a variety of materials and applications.



# What is MELD?



- Temperatures reach 60%-90% of the filler bar's melting point during deposition
- Simple process with predictable and repeatable results
- Flexibility in the material supply chain
- Parts are measured in meters, not millimeters

# **MELD Machine Models**



# **ARMY GVSC Additive Applications**

The U.S. DEVCOM Army Ground Vehicle Systems Center (GVSC) has awarded the contract to build the world's largest metal 3D printer using the MELD technology. It will have the capability of printing large parts for military ground vehicles.

The printer has a build volume of 12ft x 20ft x 30ft and is active today.

GVSC will use it to manufacture monolithic hulls, amongst other parts.







# **MELD Capabilities**

The MELD process can be used for AM manufactured components, printing metal onto existing structures/applications, repair, coating, and joining similar and dissimilar metals and metal matrix composites.





## MELD Manufacturing & PrintWorks

## > Virginia Tech Advanced Manufacturing Team

- Virginia Tech Macromolecules Innovation Institute
- > Navy AM Center of Excellence @ IALR
- FasTech LLC

# What Differentiates VT in Additive Manufacturing?

### VIRGINIA TECH.

### **Expertise & Experience**

- VT ranked in Top 20 global AM institutions (#3 by h-index)
- DREAMS Lab 2023 Research Team of the Year from 3D Printing Industry
- Interdisciplinary expertise that spans breadth of AM value chain
- Long standing history of significant federal/industrial/DoD funding for AM research and workforce development
  - NSF, DARPA, Army, Navy, Air Force, Manufacturing Innovation Institutes, NASA, NIST, SBIR/STTR, + collaborative awards with industry

### Facilities

- Nearly all AM modalities available for materials and process research on campus
- Hot Isostatic Press; On-campus foundry
- State of the art materials characterization + large-scale X-Ray CT

### Talent

- 5<sup>th</sup> largest producer of undergrad engineers in the nation
- Several prominent VT alums in AM commercial/federal community
- AM expertise trained across disciplines: materials, processing, design, etc.
- DoD Manufacturing Engineering Education Program: Future Additive Interdisciplinary Manufacturing



## **Virginia Tech Additive Manufacturing Faculty**

**AM Processes** 



Chris Williams (ME)



Blake Johnson (ISE)



Bart Raeymaekers (ME)



Michael Bortner (ChemE)



Yao Fu (AOE)



Michael Bartlett (ME)

### **Advanced Materials**



Hang Yu (MSE)



Carolina Tallon (MSE)







Alan Druschitz (MSE)



G Q Lu (MSE)



Pinar Acar (ME)

Process & **Mechanics Modeling** 



Prahalada Rao (ISE)



David Dillard (BEAM)



Scott Case (BEAM)

### Intelligent **Manufacturing**



James Kong (ISE)



Ran Jin (ISE)





VIRGINIA TEC AM Processo	Virginia Te Adv	Virginia Tech Additive Manufa Advanced Materials			<u>Intelligent</u> Manufacturing
Mechanica	d Chemical	Materials Science	Materials Science	Industrial & Systems	Industrial & Systems
Industrial Systems	& Aerospace	Materials Science	Materials Science	Mechanics	Industrial & Systems
Mechanica	al Mechanical		Mechanical	Civil	

# VIC VIRGINIA TECH. VIRGINIA TECH.

Figure 19: Top 20 institutions in additive manufacturing by (a) the weighted number of publications (b) H-index and (c) the weighted number of publications within the top 10% of highly cited publications.



Netherlands

Data source: Web of Science

Switzerland

China

Top 20 institutions in Additive manufacturing

https://www.aspi.org.au/report/critical-technology-tracker





# DREAMS

Design, Research, and Education for Additive Manufacturing Systems



## Academic/Research Team

# **2022-2023 Academic Year Stats**

- > \$12.8M in new projects awarded
- > \$52.6M in active projects
- > 90 peer-reviewed journal articles
- > 3 Young Investigator Awards
- > 14 Professional Awards
- > 3 Patents awarded
- > 39 invited talks
- > 11 postdocs & 105 graduate students in AM research
- > 1147 students engaged in advanced manufacturing courses

<sup>13</sup> faculty; 6 Departments

### VIRGINIA TECH. Future Additive Interdisciplinary Manufacturing (FAIM)

The fundamental aim of the **FAIM program** is to create a workforce with interdisciplinary skillsets required of all future manufacturing jobs

- **Thrust 1:** Establish a Defense Manufacturing Consortium
- **Thrust 2:** Create a "Manufacturing Spine" Curriculum
- **Thrust 3:** Interdisciplinary FAIM Undergraduate Minor and Graduate Certificate
- **Thrust 4:** Drive growth of the FAIM Workforce through Diversity
- Thrust 5: Industry Short Courses

Increase	Educate	Engage	
talent pool	engineering talent	industry	
<ul> <li>Educate K-12 about the opportunity of future manufacturing jobs</li> <li>Access an untapped, diverse influx of new manufacturing engineers</li> </ul>	<ul> <li>Teach interdisciplinary skill set required to fill future manufacturing jobs</li> <li>Embed manufacturing throughout the curriculum as a <i>"manufacturing spine"</i></li> <li>Create interdisciplinary undergraduate and graduate degrees</li> </ul>	<ul> <li>Drive experiential learning via industry-sponsored projects embedded in the curriculum and via industry internships</li> <li>Use industry feedback to update curriculum to keep skills relevant</li> </ul>	



https://www.defense.gov/News/Releases/Release/Article/3539795/dod-awards-53-million-in-grants-under-the-national-defense-education-program/



# **Thrust 1: Defense Manufacturing Consortium**

#### **VIRGINIA TECH. Consortium Members:**

Boeing	Newport News Shipbuilding	
Raytheon Technologies	Army DEVCOM Picatinny Arsenal	
Northrop Grumman	Siemens CATCH	
GKN Aerospace	SLM Solutions	
Lockheed Martin	Big Metal Additive	
Aerojet Rocketdyne		
FORD 4RML SHIPLE		
	BoeingRaytheon TechnologiesNorthrop GrummanGKN AerospaceLockheed MartinAerojet Rocketdyne	



## **Additive Manufacturing Modalities at VT**

#### VIRGINIA TECH...



**Fused Filament Fabrication** 



Large-scale Robotic Deposition



**Aerosol Jetting** 



**Polymer Powder Bed Fusion** 



(UV-) Direct Ink Write



Hybrid Wire Arc AM



**Metal Powder Bed Fusion** 



Vat Photopolymerization



**Additive Friction Stir Deposition** 



Metal/Ceramic/Sand Binder Jetting



**Multi-Material Jetting** 



**Multi-Modality Printing** 

## **VIRGINIA TECH.** Differentiating AM Capabilities: Additive Friction Stir (MELD)

## Two AFSD systems

- Materials research system
- MELD L3
  - 14.2 ft<sup>3</sup> build volume





# Differentiating AM Capabilities: Hybrid WAAM

VIRGINIA TECH.

# Two DMS hybrid WAAM systems:

- 2Cubed: 2x2x2' build volume
- 1Cubed: 1x1x1' build volume
- Fronius CMT (GMAW) weld + milling spindle
- Integrated sensor packs + 3D scanning





# **Differentiating AM Capabilities: SLM 280**

## SLM 280

- Single laser
- Reduced build volume for material development
- Integrated MPM & LPM modules
- SigmaLabs data processing



# **Differentiating AM Capabilities: Multi-axis AM**

### **Cooperative AM robotic Workcell:**

- 2x ABB IBB 4600
- + Tilt/turn trunnion
- Automated tool changing:
  - Filament extrusion
  - Pellet extrusion
  - Continuous fiber co-extrusion
  - Direct Ink Write
  - Machining spindle
  - PnP tool



# **VIRGINIA TECH. Differentiating AM Capabilities: Foundry**

### **Foundry Institute for Research and Education (VT FIRE)**

- 300lb capacity Induction Tilt Furnace
- Lift Swing Induction Furnace
- Palmer Continuous Sand Mixer
- Investment Slurry Tanks & Rainfall Sander
- Alloy design and casting of AFSD feedstock





# **Differentiating AM Capabilities: Xray CT**

### Nikon X-ray Computed Tomography 40 C 450 CT System 1.13 x 1.3 x 1.6 m 225kV and 450kV targets



Installation: January 2024



- MELD Manufacturing & PrintWorks
- Virginia Tech Advanced Manufacturing Team
- > Virginia Tech Macromolecules Innovation Institute
- > Navy AM Center of Excellence @ IALR
- FasTech LLC





# MACROMOLECULES INNOVATION INSTITUTE

Discovery at the nexus of minds and molecules





## **MII Affiliated Faculty – VT Dept/College Distribution**



MACROMOLECULES

Discovery at the nexus of minds and molecules

INNOVATION INSTITUTE

- Aerospace and Ocean Engineering
- Biological Systems Engineering
- Biomedical Engineering and Mechanics
- Chemical Engineering
- Chemistry
- Civil and Environmental Engineering
- Computer Science
- Food Science and Technology
- Geosciences
- ICTAS
- Industrial and Systems Engineering
- Materials Science and Engineering
- Physics
- School of Architecture + Design
- Mechanical Engineering



MII Faculty by College

- College of Agriculture and Life Sciences
- College of Architecture and Hum an Studies
- College of Natural Resources and Environment
- Virginia-Maryland College of Veterinary Medicine





## MII has been a **Premiere Location** for Macromolecular Science & Engineering for Decades

- Internationally recognized polymer program in the US
  - 66 total faculty orchestrating transdisciplinary research and Ph.D. program ("Macromolecular Science & Engineering")
- Transdisciplinary, collaborative research
  - **\$6.88M research expenditures** in MII-related projects in FY20 (OSP data, staff evaluation\*)
  - \$42M in new and ongoing MII-related awards reported in 2020 FARs (includes \$22.9M GlycoMIP award)
  - 222 MII-affiliated peer-reviewed journal/conference publications in 2020; 20 papers with 2 or more MII faculty
  - 125 invited talks / presentations by MII faculty in 2020 (not bad for a pandemic!)
  - 28 patents / applications in 2020
  - Fall 2019 MII Technical Conference drew 200 registrants, 102 student posters, 33 oral presentations, 6 plenary, 20 representative attendants from 13 companies across the US
- Industrial funding and engagement
  - **\$2.073** M expenditures from industrial sources in FY20 (**30.1%** of MII research expenditures)
  - 2020 Covestro-Sponsored Lecture on 3D Printing of Biomaterials drew 150+ participants
  - MII Seminar Series sponsored by Solvay Specialty Polymers





## MII has been a **Premiere Location** for Macromolecular Science & Engineering for Decades

- Interdisciplinary Ph.D./M.S. degree program (since 2001)
  - 44 MACR PhD students as of 2020-21, over 130 total affiliated MII graduate students
  - 2018 Total Tuition Expenditures from MII Affiliated Grants = \$604,655
- Comprehensive undergraduate engagement
  - 132 undergraduate researchers spanning 7 departments; 29 years of NSF-sponsored REU summer programs
- Flagship Shared Laboratory Facilities enabling macromolecular materials innovation
  - MII-ICTAS Materials Characterization Laboratory (MCL, 420 Kelly Hall)
  - MII-MACR/Polymer Capstone Laboratory (MPCL, 1017 HHS)
- Continued external validation as a destination for innovation
  - Industry partners identify VT as a top destination for research and recruiting
  - MII Faculty continue ACS Polymer Principles and Adhesion Science industrial short course series
  - The MACR Program of MII will host the 2021 National Graduate Research Polymer Conference





## **Molecules to Manufacturing**





**Macromolecules Innovation Institute (MII)** 



## M2M: Discoveries across <u>ALL</u> Polymeric AM Platforms



*Extrusion:* Water-soluble material



*Vat Photopolymerization:* Fully Aromatic Polyimide



Vat Photopolymerization: SBR Elastomers



Binder Jetting: Water-soluble binder



*Material Jetting:* Quantum dot inks



*Powder Bed Fusion:* Polyphenylene Sulfide



Vat Photopolymerization: Phosphonium Ionic Liquid



Vat Photopolymerization: Polyurethane



- MELD Manufacturing & PrintWorks
- Virginia Tech Advanced Manufacturing Team
- Virginia Tech Macromolecules Innovation Institute
- > Navy AM Center of Excellence @ IALR
- FasTech LLC







# 





**VIRGINIA TECH**...

## #FASTECH

ONE OF THE KEY TECHNICAL PARTNERS AT THE U.S ADDITIVE MANUFACTURING CENTER OF EXCELLENCE (AM COE)

#### WITHIN THE STATE OF VIRGINIA'S CENTER FOR MANUFACTURING ADVANCEMENT (CMA)









# AM<sup>2</sup> Virginia's Additive Manufacturing and Applied Materials Tech Hub

Agile, Affordable, and Resilient Solutions for Advanced Manufacturing



Christopher B. Williams L. S. Randolph Professor Department of Mechanical Engineering <u>cbwill@vt.edu</u>







#### Large Metal AM

MELD + PrintWorks + VT + CCs

Danville: IALR, FasTech

Richmond: CCAM + VSU

Hampton Rds: NASA Langley, NNSY, NNS, Navsea Dahlgren

Charlotte NC: Siemens CATCH, Collins/RTX, Ingersol Rand, TRANE, Keselowski Adv Mfg, 3D Systems

Knoxville: UTK, ORNL

U of Kentucky

West Virginia U

#### Large AM

Metal: VT, Meld, IALR, CCAM, ORNL, NNS, etc Polymer: VT, MII, ORNL Concrete: COBOD, VT CEE & Building Construction



