

Towards Textiles 2.0 –

Building Blocks For Maturing Advanced Fiber and Fabric Products

Sasha Stolyarov, PhD

CEO

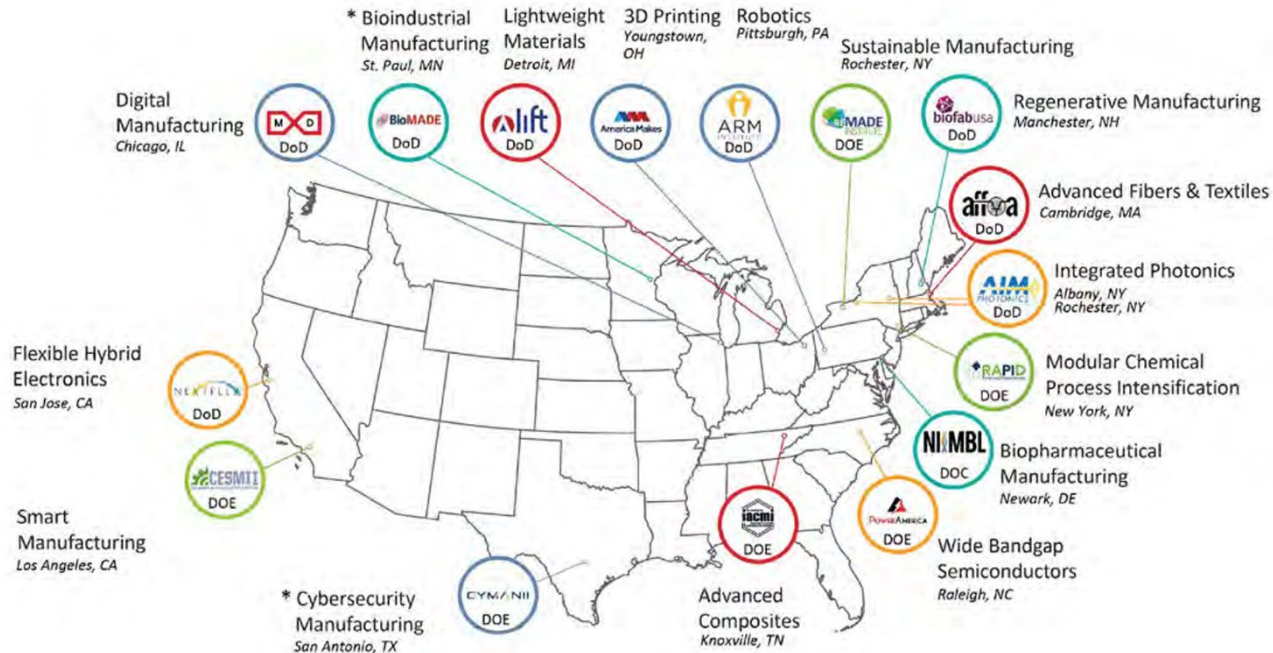
Advanced Functional Fabrics of America



Advanced Textiles
EXPO

Manufacturing USA Innovation Institutes

Vision: U.S. Global Leadership in Advanced Manufacturing



Mission

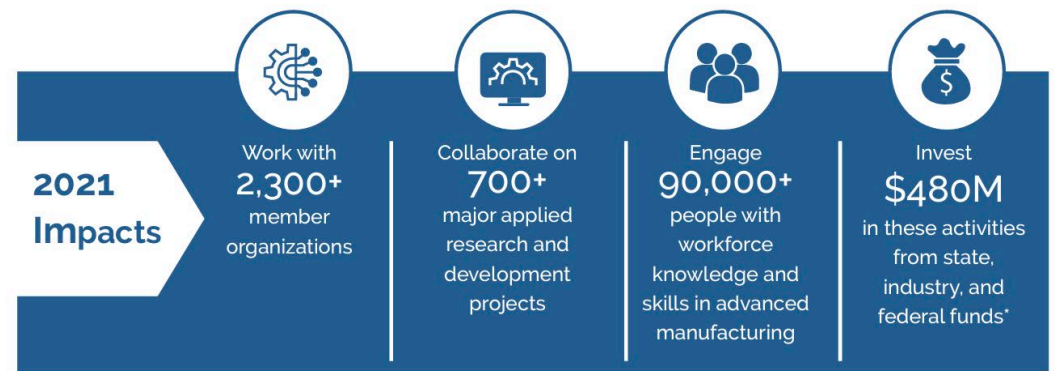
Connecting people, ideas, and technology to:

- Solve advanced manufacturing challenges
- Enhance industrial competitiveness and economic growth
- Strengthen our national security
- Create the workforce of the future

- Manufacturing USA program launched as a public-private partnership to improve U.S. manufacturing competitiveness
- Over \$2B invested to date by federal and non-federal sources
- 16 MIIs today across DoD, DoE, and DoC

MII – Manufacturing Innovation Institute

Sasha Stolyarov | Oct. 31, 2023



Reference: 2022 Manufacturing USA Highlights Report

<https://doi.org/10.6028/NIST.AMS.600-11>

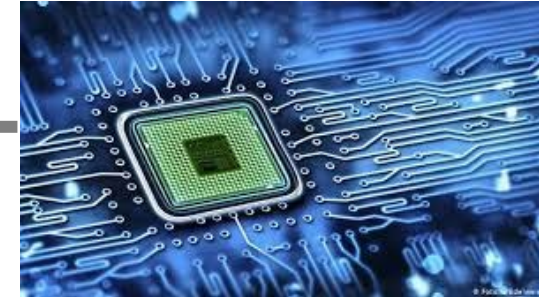
Advanced Textiles
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Vision for Textiles 2.0

Fibers / Textiles



Semiconductors / Advanced Materials

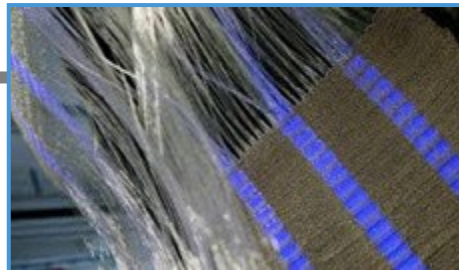


Fibers that are Devices

Fibers and yarns with engineered functionality, complex architectures, and disparate materials compositions

Fabrics as Systems

Fabrics that see, hear, sense, communicate, store and convert energy, regulate temperature, monitor health, process and store data, and change color.



Commercial Applications

Generate new markets

Defense Applications

Solve critical defense needs

Broad Range of Revolutionary Capabilities Enabled by Advanced Functional Fiber and Fabrics

Defense Applications



Warfighter Protection



Large Area Sensing



Directed Energy



Hypersonics

Commercial Applications



Healthcare & Medical



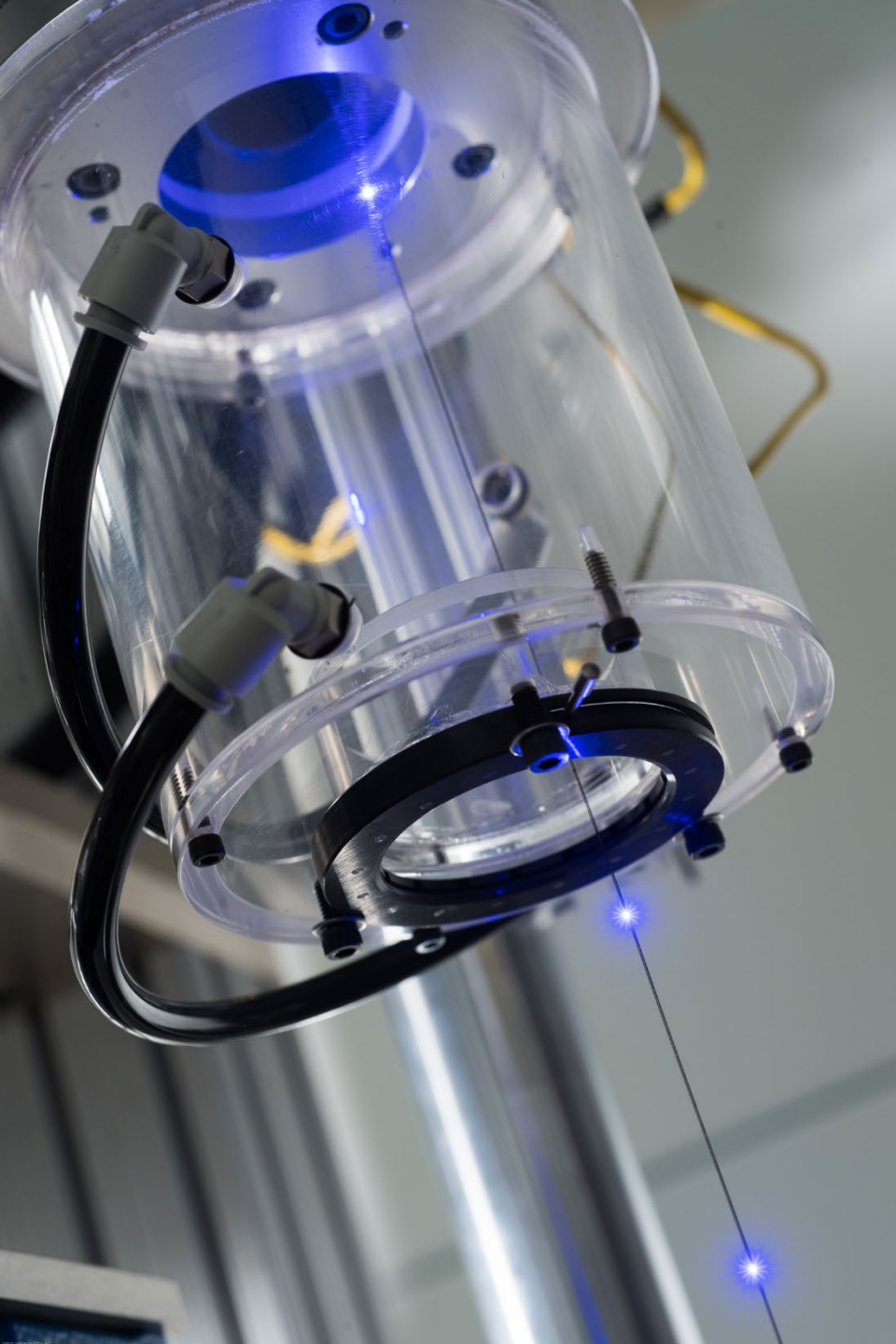
Tunable Color



Industrial Monitoring



Advanced Composites



Mission

Rekindle the domestic textile industry by leading a nationwide enterprise for advanced fiber & fabric technology development and manufacturing, enabling revolutionary system capabilities for national security and commercial markets

Achieved by

Developing and Transitioning Advanced Technology

Establishing Manufacturing Ecosystem for Advanced Products

Nurturing the Workforce of the Future

AFFOA Ecosystem

- **Leveraging complementary technologies and ecosystems for broader national impact**

- **Partnering with tough-tech investors to support of AFFOA's innovators**

- **Regional nodes** with prototyping capabilities coupled with education and workforce development



- **Facilitating partnerships and advancing MRL of breakthrough AFF technologies in support of our ecosystem**

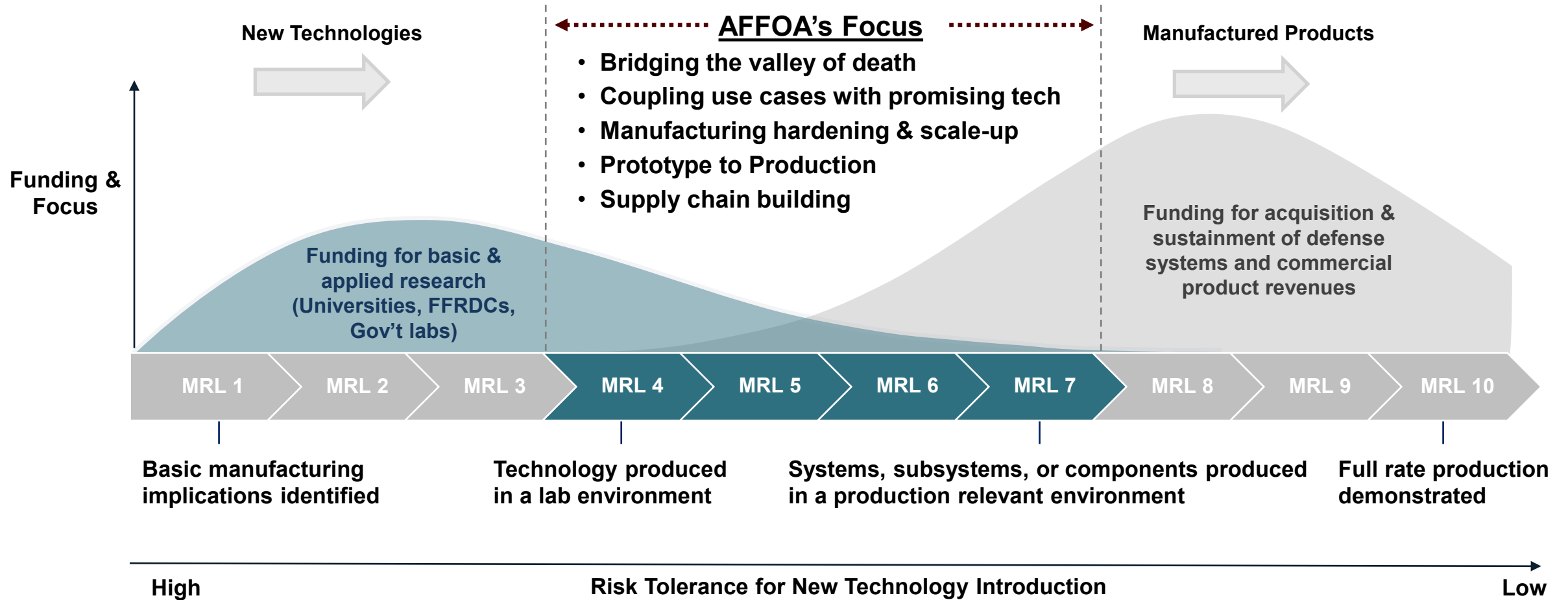
- **Fiber to Cloud capabilities: 150+ Members** spanning academia, national labs, FFRDCs, start-ups, small and medium-sized manufacturers, and large businesses

- **Supporting OSD and other government agencies in addressing critical national security needs**

- **Partnering with State agencies to accelerate regional economic and workforce development**

AFF – Advanced Functional Fabrics; MRL – Manufacturing Readiness Level
FFRDC – Federally Funded Research and Development Center

Focus on Manufacturing Readiness Level 4-7



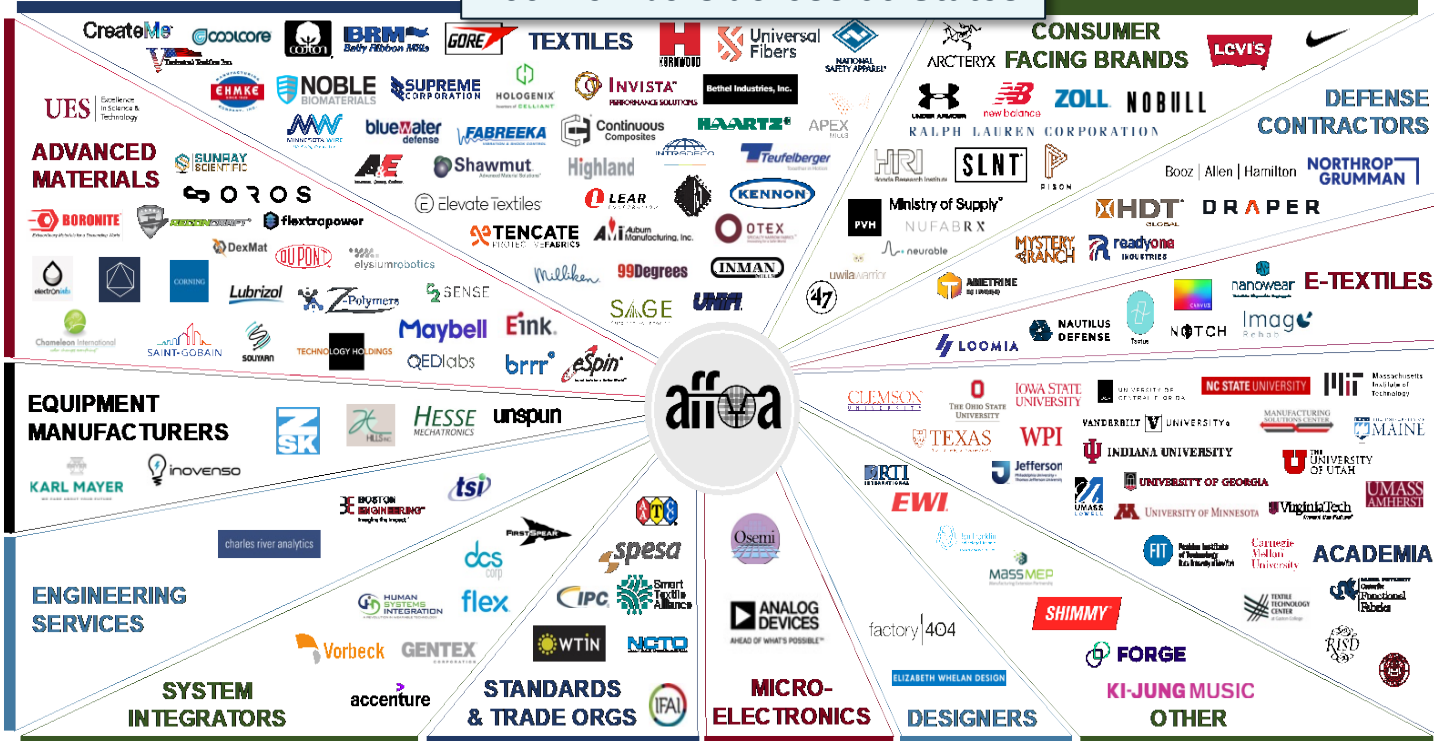
MRL = Manufacturing Readiness Level



AFFOA's National Ecosystem Fabric Innovation Network (FIN)

AFFOA stood up and operates the FIN, a nation-wide prototyping and manufacturing ecosystem, comprising a broad range of know-how and capabilities, spanning the full value chain from fiber to system integration.

155 Members across 35 States



AFFOA's Role as Ecosystem Leader

- Convene and Connect
- Facilitate industry road-mapping
- Facilitate integrated system prototyping
- Technical consulting within industry
- Transition capabilities to industry and USG
- Align dual-use commercial and DoD supply chain challenges

36 Start-Ups 26 Academia 11 Non-Profits 61 Manufacturers 21 Industry



AFFOA Headquarters

HQ Facility at a Glance

- Established May 2017 in Cambridge, MA
- 12,000 sq. ft facility
- State-of-the-art manufacturing equipment leveraged by industry and DoD
- 45 employees (product design, engineering, manufacturing, contracting, EWD)



Fiber and Yarn Devices

- Multimaterial fiber drawing (5 draw towers; polymer and glass fiber capabilities)
- Functional fiber to yarn processing
- Preform manufacturing

Textile & System Assemblies

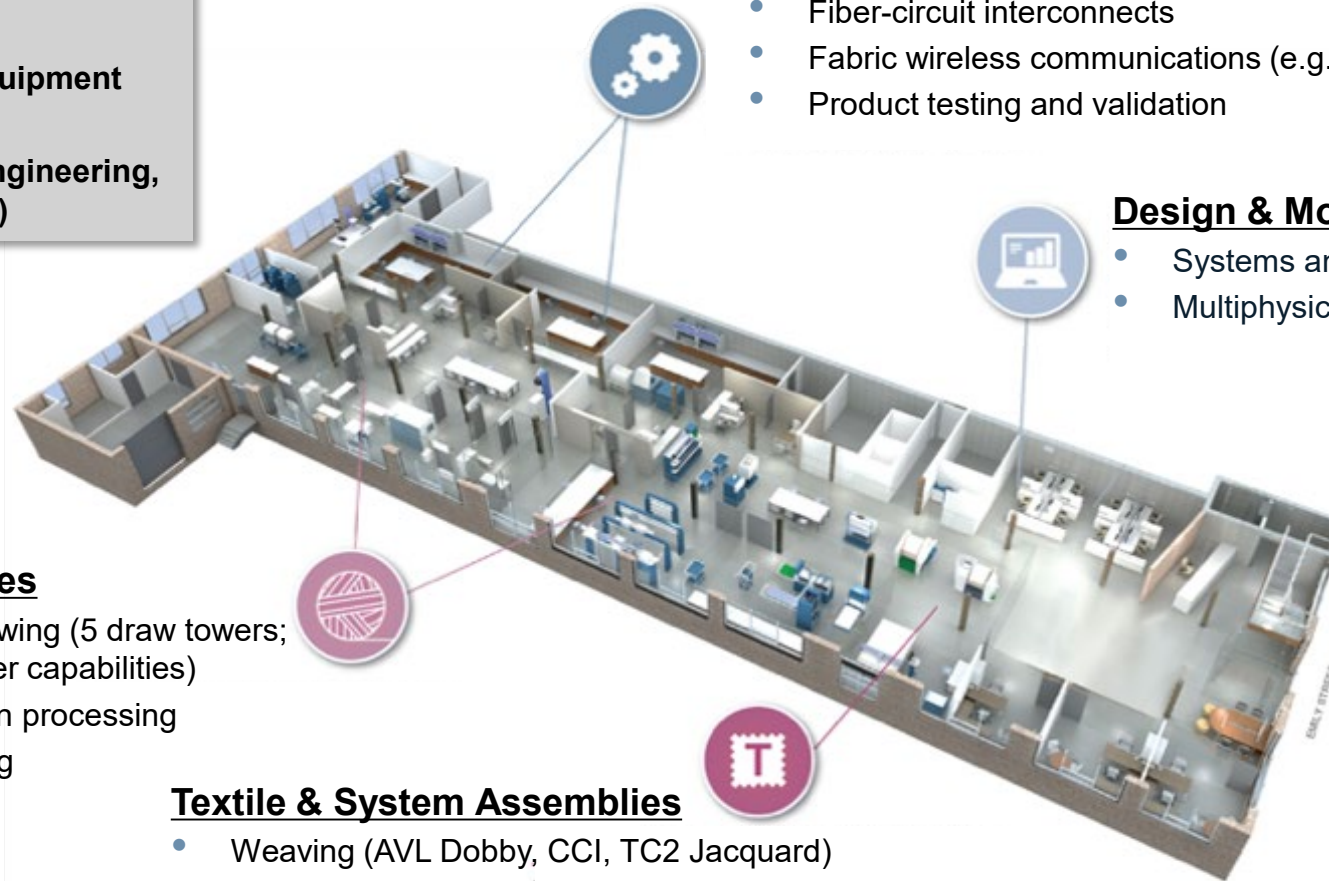
- Weaving (AVL Dobby, CCI, TC2 Jacquard)
- Knitting (Stoll ADF, Shima Seiki, Santoni)
- Composites

Systems Integration

- Fiber-circuit interconnects
- Fabric wireless communications (e.g. fabric to cloud)
- Product testing and validation

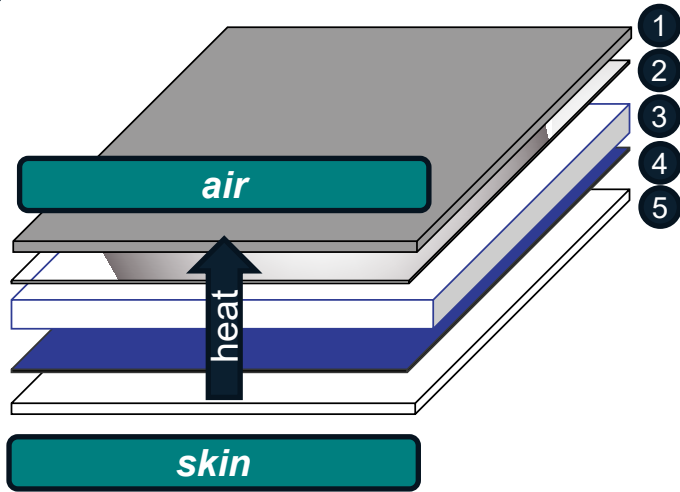
Design & Modeling of Textile Systems

- Systems analysis driven product design
- Multiphysics fiber and fabric modeling



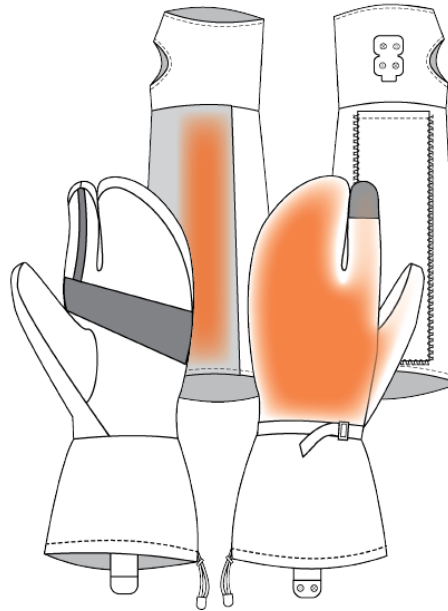
AFFOA HQ Capability: End-to-End Design

Material Analysis & Layout

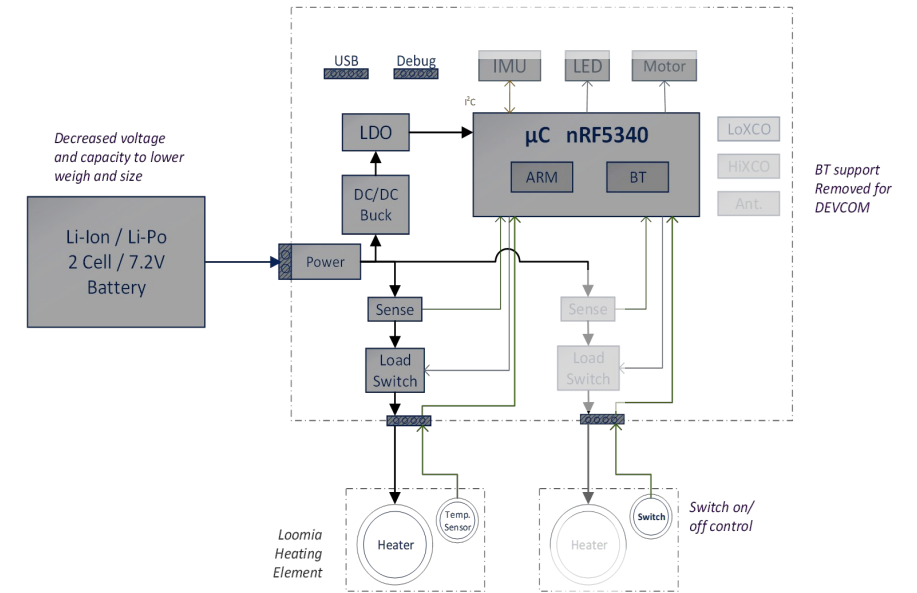


- 1 Outer Liner
- 2 Thermal Reflector
- 3 Insulation
- 4 Active Heating
- 5 Inner Liner

Soft Goods



Hardware/Software



Key Takeaways:

Systematic design and pattern layout for

- benchmark material properties for complex interaction between clothing layers, equipment, human body, and environmental conditions
- Quick turn prototype for commercial and government evaluation



Fielded Prototype Demonstration

AFFOA HQ Capability: Manufacturability Assessment




STOLL - knit
Knit Sleeves with traces




Santoni - knit
Circular knit body fabric



TC2 - weave
Woven collar with traces



ZSK - Embroidery
Traces, Connectors

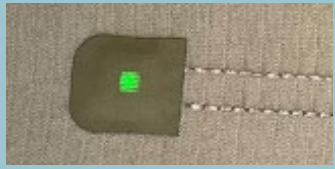


MRL Assessment
1 2 3 4 5 6 7 8 9 10


Cut & Sew
Sub-system Assembly



Lamination
Encapsulation of devices, trace insulation



Cut & Sew
Final assembly

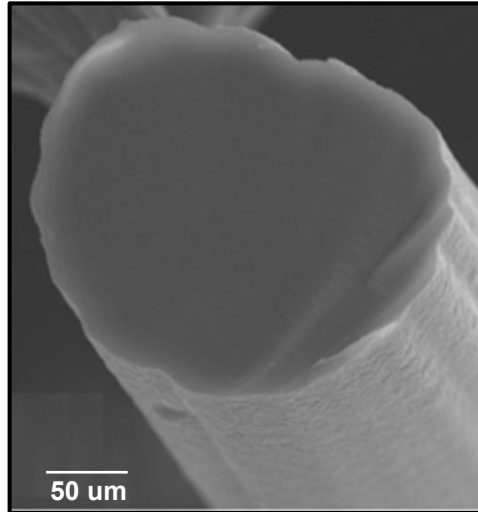


Textile & Electrical Test Standards for Quality Control



AFFOA HQ Capability: Fiber Microelectronics

Traditional Fiber

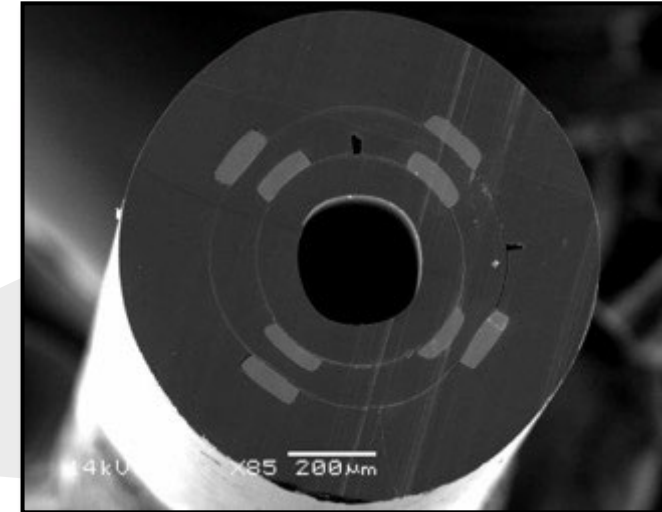


- **Single Material**
- **No Architecture**
- **Single Functionality**

Mainstay of traditional textile industry



Functional Fiber Microsystem



Sorin *et al.*, Nano Letters 9, 2009

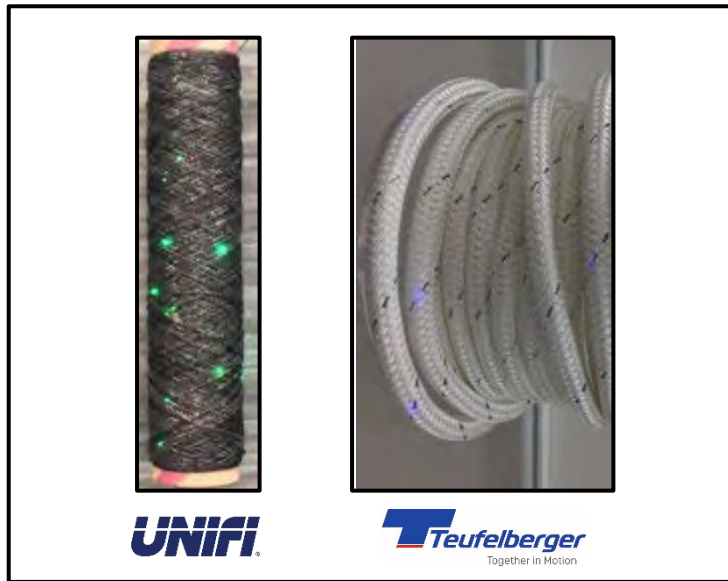
- **Multimaterial - Metals, Semiconductors, Insulators**
- **Device Architecture**
- **Multifunctional**

Unlimited potential for new capabilities

Fiber to Textile Integration

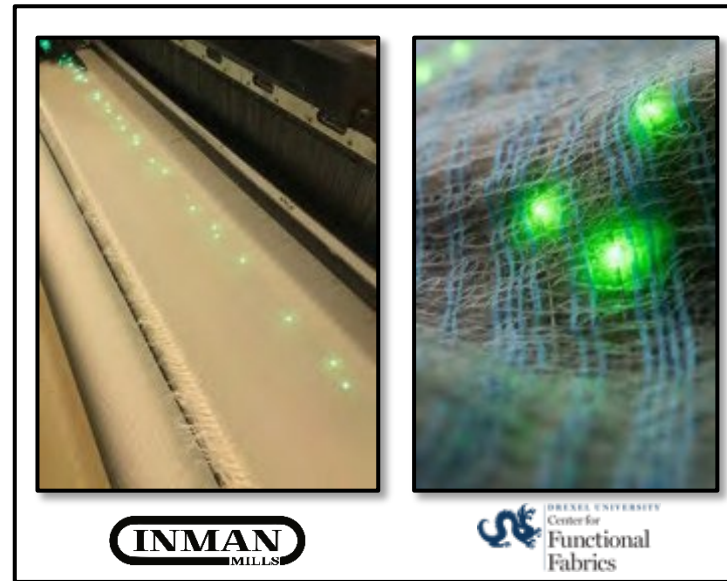
Fibers manufactured at AFFOA are integrated into yarns, ropes, fabrics and composites using industrial scale manufacturing processes

Yarns & Ropes



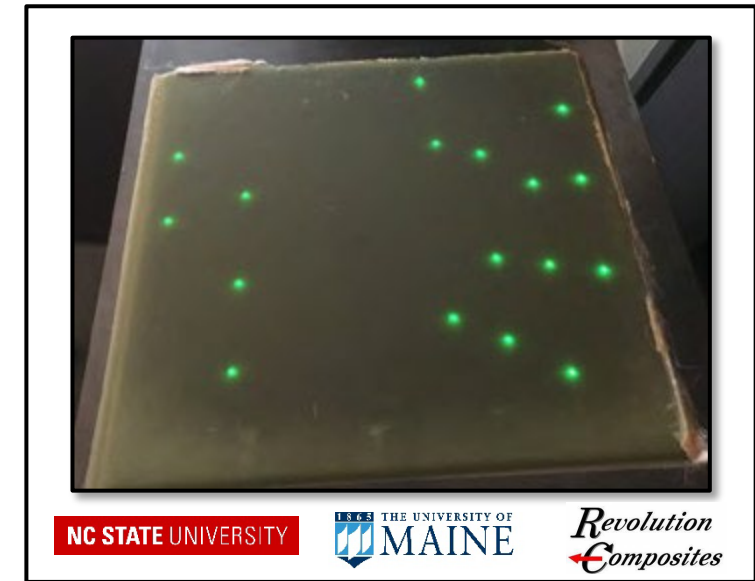
- Natural / synthetic fiber blends
- Multi-filament yarns
- Diameter range: 300 μm – 30 cm

Wovens, Nonwovens, & Knits



- Wovens: weft insertion
- Tubular and flatbed knitting
- Advanced nonwoven filters

Composites



- Glass fiber
- Carbon fiber
- Advanced thermoplastics

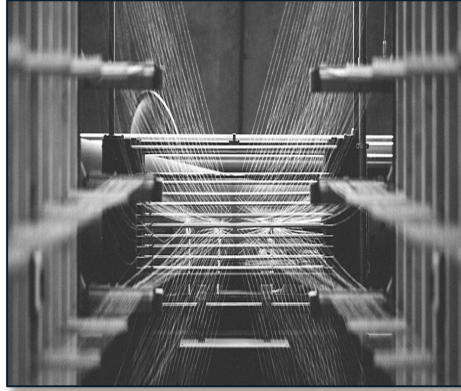
Technology Transition Success Stories

Digitally-Connected Textiles



 **BITRIP**

Conductive Thread



DEXMAT

Soft Robotics for Healthcare



Imago
REHAB

Manufacturing Life Preservers



KENNON

Nonwovens Manufacturing



 **UNIVERSITY OF GEORGIA**
1785

Medicine-Infused Fabrics



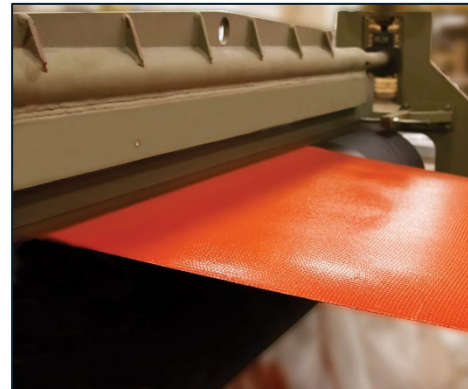
NUFABRX

Boron Fiber Composites



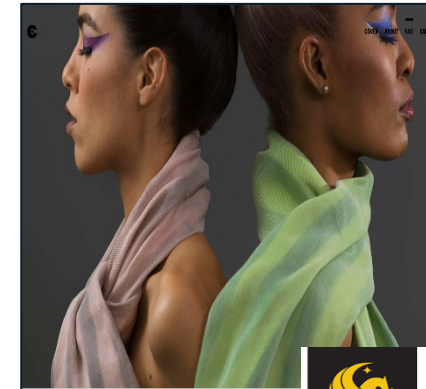
 **Specialty Materials**

Silica Fabrics



AMI Auburn Manufacturing, Inc.
INNOVATION ON FIRE

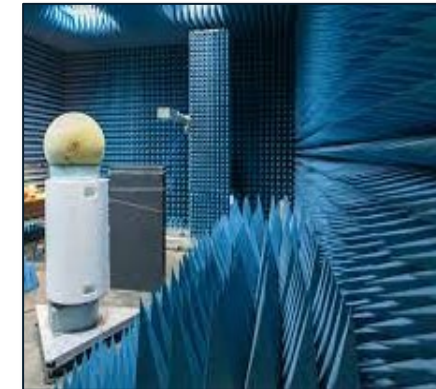
Color Changing Fabrics



ChroMorphous

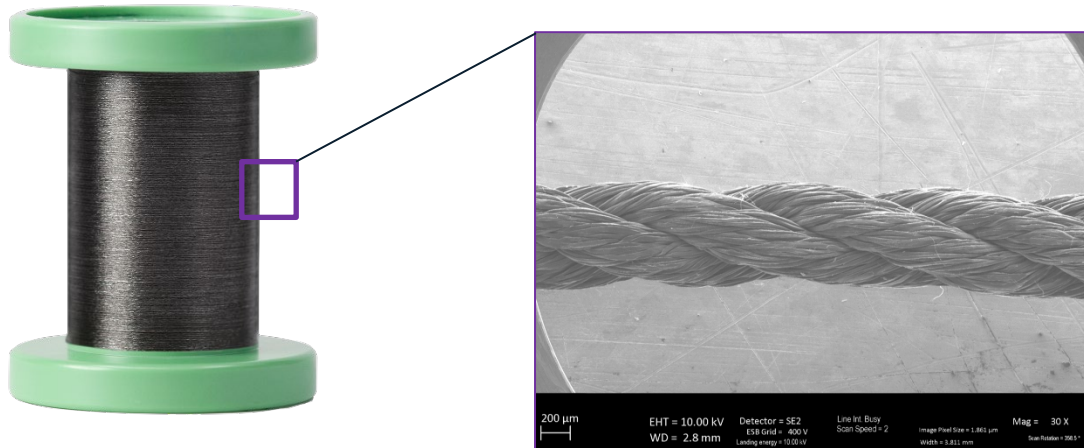
 **UCF**

Engineered RF Fabrics



NOTCH

Galvorn Yarn

Highlights

- AFTTR, Project Call 2.0: 2020-2022
- Applications: wearables, defense, automotive
- Raised \$3M seed round in 2023
- Highly conductive: 10MS/m
- 10X stronger than steel and half the weight of aluminum
- 5-6x lighter than copper
- Biocompatible
- Potential to be carbon negative at scale

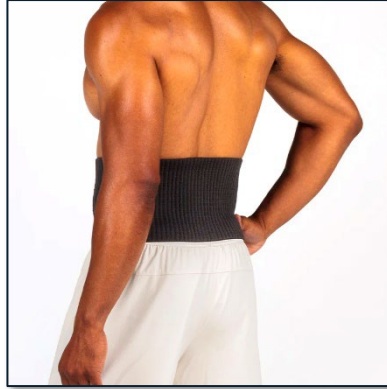
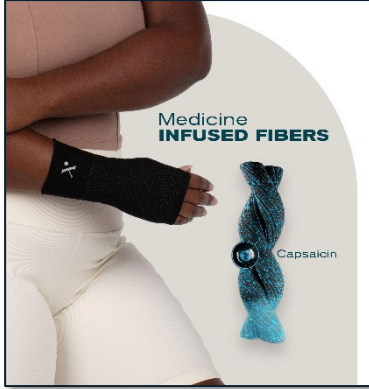
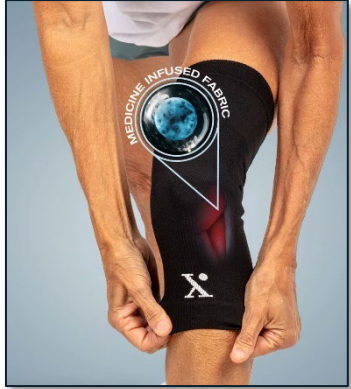
How has AFFOA supported you?

"AFFOA's unwavering support, not only financially but through their invaluable network, has played a pivotal role in DexMat's journey. It's not only helped us to develop fabric form factors of Galvorn materials and collaborate effectively with organizations seeking to integrate conductive Galvorn yarns and threads into their products, but it has also been valuable in raising our seed funding round from investors earlier this year, propelling our growth even further."

*- Dmitri Tsentlovich, PhD
Chief Technology Officer, DexMat*

Partners: pafdc @  DREXEL UNIVERSITY
Center for
Functional
Fabrics

 THE UNIVERSITY OF
NEW MEXICO



Highlights

- Starting / Ending MRL: 3 / 10
- Growth from 2 employees to 30
- Supply chain within 1-hour drive of Conover, NC HQ
- In 2021, No. 50 on Inc. 5000, America's fastest growing private companies
- Over 1M units sold in 15,000 retail stores
- Working with multiple leading brands to add medicine functionality to their existing product line(s)

How has AFFOA supported you?

“We’re extremely appreciative of all the support from AFFOA in enabling early development funding, connections to network partnerships and industry expertise across a wide range of areas. What we’re doing is so unique, that it really takes an outside the box group of thinkers, like AFFOA, to truly understand our needs and support of our growth.”

*- Jordan Schindler
CEO, Nufabrx*

Partners:



Color Changing Fabrics

How has AFFOA supported you?

“We were able to assemble a team spanning the United States in just weeks. Not years, weeks. This enabled us to realize a fully activatable color-changing dress made by a lead designer from the starting point of a single color-changing fiber less than a year prior — thanks to AFFOA. Not content to stop there, AFFOA then guided us through the process of developing an automated system to enable the mass-manufacturing of electrically connected color-changing fabrics, providing weekly meetings with an AFFOA team member with years of experience in the process we were utilizing. Simply put, we could not have done this without AFFOA.”

*- Joshua Kaufman, PhD
Research Assistant Professor, UCF
Founder and CEO, ChroMorphous*

Highlights

- Starting / Ending MRL: 3 / 7
- Prototyped full color changing product prototypes, from fiber to cloud, all with US-based partners across the FIN
- Developed ultrasonic welding to streamline connectorization

Sasha Stolyarov | Oct. 31, 2023

Partners:



President Biden Visits AFFOA Member Auburn Manufacturing, Inc.



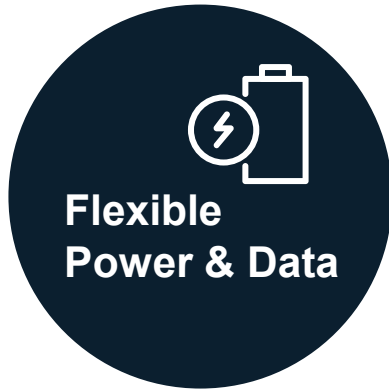
President Biden signing “Invent and Invest” Executive Order promoting “Invent it Here, Make it Here” at AFFOA Member Auburn Manufacturing, Inc. (AMI) in Auburn, ME. July 28, 2023



“AFFOA is providing essential technical support to specialty textile makers like AMI. Our close collaboration with AFFOA is speeding our product entry into aerospace applications from years to months, while providing assurance that our products will meet rigorous technical requirements.”

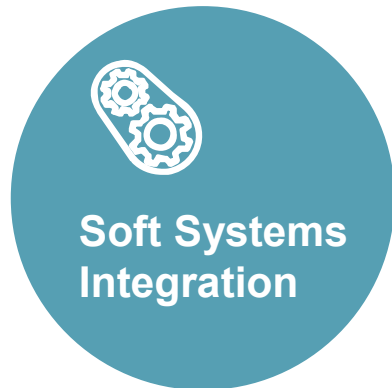
– Kathie Leonard, CEO Auburn Manufacturing Inc.

Technical Working Groups (TWG)



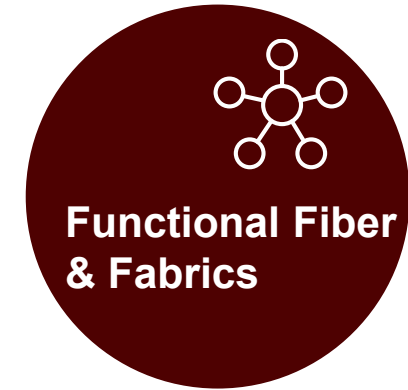
**Flexible
Power & Data**

Integrate distributed elements (electronic and textile) within a soft system



**Soft Systems
Integration**

Wearable and non-wearable system integration elements such as connectors and interface devices



**Functional Fiber
& Fabrics**

Increase fiber functionality, both IC insertion and continuous functional fibers



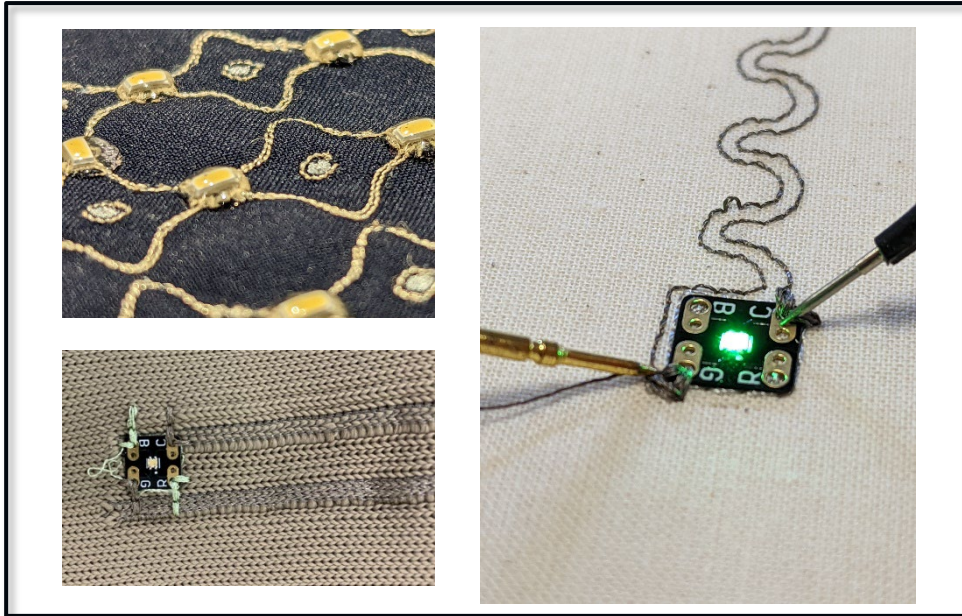
**Industry
Infrastructure**

Building blocks of an industry including reliability testing, materials database, equipment development, and modeling

Infrastructure Development

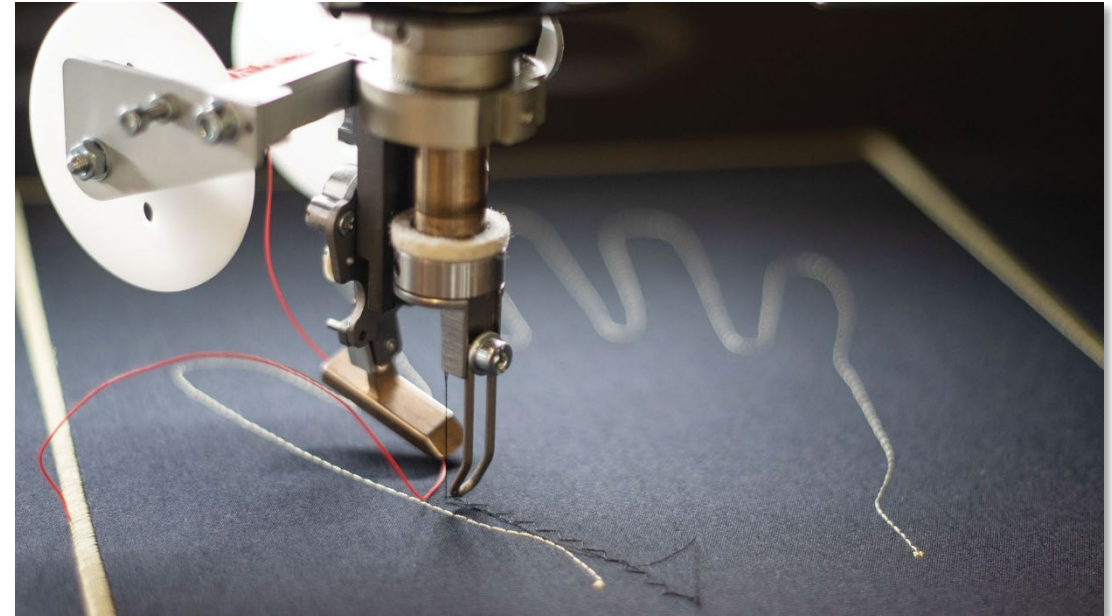
Connectorization, Conductors, Encapsulation

Connectorization



- State of the art analysis and inspecting commercially available components
- Procuring connectors, replicating joining capabilities, evaluating new joining technologies
- Capturing cost and manufacturability alongside performance

Conductors and Encapsulation



- State of the art analysis on commercially available conductors, their compatibility with textile processing, and compatibility with interconnect and encapsulation processes
- Benchmarking encapsulation materials and processes
- Developing a palette of encapsulation solutions

Infrastructure Development

Digital Engineering

E-Textiles lack digital design tools and infrastructure to produce robust, scalable products.

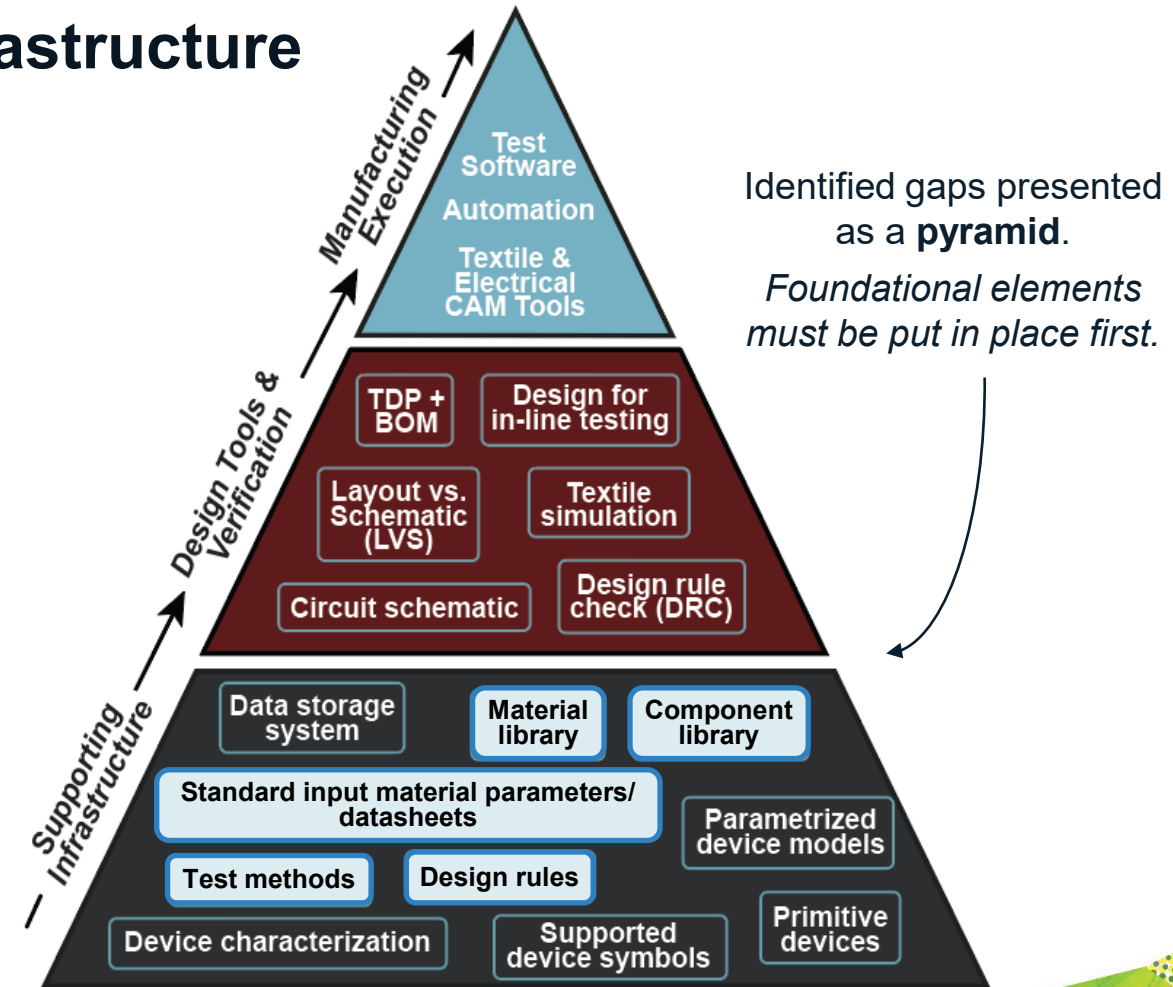
Customer discovery, cross-institute workshop, and TWG roadmaps identified several opportunities including:

- Product creation in a **digital 2D/3D environment**.
- **Material library** including relevant fabrics and components with **validated data sets**.
- Textile process **design rules** that define the constraints of manufacturing.

Further work is needed to develop design tools and supporting infrastructure elements.



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Technical Thrust Areas

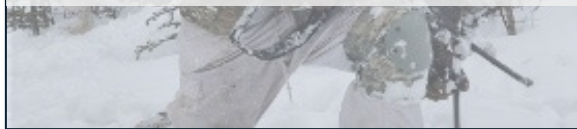
Soft System Development

- Human health and performance monitoring
- Healthcare Wearables
- Medical textiles



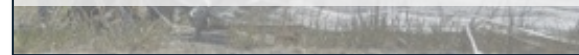
Environmental Protection

- Thermal regulation platforms for arctic environments
- Advanced insulation tech
- Chemical, Biological, Radiological, Nuclear, and Explosive protection



Multi-functional Materials

- Functional Composites
- Aerospace-grade silica textiles
- Multimaterial Fibers
- Biosafety Level-4 Suit
- Multifunctional materials
- PPE
- Advanced textile chemistries



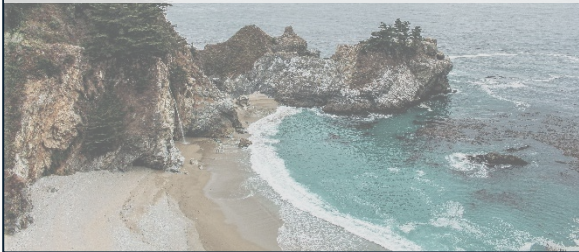
Sustainable Textiles & Processes

- Textile circularity
- Bioderived fibers
- Biomanufacturing



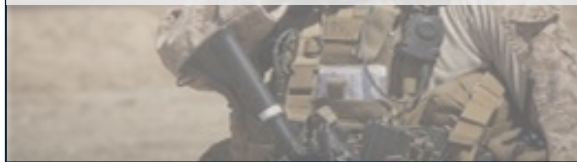
Large-Area Distributed Sensing Technologies and Systems

- Structural Health Monitoring
- Persistent Undersea Sensing
- Large-area sensing



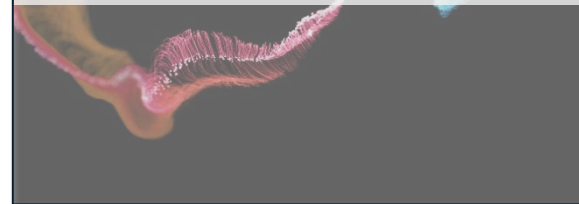
Size, Weight and Power Reduction Technologies

- Performance communications
- Textile Power & Data Infrastructure
- Textile sensing and actuation
- Signature Management



Digital Engineering & Textile Manufacturing Scale-Up

- E-Textile Digital Design Tools
- Digital Manufacturing Tools
- Process Design Rules
- Automated manufacturing



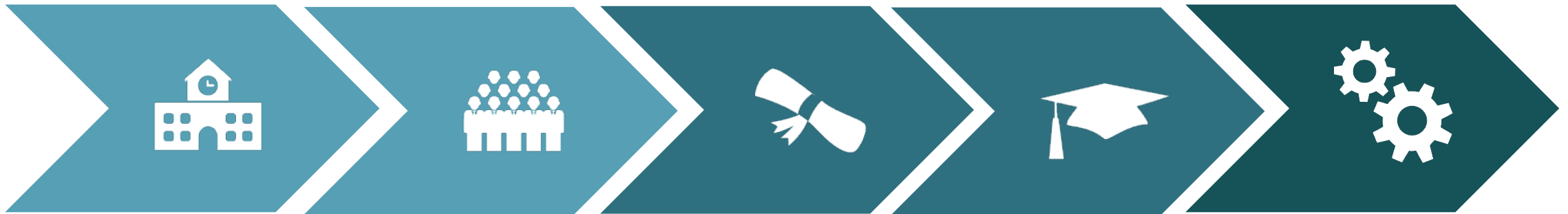
Education & Workforce Development

- K-12 STEM engagement
- Curriculum Development
- AFF Workshops



AFFOA's EWD Initiatives: The Lifecycle of a Learner

AFFOA's education and workforce development initiatives focus on learning across the academic lifecycle, from cradle to career.



K-12

- Mbadika STEM Kits
- Advanced Functional Fabric Curriculum (Explo, Lowell Project Learn)
- HS Experiences (Cambridge STEAM)

INCUMBENT WORKFORCE

- DoD SkillBridge
- NC DMCS*
- North Carolina Regionalism Initiative
- XPrize Rapid Reskilling Challenge
- MassBridge

ASSOCIATE'S-BACHELOR'S

- Advanced Fiber and Fabrics Workshop (MITxFIT)
- Internships/Co-Ops
- West Point Capstone Projects
- RACER PPE Coursework

POST-SECONDARY

- Advanced Fabric Coursework
- Sabbaticals
- Hackathons

ENTREPRENEURS & STARTUPS

- NC DMCS*
- Advanced Fabric Entrepreneurship Program (AFEP)
- Entrepreneurship in Residence (EIR)

Legend

2023 Programs
(planned/active)

Prior Programs

DMCS – Defense Manufacturing Community Support Program



EWD Highlight: *Engineering Design with Prototyping Curriculum*

Goal:

- Provide high school students with hands-on AFF experience

Program Overview:

- Two 3-week sessions in July and August 2023
- 25 students per session
- Integrated AFF EDP curriculum into the Engineering Concentration Course
- Students prototype solutions to challenge problems using fabrics and electronics

AFFOA Engagement:

- Hosted students at HQ for an overview of AFF technologies
- Leverage of AFFOA's digitized curriculum
- AFFOA staff attending final student presentations on campus

AFF – Advanced Functional Fabrics
EDP – Engineering Design with Prototyping

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“The EDP curriculum from AFFOA was the perfect way to wrap up Explo’s Engineering Concentration. Students were able to engage hands-on with advanced fabrics and work with real engineers, which made the entire process so much richer; they were able to not just learn about being engineers but practice it themselves! One student said that they especially enjoyed “learning how to incorporate circuits into something soft because I had never interacted with this kind of thing before”, while another one simply stated that “AFFOA is an epic company.”

*- Alex Trunell
EXLPO Course Instructor*

Selected Student Quotes

- *“I really liked how the AFF engineering project had me involved in every part of the engineering process, from hand-on building a prototype to presenting to experienced business professionals. It was very interdisciplinary, which I personally enjoy.”*
- *“[I learned] how to sew and stitch technology into clothing to make advanced fabrics.”*
- *“[I learned about] the way fabrics are used in the engineering world.”*

EWD Highlight: Inspiring Next Generation Learners with STEM Kits



“After a decade of operation, Mbadika is well aware of what makes a partner and an essential partner. Mbadika (bah-GEE-kah) has been proud to partner with AFFOA since 2022 in order to bring our latest initiative, M⁰Lab, to reality. As an organization focused on designing the future of STEM education, for students by students, AFFOA has been essential to bringing our inaugural fabric science product line to reality. AFFOA has helped us significantly scale our efforts to impact the educational landscape and we simply can’t wait for what the next year of our partnership can bring.”

*- Netia McCray
CEO/Founder, Mbadika*

The M⁰Lab Field Kit | Updates



Project 1



Project 2



Project 3

Learn how M⁰ ensures fabrics are dyed.



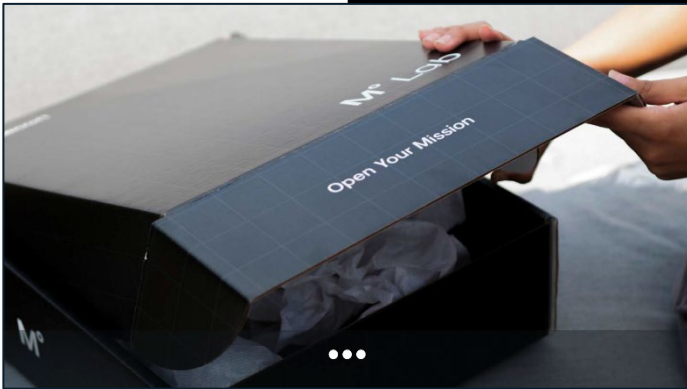
Project 4

Learn how coffee beans help control order and DWR creates water-resistant coatings in M⁰ fabrics.



Project 5

Learn how M⁰ designs for empathy, sustainability, and the need to consistently innovate.



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Summary

Innovation Ecosystem

AFFOA leads the US Fabric Innovation Network, fostering intra-network collaborations while building broad national awareness of the emerging advanced functional fabrics enterprise.

Technology & Manufacturing Innovation

AFFOA bridges the “valley of death” gap between early stages of innovation and commercialization by complementing R&D innovations with de-risking manufacturability.

Education & Workforce Development

EWD programs focused on inspiring, preparing and growing the future multi-disciplinary advanced textile workforce.

Get Involved!



Thank you!