AFFOA Presentation

November 14, 2018

Mission

AFFOA is an independent non-profit; its mission is to enable a domestic manufacturing-based revolution by transforming traditional fibers, yarns, and fabrics into highly sophisticated, integrated and networked devices and systems.

the *new* software

affoa

THE FABRIC REVOLUTION

FROM FIBER DEVICES TO FABRIC SYSTEMS

MOORE'S LAW FOR FIBERS – Fibers that have the functionality of semiconductor devices yet are produced at fiber lengths, uniformity and cost.

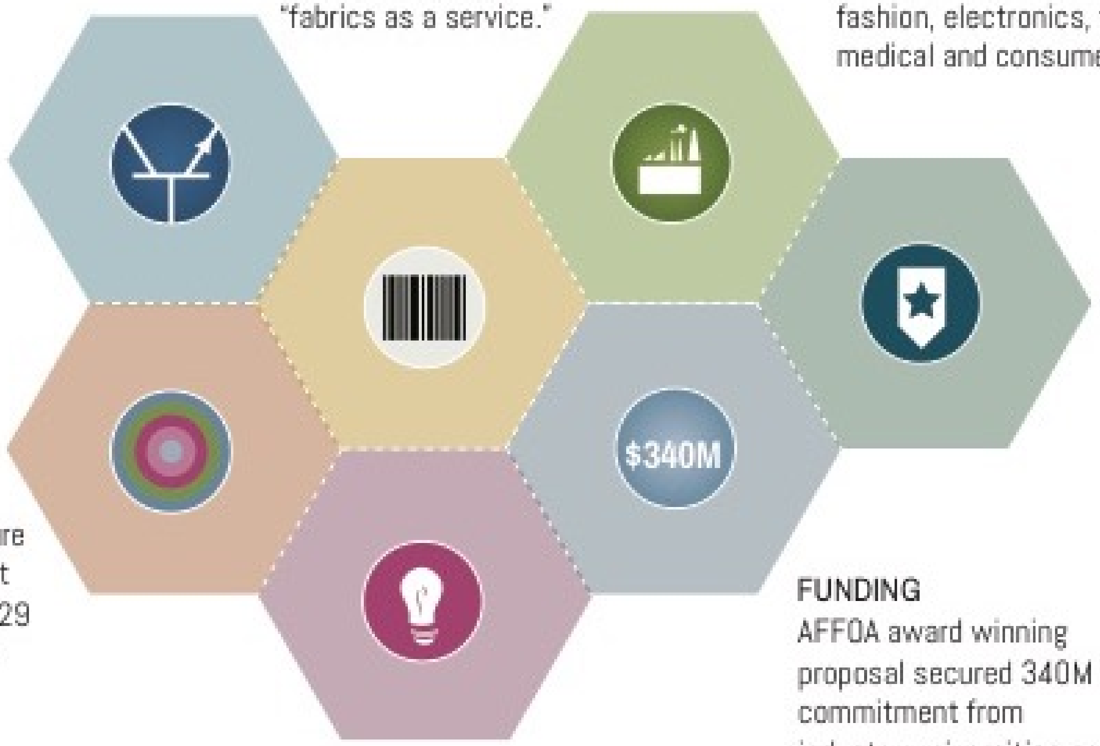
FABRICS AS A SERVICE – Fabrics that see, hear, sense, communicate, store and convert energy, regulate temperature, monitor health and change color.

Institute Elements

MOORE'S LAW FOR FIBERS
The world's largest cache of fiber device intellectual property enabling the first technology and manufacturing roadmap for advanced fabrics.

PRODUCT
AFFOA is a product oriented manufacturing institute delivering "fabrics as a service."

INDUSTRIAL SUPPORT
AFFOA is funded by industry to accelerate introduction of revolutionary fabric products across industries from materials to apparel, fashion, electronics, transportation, defense, medical and consumer good sectors.



GOVERNMENT
AFFOA works closely with government partners, specifically the DoD to deliver revolutionary fabric products to the benefit of our men and women in uniform.

FABRIC INNOVATION NETWORK (FIN)
A collaborative infrastructure of 100 prototyping and pilot manufacturing facilities in 29 states spanning the entire connected fabric manufacturing: CAD, fiber devices, textiles, system integration.

FABRIC DISCOVERY CENTERS (FDCs)
A national network of centers combining advanced fabric start-up incubators with end-to-end prototype facilities with education and work force development.

FUNDING
AFFOA award winning proposal secured 340M in commitment from industry, universities and state governments to fuel the AFFOA manufacturing innovation engine.

Membership Accrual

Startup (32)
99 Degrees Custom
American Boronite
APJet
BF+DA
Biotectix
Biowear
Blue Export Group
Bonbouton
Brrr!
Chameleon International
Electroninks
Elizabeth Whelan Design
Empatica
Factory 404
FullScaleNano
Future Tech Lab (FTL)
GloCal Network
Kalea Wear
Loomia
Ministry of Supply
Nanocomp Technologies
Nanowear
Parent Technology Group
Principled Design
Protect the Force
Solielle Design Studio
TexDel
Textile Instruments
Uwila Warrior
Vorbeck Materials
Voxel8
WETESO

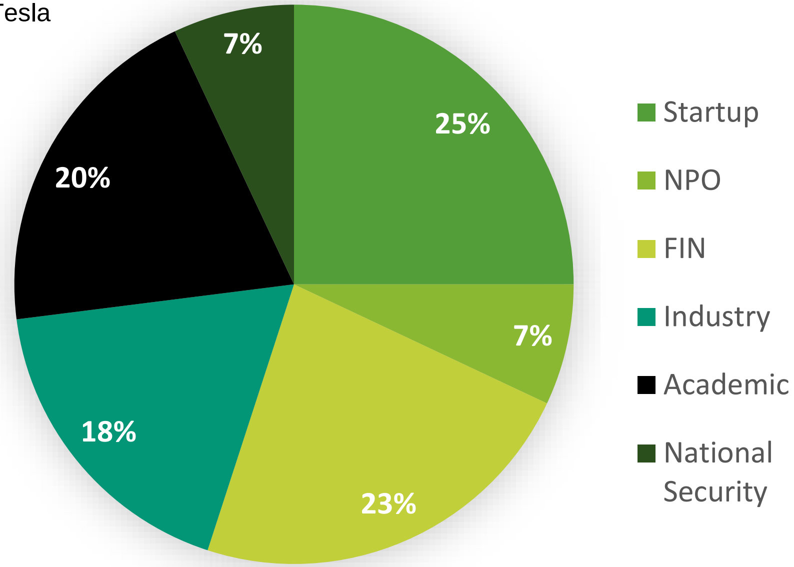
Academic (26)
Carnegie Mellon
Clemson University
Drexel University
FIT
Gaston College - TTC
Indiana University Bloomington
Iowa State University
Jefferson University
Manufacturing Solutions Center
MassMEP
MIT
NC State University
Ohio State University
Pennsylvania State University
RISD
Tufts University
UMass Amherst
UMass Dartmouth
UMass Lowell
University of Central Florida
University of Georgia
University of Kentucky
University of Maine
University of Minnesota
University of Texas at Austin
Virginia Tech

FIN (30)
American & Efird
Apex Mills
Auburn Manufacturing
Bluewater Defense
Boston Engineering
DSM Dyneema
E Ink
Fabreeka
FilSpec USA
Flextronics
Haartz
Hills
IDEO
Inman Mills
International Textile Group
Intradeco Apparel
Karl Mayer
Lakeland Industries
Milliken & Company
Otex Specialty Narrow Fabrics
Renfro Corporation
RTI International
Saab Barracuda
Sage Automotive
Shawmut Corporation
Tencate Protective Fabrics
Teufelberger
Triton Systems
UNIFI
Warwick Mills

Industry (23)
3M
47 Brand
Airbus
Analog Devices
Bose
Cintas
Corning
DuPont
Gap
Highland Industries
Invista
Lear
Lenzing
Lubrizol Advanced Materials
New Balance Athletics
Nike
Procter & Gamble
PVH
Saint-Gobain
Steelcase/DesignTex
VF Corporation
Sumitomo Chemical
Tesla

NPO (9)
AAFA
AATCC
Ben Franklin Tech
FabNewport
IFAI
Lean Enterprise Institute
Nashville Fashion Alliance
NCTO
SEAMS Association

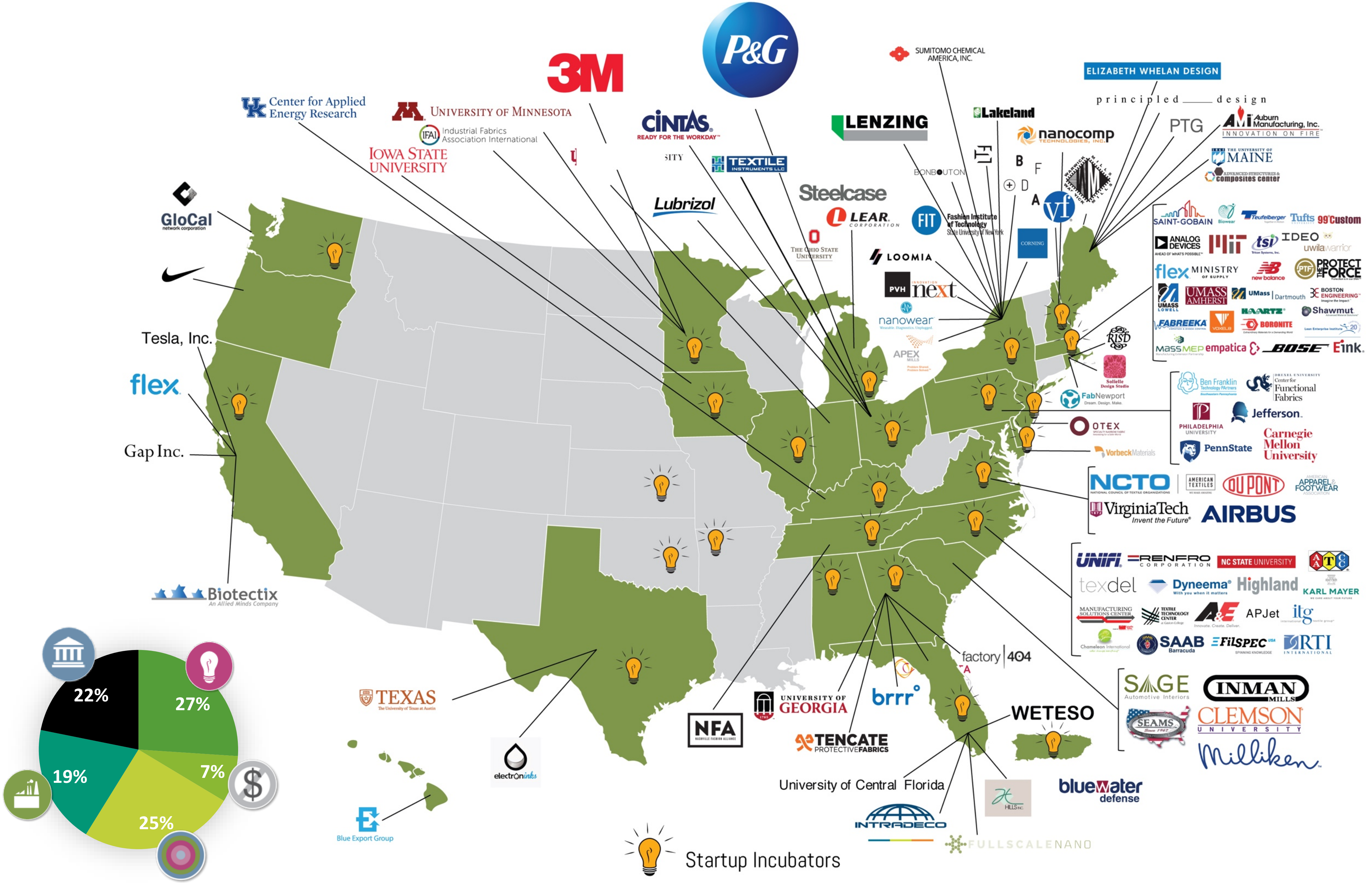
National Security* (10)
ARDEC
Army Futures Command
DTRA
Jet Propulsion Laboratory
MIT Lincoln Laboratory
NASA
NSRDEC
NUWC
USARIEM
USSOCOM



130 ORGANIZATIONS

* Strategic National Security Partners

A National Movement



Membership Value Proposition by Category

Exposure, Strategic Partnerships, Funding, Business Opportunities, Mentorship

Technology Transfer, Education and Entrepreneurship, Funded Projects

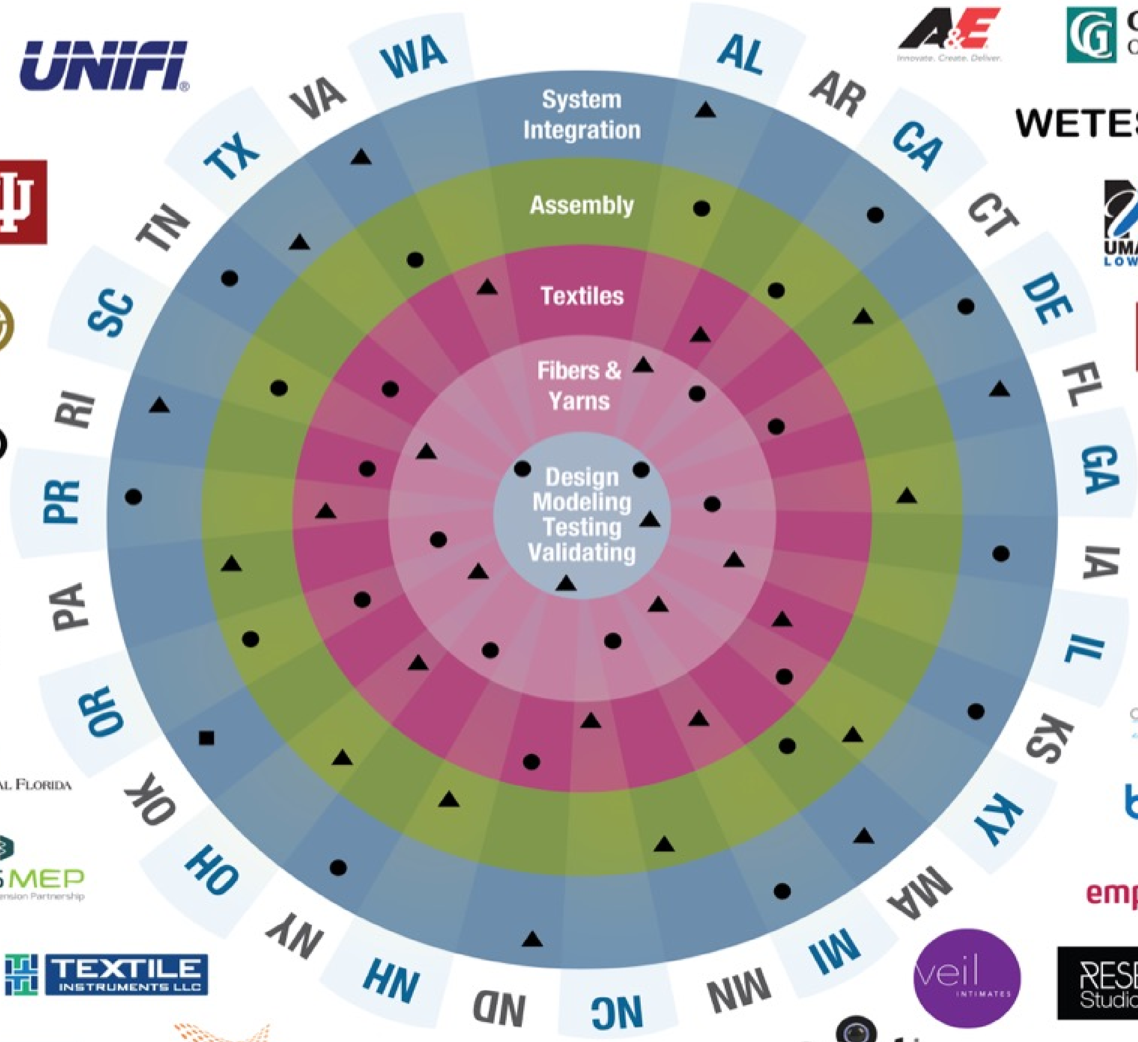
Access to New Markets, Business Development Opportunities, Expertise in IP Protected Technology, Brand Partnerships

Early Access to Technology, Product Design & Development, Business Opportunities, Domestic Supply Chain

Breakthrough Capabilities for National Security, High Quality Jobs, Domestic Supply Chain, RFT Products

- Account Ownership
- National Prototyping Network
- Member Portal
- MicroAward Program
- Robust CRM System
- One Stop Licensing
- Member Events
- Identifying Relevant Opportunities

Advanced Fabric Prototyping Network



Force Fibers
Auburn Manufacturing, Inc. INNOVATION ON FIRE
UNIFI
A&E Innovate. Create. Deliver.
Gaston College Opportunities For Life
NFA
SAGE Automotive Interiors
WETESO
FilSPEC USA
University of Minnesota
Lakeland
The Ohio State University
UMASS LOWELL
BORONITE Extraordinary Materials for a Demanding World
factory|404
CLEMSON UNIVERSITY
OTEX Specialty Narrow Fabrics
PTF
MIT
Warwick Mills
nanowear Wearable. Diagnostics. Unplugged.
TEXAS The University of Texas at Austin
Biowear
INMAN MILLS
electroninks
FIT
Manufacturing Solutions Center
CORNING
nanocomp Technologies, Inc.
Vorbeck Materials
B F D A
Philadelphia University
PennState
UMASS AMHERST
BONBOUTON
Rebel
Chameleon International color changes everything
tsi Triton Systems
itg international textile group
UMass Dartmouth
GloCal network corporation
RISD
University of Central Florida
brrr°
RENFRO CORPORATION
bluewater defense
UK Center for Applied Energy Research
Blue Export Group
MassMEP Manufacturing Extension Partnership
empatica
SEAMS
INTRADECO
SAAB Barracuda
Drexel University Center for Functional Fabrics
TEXTILE INSTRUMENTS LLC
veil intimates
RESERVED Studio
University of Georgia
Carnegie Mellon University
uwilawarrior
MINISTRY OF SUPPLY
Hills Inc.
APEX MILLS
RTI INTERNATIONAL
American Fiber Manufacturers Association, Inc.
apjet INC.
TENCATE
NC STATE UNIVERSITY
Biotectix An Allied Minds Company
FabNewport Dream. Design. Make.
WISEWEAR
Jefferson.
flex
Iowa State University
Ben Franklin Technology Partners
LOOMIA
HAARTZ
The University of Maine
Dyneema With you when it matters
NCTO
FULLSCALENANO
principled ___ design
Milliken
ATACAMA
ELIZABETH WHELAN DESIGN
Parent Technology Group, LLC
VirginiaTech Invent the Future
texdel
affoa

KEY ● Prototype Facilities ▲ Pilot Facilities

Moore’s Law for Fibers

LETTER

https://doi.org/10.1038/s41586-018-0390-x

Diode fibres for fabric-based optical communications

Michael Rein[1,2,3], Valentine Dominique Favrod[1,4], Chong Hou[2,3], Tural Khudiyev[2,3], Alexander Stolyarov[5], Jason Cox[6], Chia-Chun Chung[6], Chhea Chhav[6], Marty Ellis[7], John Joannopoulos[2,3,8] & Yoel Fink[1,2,3,6]*

Semiconductor diodes are basic building blocks of modern computation, communications and sensing[1]. As such, incorporating them into textile-grade fibres can increase fabric capabilities and functions[2], to encompass, for example, fabric-based communications or physiological monitoring. However, processing challenges have so far precluded the realization of semiconducting diodes of high quality in thermally drawn fibres. Here we demonstrate a scalable thermal drawing process of electrically connected diode fibres. We begin by constructing a macroscopic preform that hosts discrete diodes internal to the structure alongside hollow channels through which conducting copper or tungsten wires are fed. As the preform is heated and drawn into a fibre, the conducting wires approach the diodes until they make electrical contact, resulting in hundreds of diodes connected in parallel inside a single fibre. Two types of in-fibre device are realized: light-emitting and photodetecting p–i–n diodes. An inter-device spacing smaller than 20 centimetres is achieved, as well as light collimation and focusing by a lens designed in the fibre cladding. Diode fibres maintain performance throughout ten machine-wash cycles, indicating the relevance of this approach to apparel applications. To demonstrate the utility of this approach, a three-megahertz bi-directional optical communication link is established between two fabrics containing receiver–emitter fibres. Finally, heart-rate measurements with the diodes indicate their potential for implementation in all-fabric physiological-status monitoring systems. Our approach provides a path to realizing ever more sophisticated functions in fibres, presenting the prospect of a fibre ‘Moore’s law’ analogue through the increase of device density and function in thermally drawn textile-ready fibres.

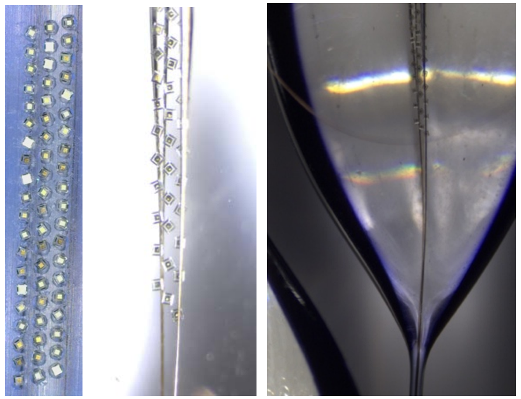
Efforts to increase fibre functions can lead to substantial advantages because the inherent scalability of textile production can be harnessed to produce functional fabrics at a large scale[3,4]. The preform-to-fibre drawing process has been demonstrated to deliver considerable functional capabilities on the fibre and textile level through the incorporation of materials with disparate electronic and optical properties into monofilaments[4–10]. Nevertheless, this process has been limited to materials that could be co-drawn[10] in their viscous states and are typically inferior in performance to ‘device-grade’ materials that are made using wafer-based approaches[11,12]. In this work, we combine scalable preform-to-fibre drawing with high-performance prefabricated semiconductor devices. Specifically, we incorporate functional semiconductor devices and electrical conductors into a polymer-clad preform, where the viscous polymer cladding simultaneously facilitates device packaging and electrical connectorization in situ during the thermal draw. This process enables new fibre and textile optical communication functionality at unprecedented data rates, as well as a viable path to introducing a gamut of alternative electronic devices into thermally drawn fibres.

The fabrication approach used to produce these fibres is illustrated in Fig. 1a, b. Prefabricated semiconductor devices are embedded in prescribed locations along the preform. As the preform is thermally drawn, the diodes separate axially while their lateral position is preserved by the surrounding viscous polymer. During the drawing process, electrical conductors are unspooled into hollow channels flanking the diodes. The lateral separation of these wires is gradually reduced in the neck-down region until electrical contact is made with the devices. In contrast with previously reported work, where low-melting-temperature metals were thermally co-drawn in polymer fibres[5,10,13], this work demonstrates the ability to embed high-melting-temperature tungsten or copper metallic wires in the fibres during the draw, thus providing highly conductive electrical conduits for the devices. It is worth noting that neither the wires nor the diodes scale down in size during the draw, nor they are in contact with each other in the preform. The preform design and the drawing process itself facilitate the electrical connection between the wires and the devices, as shown in Fig. 1b, c.

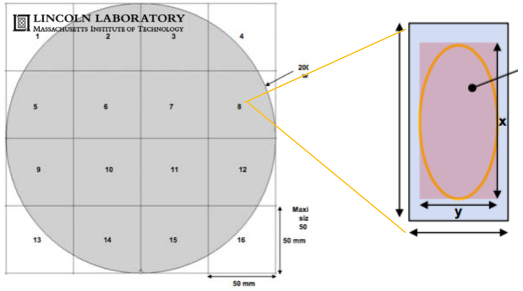
Fibres produced using this approach result in a linear array of semiconductor devices uniformly spaced along the fibre length and electrically connected in parallel, with fibre size as small as 350 μm × 350 μm. Electrical connection to the in-fibre electrodes is achieved by stripping away the polymer cladding at one end of the fibre. When a voltage is applied to the embedded wires, the in-fibre light-emitting diodes (LEDs) emit light, as shown in Fig. 2a for several fibre samples containing LEDs of different colour. This discovery is the first demonstration of a thermally drawn fibre with embedded semiconductor devices that are able to emit light when the fibre is supplied with electrical current, circumventing the necessity of applying external coatings or conductors[14–20]. Moreover, unlike other[17–20] approaches that yield short fibre lengths, the current approach enables kilometres of functional fibre to be drawn from a single preform with more than a hundred discrete devices connected in parallel throughout the entire fibre. The linear device density in the fibres can be directly controlled by varying the linear density of devices in the preform (for a given preform-to-fibre draw-down ratio) or by introducing several layers of devices and wires in the preform, as demonstrated in Extended Data Fig. 1. For example, for a draw-down ratio of 40, we are able to reduce the inter-diode distance from 2 m to approximately 17 cm. Addition of more layers in the preform will potentially lead to even higher device density in the fibres.

This technique is not limited to the incorporation of LEDs into fibres; other electronic devices could be embedded within thermally drawn fibres in a similar fashion. We embedded p–i–n photodetectors into fibres to enable high-bandwidth photodetection, in contrast to amorphous chalcogenide photoresistive materials previously drawn in fibres[10], which have much lower responsivity and bandwidth compared to crystalline semiconductors such as Si, Ge or GaAs. The method used for the introduction of crystalline GaAs semiconducting p–i–n photodiodes is shown in Extended Data Fig. 2. Characterization of the photodetecting fibres was carried out by illuminating them with the red LED fibres. Figure 2e shows a clear rectifying behaviour of the

[1]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA. [2]Research Laboratory of Electronics (RLE), Massachusetts Institute of Technology, Cambridge, MA, USA. [3]Institute for Soldier Nanotechnologies, Massachusetts Institute of Technology, Cambridge, MA, USA. [4]Department of Materials Science, Swiss Institute of Technology (EPFL), Lausanne, Switzerland. [5]MIT Lincoln Laboratory, Lexington, MA, USA. [6]Advanced Functional Fabrics of America (AFFOA), Cambridge, MA, USA. [7]Inman Mills, Inman, SC, USA. [8]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA. *e-mail: yoel@mit.edu

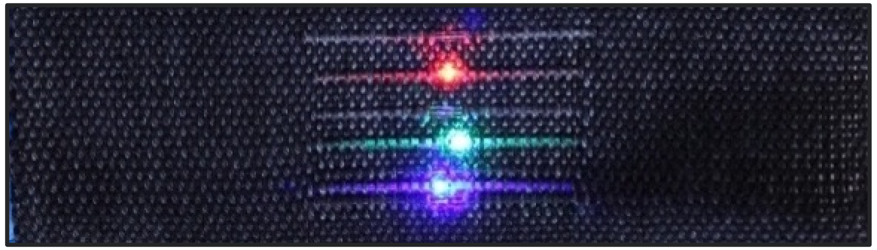


Device spacing: 5 cm

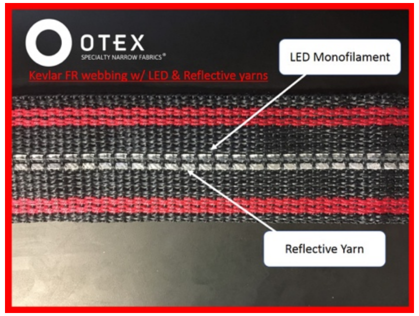


Custom chips for improved connections and textile quality

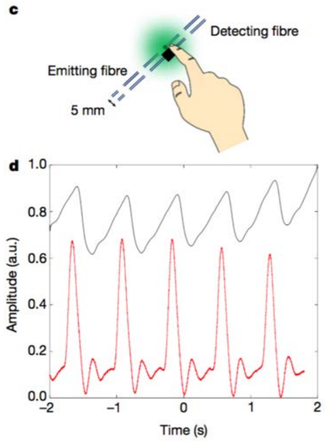
LINCOLN LABORATORY
Massachusetts Institute of Technology



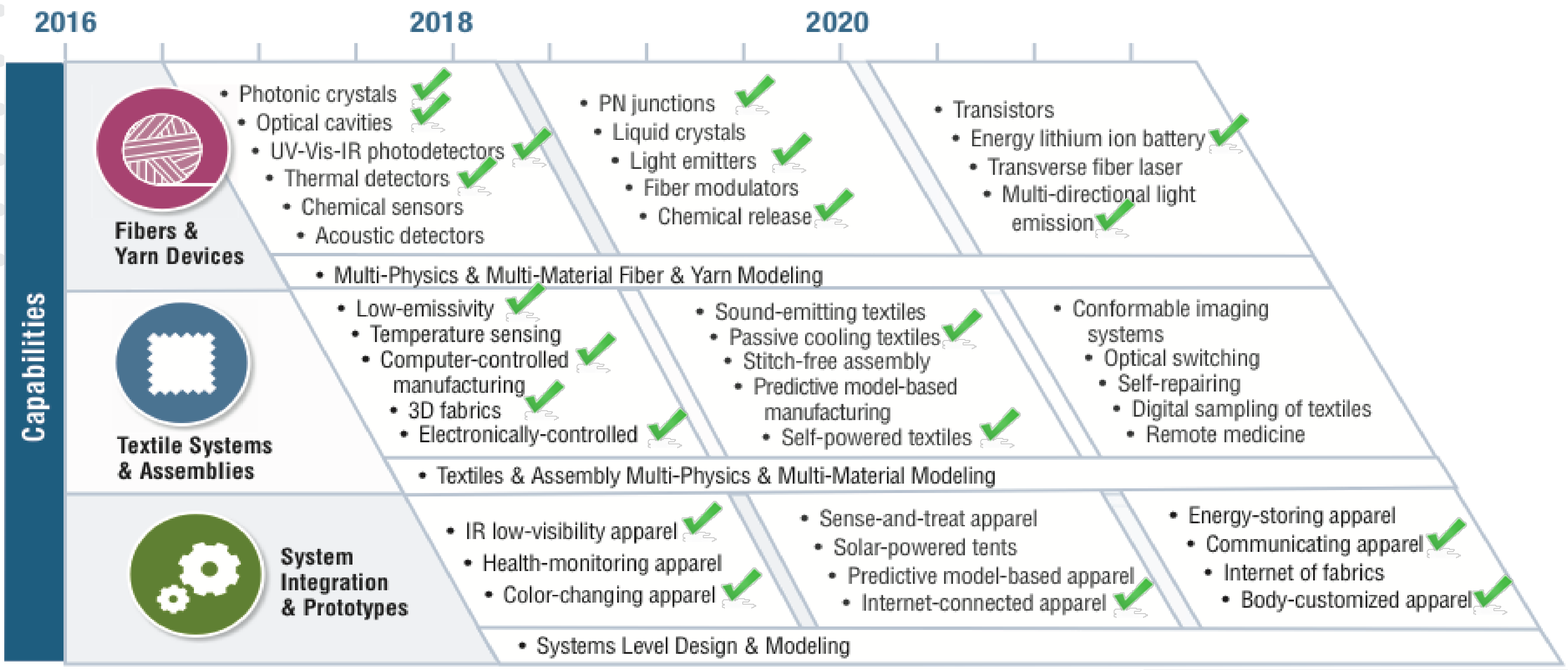
Fabric spectrometers for chemical sensing



Optical communication



Physiological monitoring



Roadmap 1.0

"AFFOA's proposal Roadmap was a sexy marketing pitch"
– famous quotes from an unnamed subject matter expert

IP Derived Roadmap

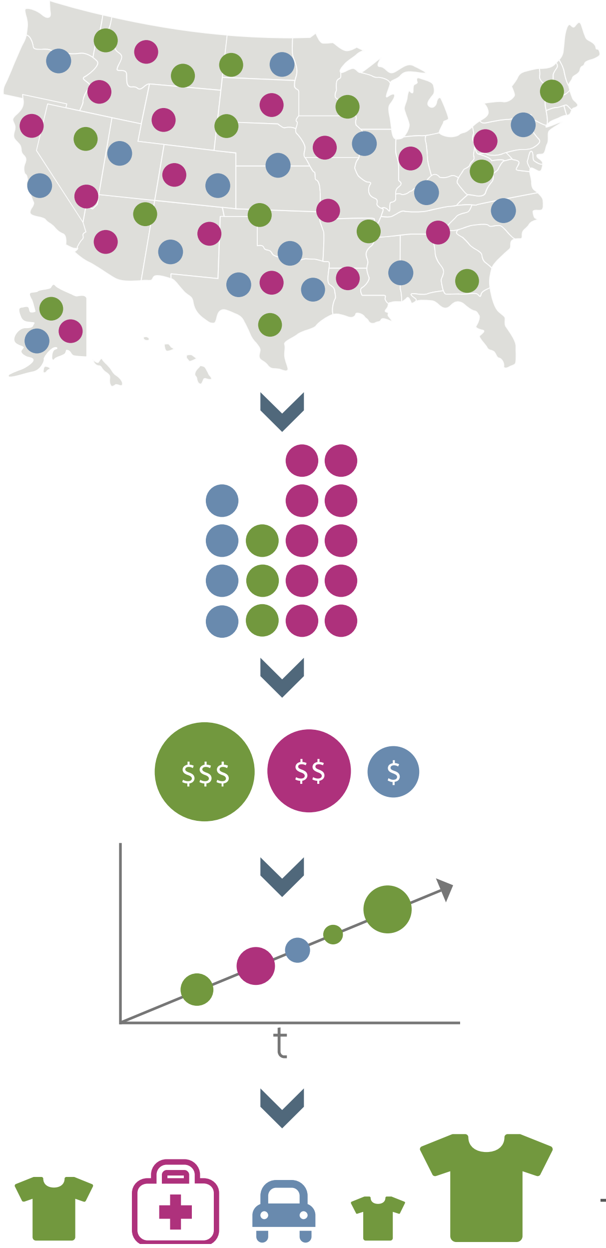
IDENTIFY
Geographically distributed IP in fibers, fabrics and textiles

CLASSIFY
Core IP Capabilities (CIC)
e.g. Antennas, Batteries, Color Change, FR, Antimicrobial, Heating/cooling

PRIORITIZE
Rank by market potential, time to market, enabling/strategic

ROADMAP
Key Technology Capabilities – Tech and manufacturing roadmap

INVEST
Roadmap projects



200,000 Patents and Applications - *July*

1,200 University RFT Patents and Applications with validation - *Sept*

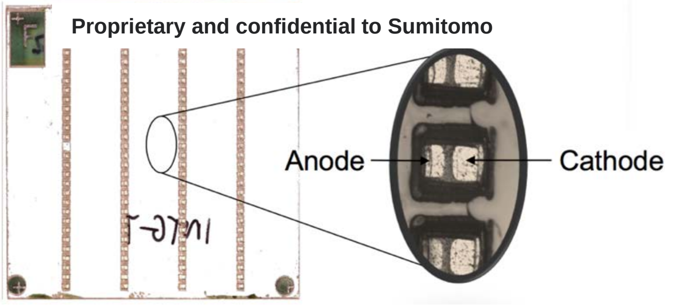
40 Core IP Capabilities - *Sept*

Roadmap 1.5 - *Oct*

10 Roadmap Project Topics Released - *Nov*

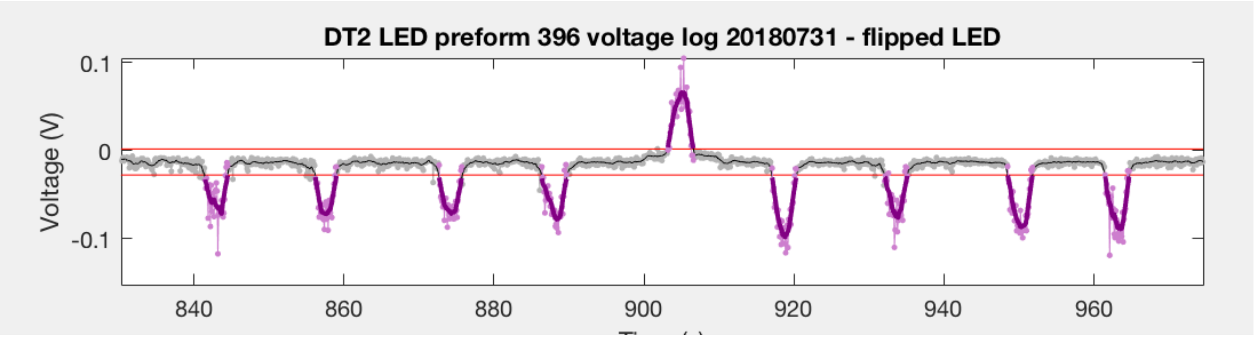
FABRIC COMMUNICATIONS

Fabric Forms and System Integration



Custom photodiodes

Active LOOks rope



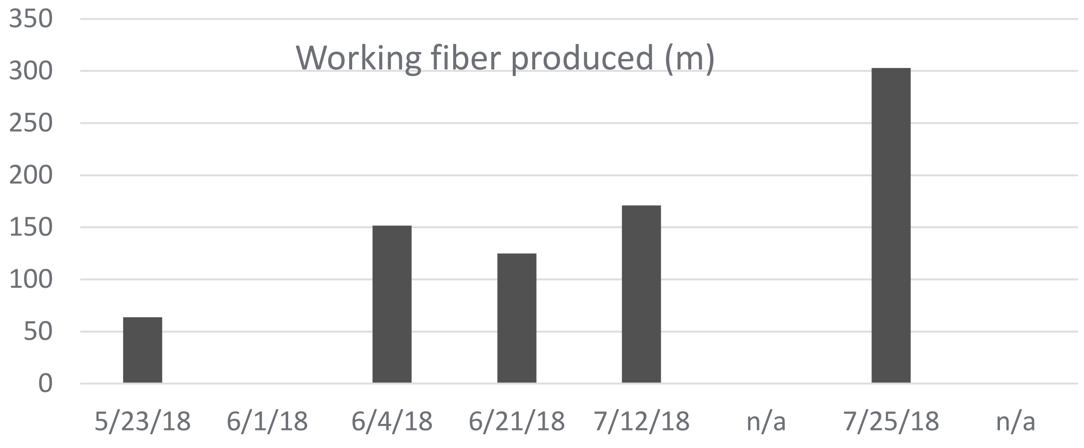
In-line characterization of chip location and function

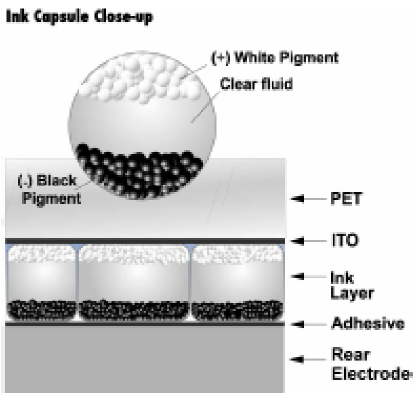
- Yarn covering yield 95% (65% Q2)
- Braiding for mechanical strength
- First functional nonwovens, composites, ropes
- Channel weave structure for product prototypes
- Clip to Connect plugs
- Active LOOks rope
- Puck controller
- Garment integration
- Custom wavelength tuned photodiodes
- Proprietary project
- In-line characterization – rapid learning & higher utilization
- Manufacturing scale

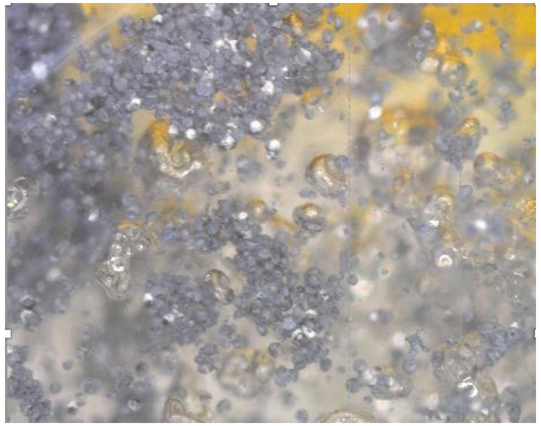
COLOR CHANGE

Scale and Materials

- Lensing structure scaled – 750m Q3 (64m Q2)
- Microcapsule formulations for colors and stability
- Delustering – 3x reduction in gloss with x% reduction in contrast
- Antireflective coatings for delustering and increased contrast
- Fiber production and swatch weaves for Proprietary Project
- Automated filling prototype
- Transparent conductors developed for lower switching voltage

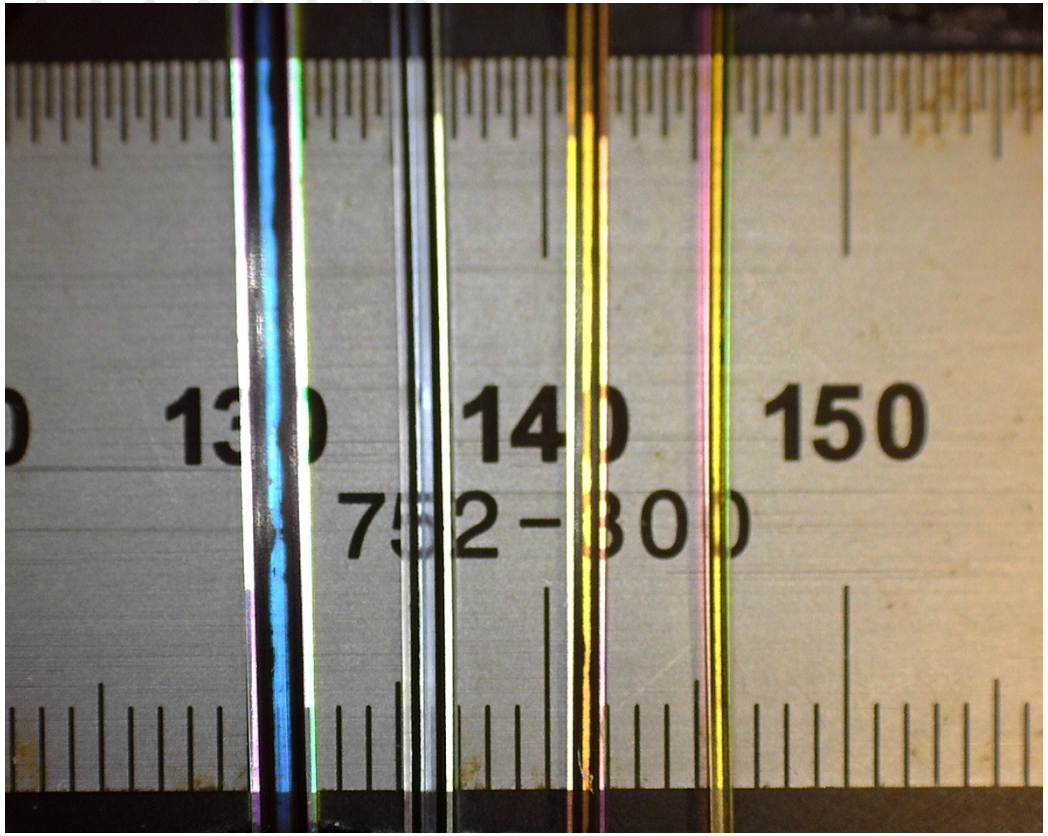






ELECTRIFICATION

Scale and Materials

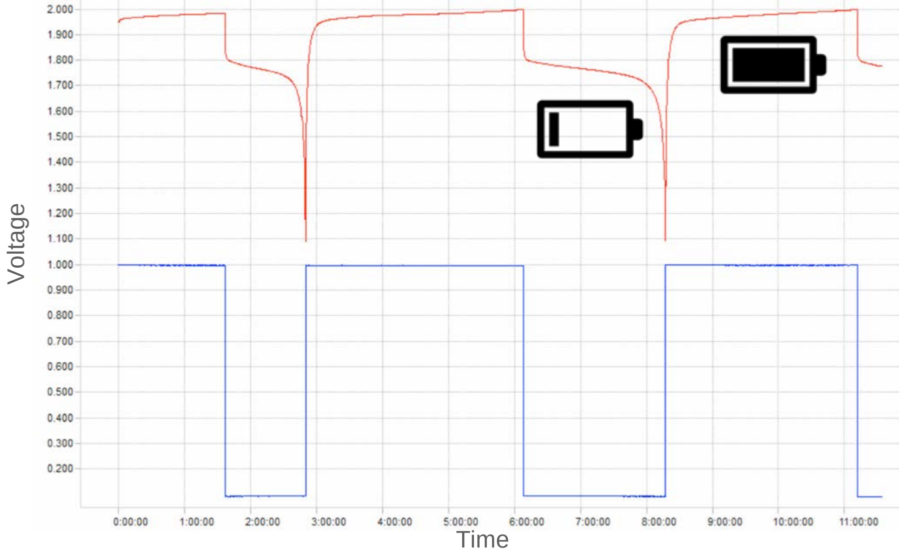


Supercapacitor

- Diameter reduction 0.7 x 0.4 mm (0.8 x 0.6 mm Q2) with higher capacity 0.2 mWh/m (0.11mWh/m Q2)
- 3 mWh in single draw (1.1 mWh Q2)
- Capacity increase volumetric and linear
- Scale – gel casting and low resistance wire 50 m max length (25 m Q2)
- Charge capacity retention – 92% over 331 cycles

Li-ion Rechargeable Battery

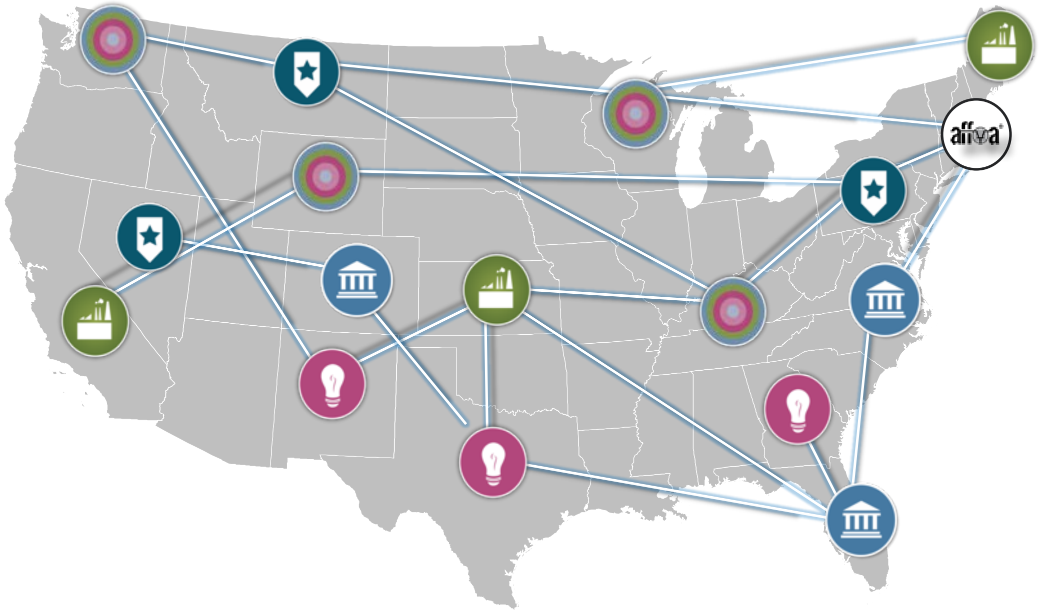
- Scale - convergence draw yield of 30 meters
- >5 meter continuous working fiber
- Low mixing
- 3.7V chemistry



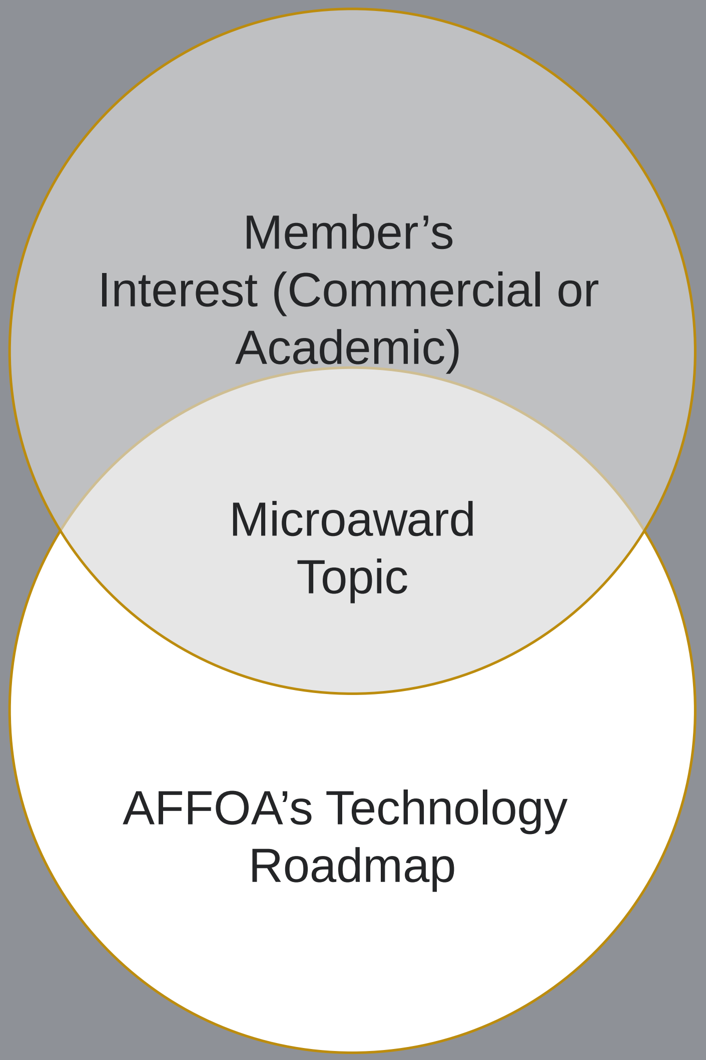
affoa®

MicroAwards - “shot clock innovation”

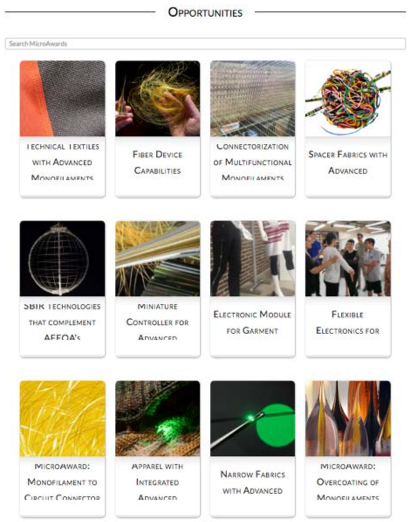
- New Business Opportunities
- Integrate and Advance National Prototyping Network
- Rapid Prototyping to Manufacturing
- Execute Advanced Fabrics Roadmap
- 90 day “shot clock innovation” cycles
- Rapid Engagement: 21 days from submission to award



CAD - IT



Microaward Topics



- Microaward postings based on roadmap gaps & members interest
- All microaward opportunities open to entire membership
- Members suggest suitable topics
- AFEP & Project Call support aligned with roadmap
- Follow-on recommendations from successful performance

Streamlined Application Process

21 Days From Submission To Award

Follow On Opportunities Toward Commercialization

IDENTIFY

Identify overlap with AFFOA's technology roadmap.

SUBMIT

2-page application: Deliverables, tasks & price.

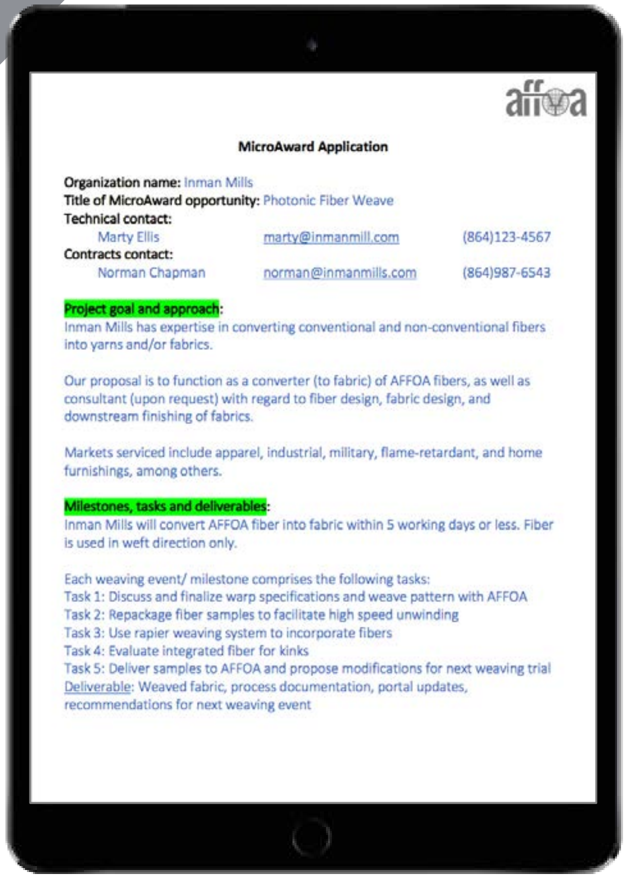
CONTRACT

2-page Terms & Conditions for commercial work.

EXECUTE

Launch project,
Iterate & collaborate.
Complete in 90 days.

Sample Application



MicroAward Application

Organization name: Inman Mills
Title of MicroAward opportunity: Photonic Fiber Weave
Technical contact:
Marty Ellis marty@inmanmill.com (864)123-4567
Contracts contact:
Norman Chapman norman@inmanmills.com (864)987-6543

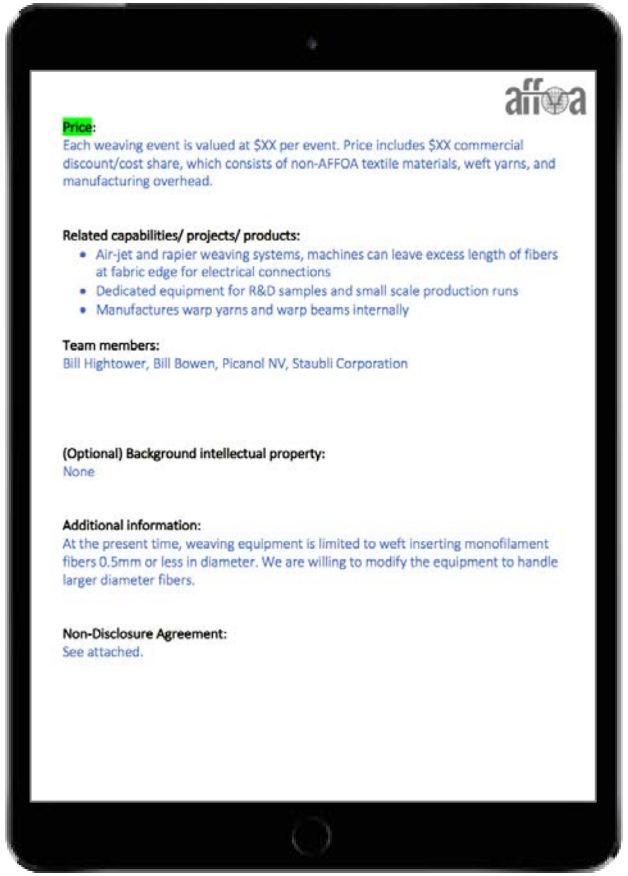
Project goal and approach:
Inman Mills has expertise in converting conventional and non-conventional fibers into yarns and/or fabrics.

Our proposal is to function as a converter (to fabric) of AFFOA fibers, as well as consultant (upon request) with regard to fiber design, fabric design, and downstream finishing of fabrics.

Markets serviced include apparel, industrial, military, flame-retardant, and home furnishings, among others.

Milestones, tasks and deliverables:
Inman Mills will convert AFFOA fiber into fabric within 5 working days or less. Fiber is used in weft direction only.

Each weaving event/ milestone comprises the following tasks:
Task 1: Discuss and finalize warp specifications and weave pattern with AFFOA
Task 2: Repackage fiber samples to facilitate high speed unwinding
Task 3: Use rapier weaving system to incorporate fibers
Task 4: Evaluate integrated fiber for kinks
Task 5: Deliver samples to AFFOA and propose modifications for next weaving trial
Deliverable: Weaved fabric, process documentation, portal updates, recommendations for next weaving event



Price:
Each weaving event is valued at $XX per event. Price includes $XX commercial discount/cost share, which consists of non-AFFOA textile materials, weft yarns, and manufacturing overhead.

Related capabilities/ projects/ products:
- Air-jet and rapier weaving systems, machines can leave excess length of fibers at fabric edge for electrical connections
- Dedicated equipment for R&D samples and small scale production runs
- Manufactures warp yarns and warp beams internally

Team members:
Bill Hightower, Bill Bowen, Picanol NV, Staubli Corporation

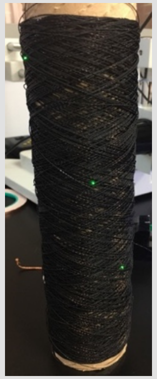
(Optional) Background intellectual property:
None

Additional information:
At the present time, weaving equipment is limited to weft inserting monofilament fibers 0.5mm or less in diameter. We are willing to modify the equipment to handle larger diameter fibers.

Non-Disclosure Agreement:
See attached.

90 Day
Shot Clock Innovation

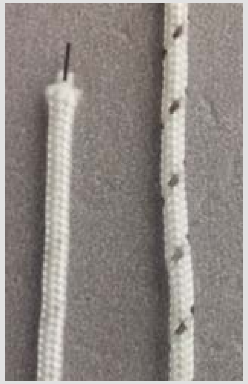
Yarn Covering of LED Monofilaments

Sprint #1	Sprint #2	Sprint #3	Sprint #4	Sprint #5	Sprint #6
					
04/27/18	05/14/18	06/13/18	07/06/18	09/14/18	09/28/18
Yarn cover surrogate (75% coverage)	Yarn cover LED fiber: 30% yield	Reduce tension: 90% yield	Verify yield consistency: 93% yield	Produce strong multifilament core	Yarn cover multifilament core

AFFOA visits Unifi

Pivot from producing stretchable yarn to strengthening core

Ropes For High Visibility Optical Communications

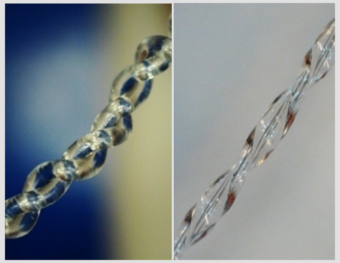
Sprint #1	Sprint #2	Sprint #3	Sprint #4	Sprint #5	Sprint #6
					
06/08/18	06/20/18	07/20/18	07/27/18	09/14/18	09/28/18
Braid surrogate	Integrate LED mono in sleeve and core of lace, Low yield	Integrate LED mono in ropes, No breakage	Demonstrate Active LOOKs for Teufelberger's President	Increase LED exposure, determine yield	Integrate photodiode fiber, demonstrate optical comm

Identified & implemented process modifications

90 Day
Shot Clock Innovation

DREXEL UNIVERSITY Center for Functional Fabrics

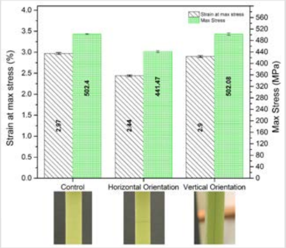
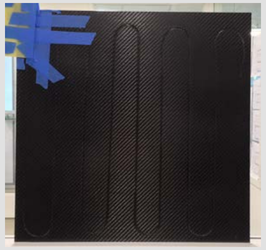
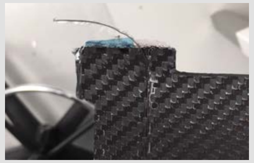
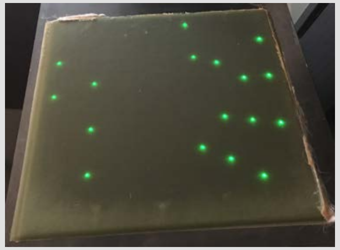
3D Knitted Apparel

Sprint #1	Sprint #2	Sprint #3	Sprint #4	Sprint #5	Sprint #6
					
05/31/18	06/14/18	06/21/18	07/12/18	08/22/18	09/05/18
Monofilament twisting improves bend radius but affects mechanical performance	Evaluate monofilament integration method: Rib knit architecture and interlock track damage monofilaments	Determine optimal monofilament integration method: Inlay tracks with rib structures	Design prototype to incorporate inlay structure	Knit vest prototype	Verify LED functionality in all 4 monofilaments

90 Day
Shot Clock Innovation

NC STATE UNIVERSITY

Composites with LED Monofilaments

Sprint #1	Sprint #2	Sprint #3	Sprint #4	Sprint #5	Sprint #6
					
06/11/18	07/02/18	07/16/18	07/30/18	08/15/18	08/31/18
Integrate surrogate in glass fiber composite (Prepreg laminate stack)	Perform mechanical tests: Horizontal monofilament orientation reduced tensile properties	Integrate LED monofilament in glass fiber composite	Integrate LED monofilament in carbon fiber composite	Test LED functionality: Monofilament breakage, attributed to curing conditions	Modify process, integrate LED monofilament in glass fiber composite

Modified curing conditions:
- ✓ Temp: 132 → 120^{o}C
- ✓ Pressure: 45 → 30 psi

MicroAwards

By The Numbers

Volume	Q3	Q1 + Q2
Active Solicitations	21	12
Applications Received	19	21
Commercial Awards	7	5
University Awards	3	5

Velocity (days to award)	Q3	Q1 + Q2
Commercial	21	23
Universities	60	61

Value	Q3	Q1 + Q2
Amount (Federal/Cost Share)	$843K ($213.3K)	$403K ($125K)
# of Sprints Complete	49	10

MICROAWARDS – Accelerating Roadmap Execution

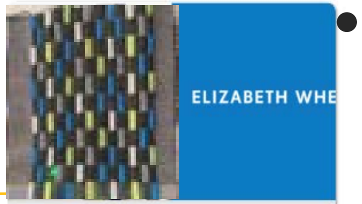
Yarn Covering of Monofilaments

AFFOA HQ, Unifi Inc.

Ring Twisting and Braiding of Monofilaments

Integration of Monofilaments into Yarns

3D Knitted Apparel



Monofilament Woven Fabric

Q3 ’18

- 10 cm Device Density
- 300 x 400 μm
- Overcoated Fibers
- *Yarn Covering Yield 90%*
- *Braiding*
- *Corespun Yarns*

- Fiber Lay
- *3D Knit Apparel*
- *Weaves for Safety and Furniture*
- *Composites*
- *Non-wovens*
- *Channel Weave*

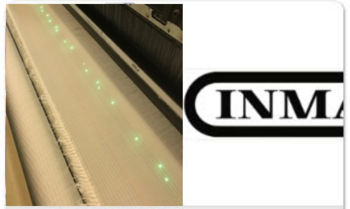
- *Active LOOks Rope*
- *Clip-2-Connect Plugs*
- *Pucks for Garments*
- *Garment Integration n=10*

Composites with Monofilaments

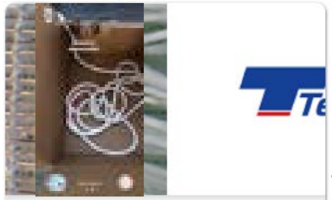
Nonwoven Fabrics with Monofilaments

AFFOA HQ

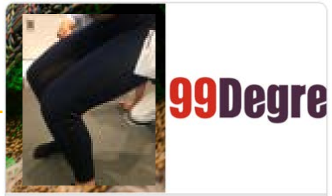
Composites with Advanced Monofilaments



Monofilament Weave



Ropes for optical communication

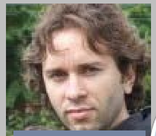


Apparel with Integrated Advanced Monofilaments

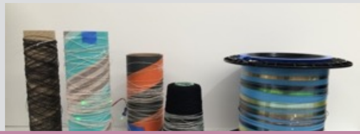
Electronic Module for Garment Systems

Fiber to Circuit Interconnect

affoa®



CAD-IT



Fiber & Yarn Devices

Textile Systems & Assemblies

T A

System Integration & Prototypes

MIT Massachusetts Institute of Technology

Software for knitting controllable patterns
- Reviewing

UNIFI

Yarn covering
- Sprint #4
- Improve properties

CLEMSON UNIVERSITY

Braiding
- Sprint #4
- Improve properties

INMAN MILLS

Yarn covering
- Sprint #1
- Spin staple fibers around monofilament

Drexel University

Trans. Conductors
- Sprint #2
- Material for fiber draw

MIT Lincoln Laboratory

Custom Si chips
- Sprint #1
- Custom chips for fiber

The University of Maine

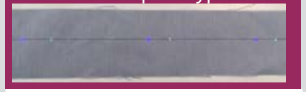
Overcoating
- Contracting
- Improve properties

UMass Lowell

Trans. Conductors
- Contracting
- Material for fiber draw

INMAN MILLS

Weave
- Sprint #4
- Product prototype

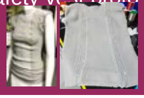


ELIZABETH WHELAN DESIGN

Weave
- Sprint #6
- Enhanced visibility fabric

Drexel University

3D Knit
- Sprint #6
- Safety vest proto

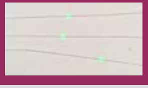


APEX MILLS

Warp Knit
- Sprint #1
- Apparel & furniture proto

3M

Non-wovens
- Sprint #3
- Product prototype



The University of Maine

Composites
- Sprint #2
- LED composite panels

NC STATE UNIVERSITY

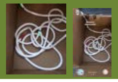
Composites
- Sprint #6
- LED composite panels

INMAN MILLS

Composites
- Sprint #1
- Fabric composite panels

Teufelberger

Rope for comm
- Sprint #4
- Product prototype



Teufelberger / DFDC

Rope for underwater comm
- Sprint #1
- Underwater comm

OTEX

Industrial webbing
- Contracting
- Webbing for safety, fire app

NC STATE UNIVERSITY

Crotchet knit
- Contracting
- Crotchet knitted fabrics

TEXAS The University of Texas at Austin

Non-wovens
- Contracting
- Non-woven panels

HAARTZ / Drexel University

Finished CTS
- Contracting
- Automotive fabric proto

OTEX

Seatbelt
- Reviewing

99°Custom

Garment integration
- Sprint #3
- Fully integrated tights

flex

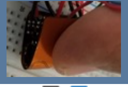
Electronic puck
- Sprint #3
- Puck for garment

Manufacturing Solutions Center / Gaston College Textile Technology Center

Testing of fiber/fabric
- Sprint #1
- Guide product development

UMass Lowell

Flex circuit
- ✓ Sprint #6
- Flex board for LiFi



UMass Lowell

Interconnect
- Sprint #6
- Connector for Clip2Connect

P&G

Wash testing of fabric
- Reviewing

UMass Lowell

Flex circuit for garment
- Reviewing

UMass Lowell

Miniature electronic controller
- Reviewing

bluewater defense / DFDC

Textile assembly and system integration for physical health monitoring of soldiers
- Reviewing

bluewater defense

Beta testing of smart fabric monitoring platform
- Reviewing

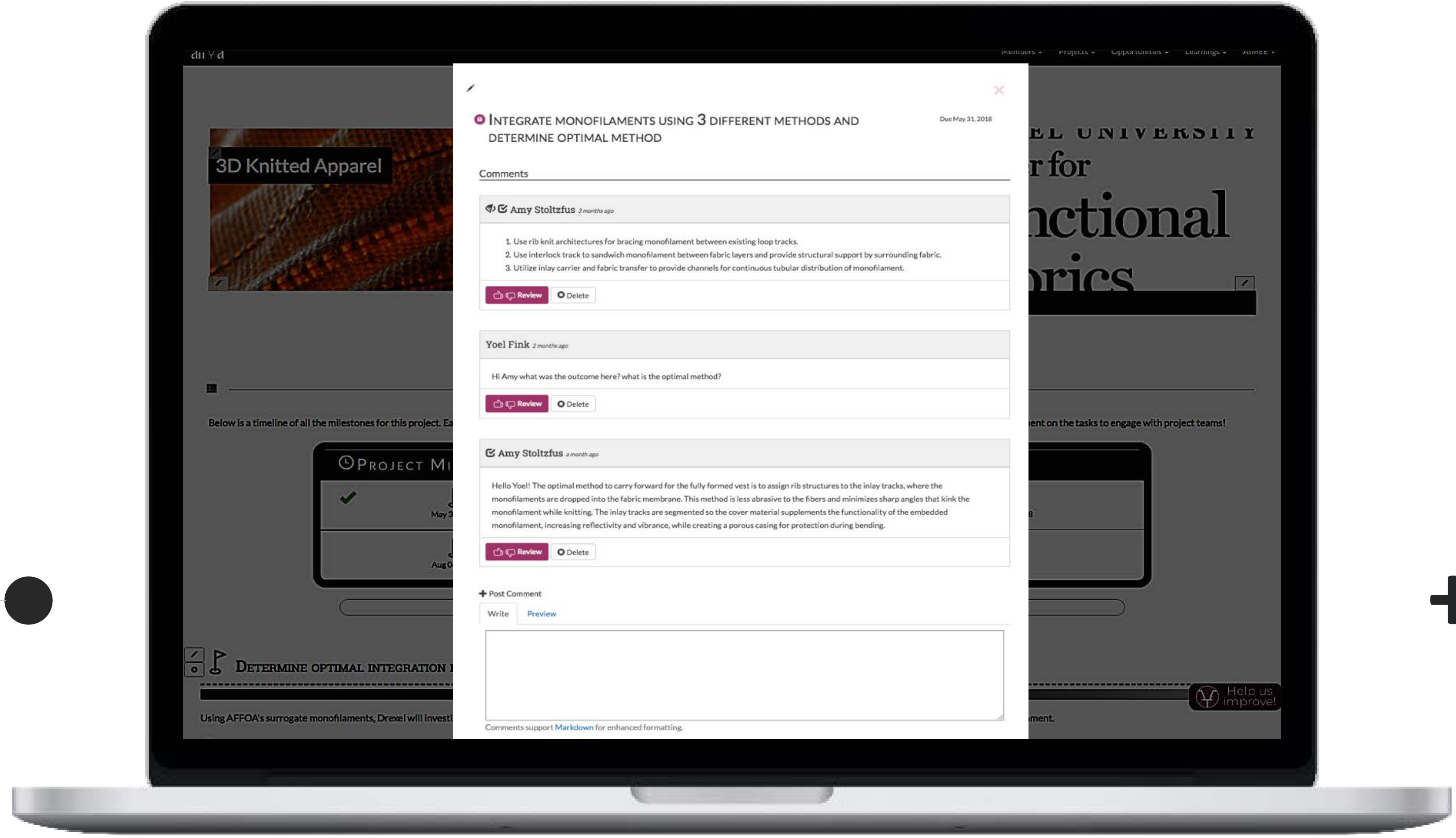
1 Completed
19 Active
6 Contracting
7 Reviewing

affoa®

Track MicroAward Updates on Portal

Portal Updates

On-Site Visits



Growing the Institute through Projects and Portal

34
Prototypes Created through Microawards

34
Microaward Project Participants on Portal

18
Microaward Projects on Portal

133
Comments on MicroAward Projects

9
Academic Groups on Portal

32
Microaward Capabilities on Portal

Rapid and Interactive Dissemination of MicroAward Learnings on Portal

Integration of Monofilaments into Yarns

Finished Fabrics and Testing

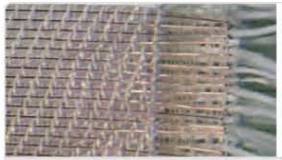
Nonwoven Fabrics with Monofilaments

AFFOA HQ

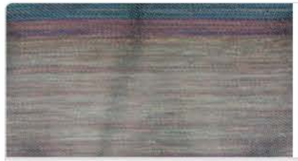
Transparent Conductive Thermoplastics using MXenes

Composites with Advanced Monofilaments

Ring Twisting and Braiding of Monofilaments



Ropes for optical communication

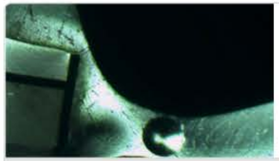


Knitted Fabrics with Monofilaments

Composites with Monofilaments

Monofilament Woven Fabric

Flexible Electronics for LiFi Hat



Fiber to Circuit Interconnect

3D Knitted Apparel

Yarn Covering of Monofilaments

Monofilament Weave

AFF Vocational HS Curriculum

LOOKS™

“The worlds first programmable backpack that is as unique as you are”

JANSPORT

INMAN MILLS

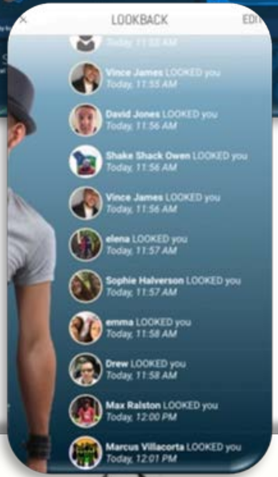
LOOKS

affoa

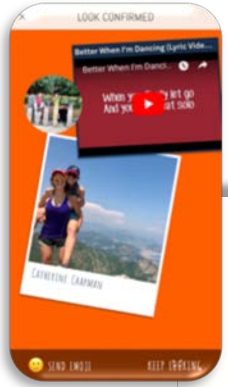
LOOks Product Layer Architecture

Applications and software

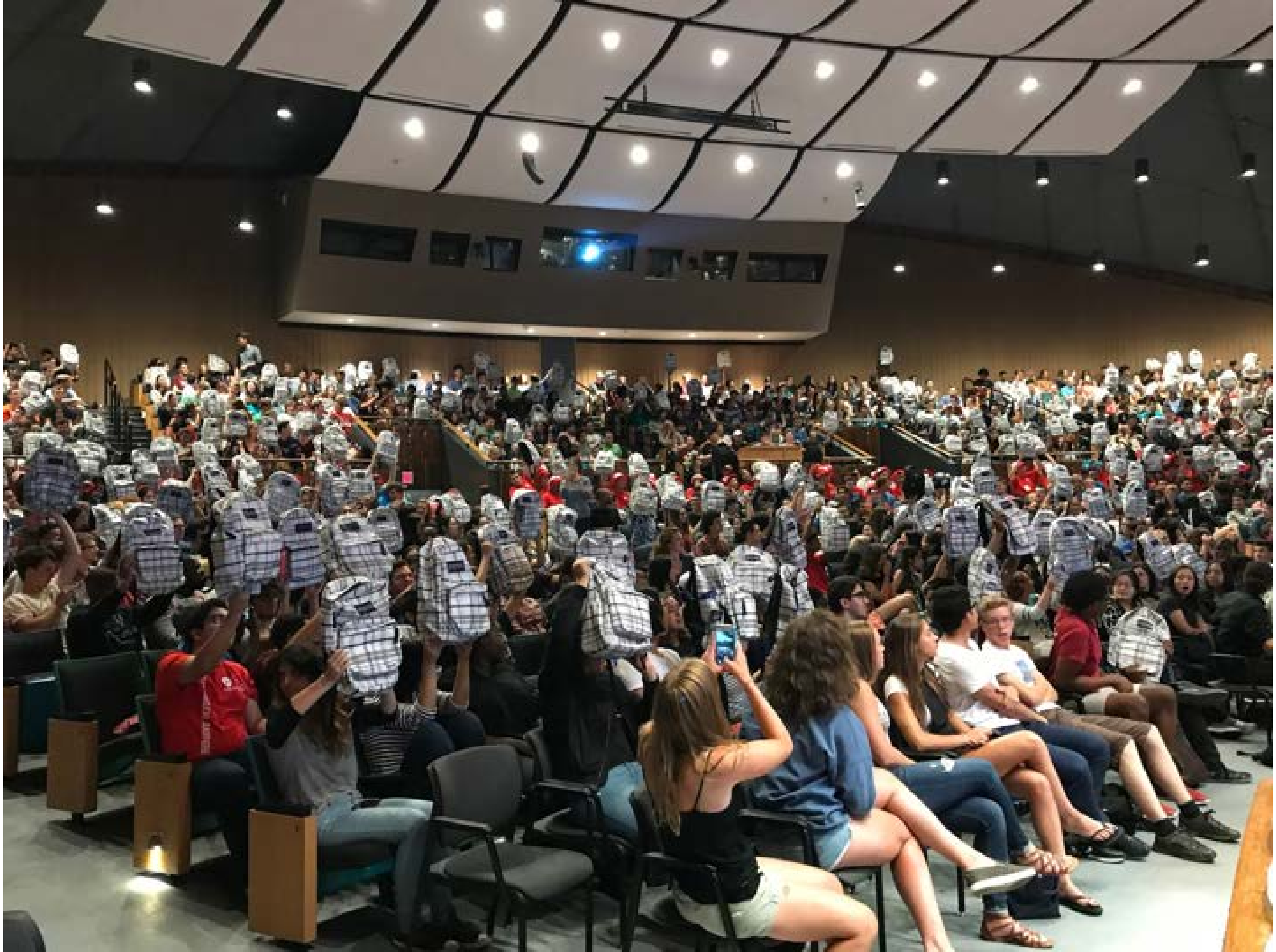
Network layer



Data layer



Physical layer



LOOks® Licensing Opportunities

1

Schools + Conferences

Schools: Unique, branded product to communicate with & among students.
Conferences: Unique branding/sponsor opportunity, could replace nametags. Improved networking

2

Retail + Shoppers

Retail: Retailers advertise, promote sales, and learn about consumers' shopping habits.
Shoppers: Special promotions, find items easier in store

3

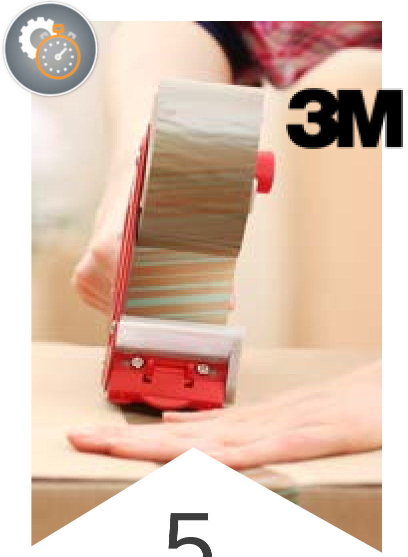
Rope

Rope: Identify rope quality, share user stories; military, sports, nautical, rock climbing

4

Apparel, Shoes, Accessories

Social networking, sharing, retailer tracking of goods

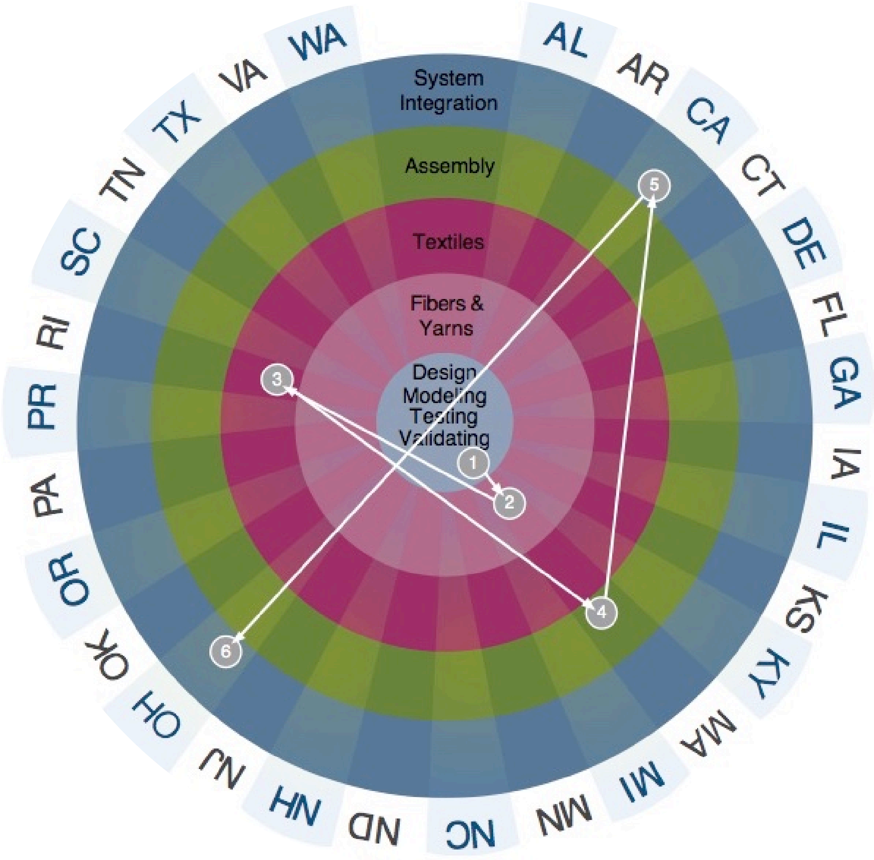


5

Tape

Packing & Storage: identify packing and storage contents

AFFOA’S FIRST PRODUCT COMMERCIALIZATION



SCOPE

Develop high visibility apparel with a major, commercial brand within 6 months using advanced fibers and fabrics

MEMBER ENGAGEMENT

1 2 affoa®

3 DARLINGTON A MOORE COMPANY

5 flex

6 P&G

4 99°Custom

HIGHLIGHTS

- 1000 Units Ordered
- 2000 meters, 10,000 LEDs
- AFFOA cobranding opportunity
- 7 organizations engaged
- Advanced trim development with commercial supplier
- Power puck development complete
- US garment maker

CUSTOMER REQUIREMENTS

- Maintain customer fit specifications regardless of fiber and SI needs
- High visibility, lumen testing
- Fabric and garment industry standard testing through approved testing facilities: ASTM & ASTCC requirements
- Minimum 6 hours battery life

Fanwear

Products Designed for Fan Engagement in large events based on active LOOks®

Update:

Actively engaged in business and product development with commercial partner

Large Spectator Events

Search, Social, Gaming Business Models

Fan to Fan, Fan to Athlete, Fan to Coach

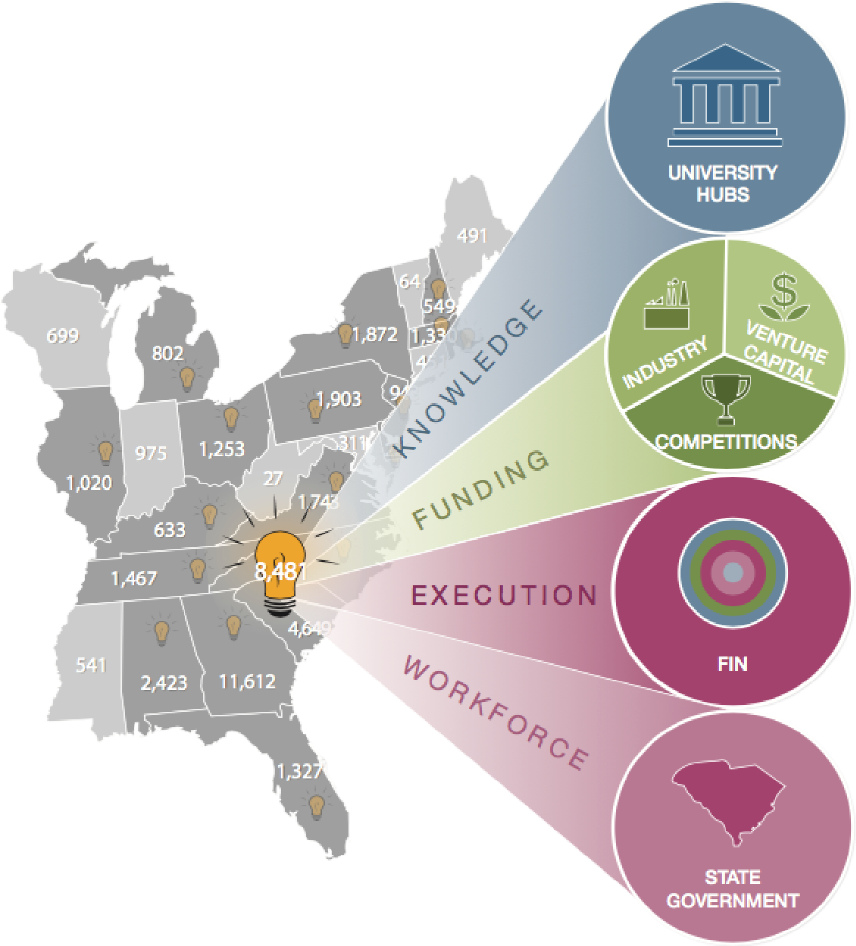
Enabling Technologies:
Active LOOks
Fabric Communications
Units:
250K
Timing:
2020 Launch Date

fabrics the new software

AFFOA lowers the barrier to innovation in the advanced functional fabric space enabling startups to thrive. AFFOA unlocks fabric product innovation in the same way that "app stores" unleashed business model innovation based on software.

AFFOA is building a national network of fabric discovery centers that colocate prototyping with incubator space and educational and workforce activities.

AFFOA combines IP, knowledge and manpower from universities, consumer insights and funding from industry, rapid prototyping through FIN and resources from public and private sectors to accelerate product innovation across the country.



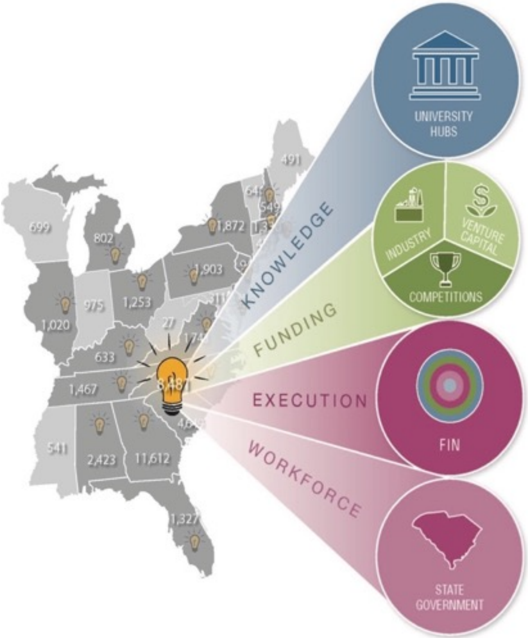
UMASS LOWELL

DREXEL UNIVERSITY Center for Functional Fabrics

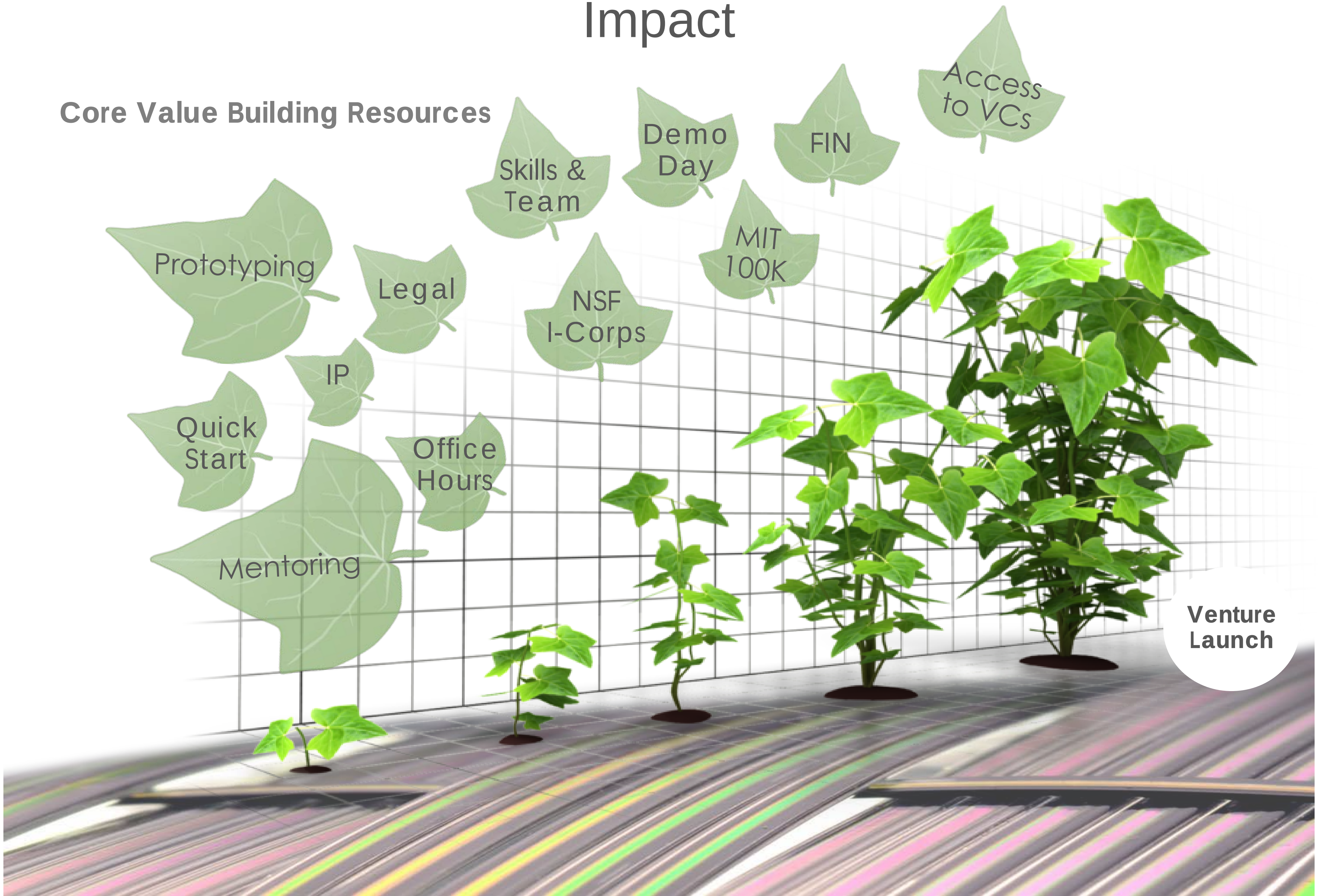
DFDC
Defense Fabric Discovery Center

Advanced Fabric Entrepreneurship Program

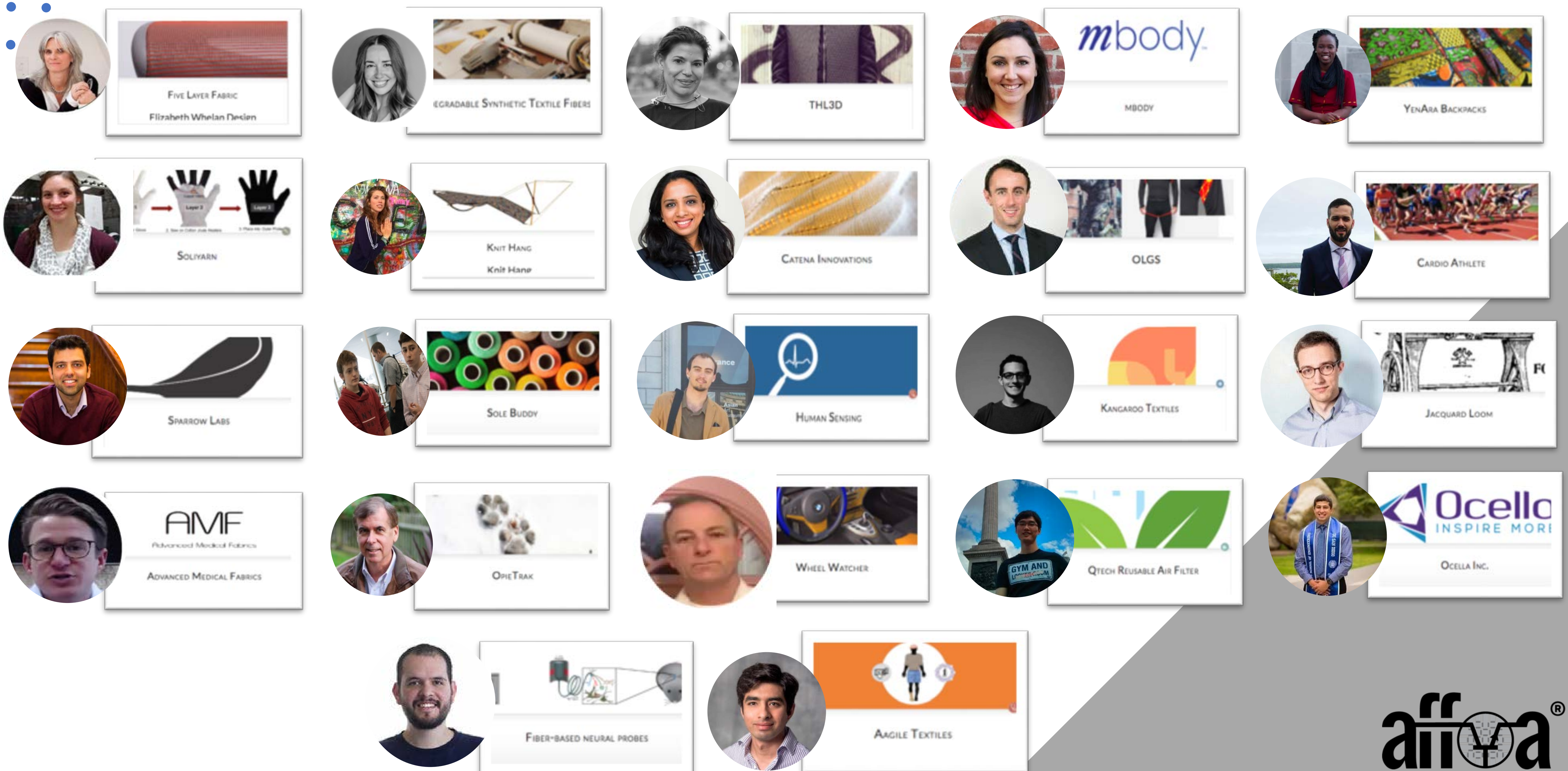
- Facilitate economic activity through pre-commercial enterprise value building, invest in entrepreneurs, business model development and product and market discovery
- Accelerate the commercialization of Advanced Functional fibers, fabrics and textile products



Aligning Resources for Accelerating Impact



AFEP Teams 2018-19



Fiver Layer Fabric

01 About Venture

Lead: Elizabeth Whelan

Expands from a single layer up to five layers to create a woven spacer fabric for use in furniture applications.

02 MicroAward for Startup

MicroAward recipient for integration of LED fibers into woven structure

03 Customer Discovery

- Chair manufacturers
- Airline industry
- Automotive

Fiber-Based Neural Probe

01 About Venture

Lead: Andres Canales, Postdoc at MIT

Fiber-based neural probe enables an understanding of the nervous system and treat conditions affecting it, such as Parkinson's disease.

02 MicroAward for Startup

Connectorize 100 Neural Probes

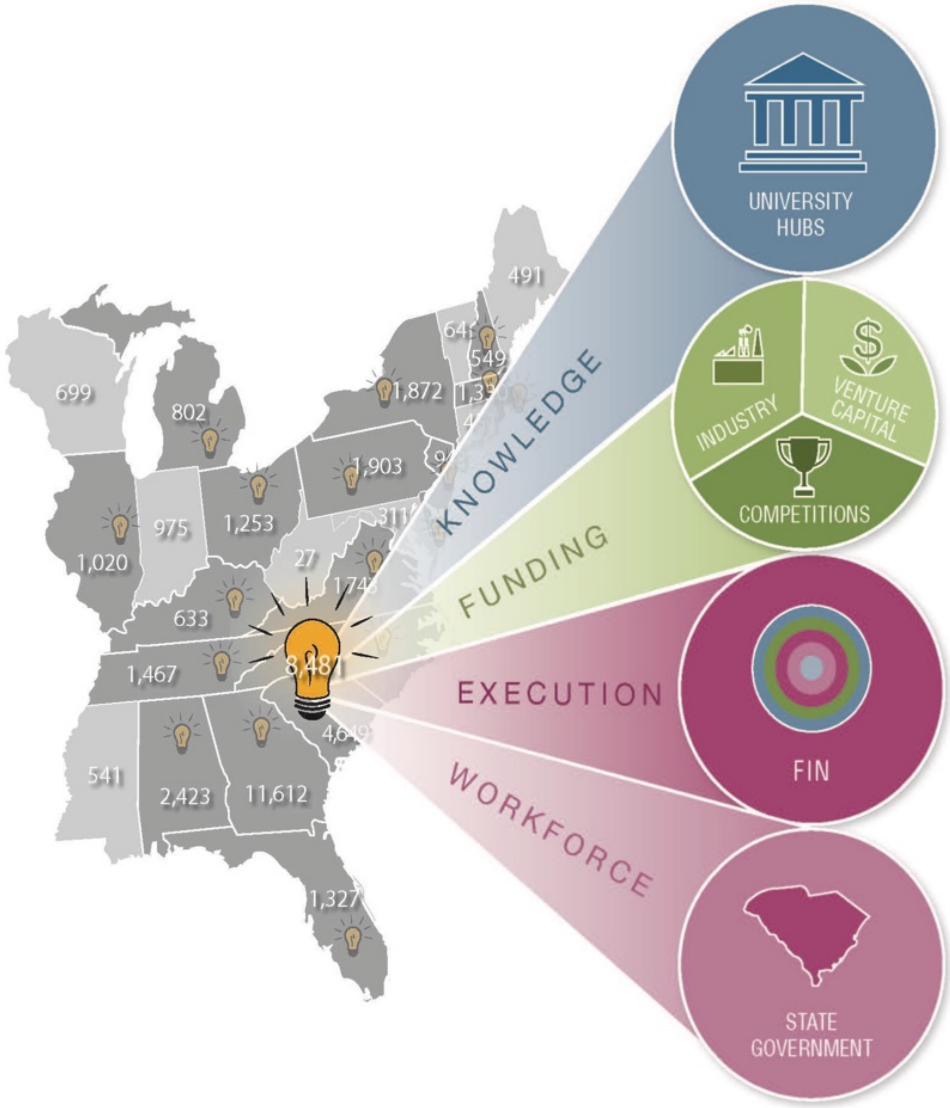
Applicant: UML

03 Customer Discovery

- Neurosurgeons
- Neuroscience labs
- Companies selling neural probes

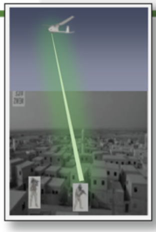
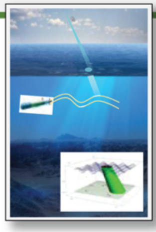
Operationalizing Fabric Discovery Center Pilot Plan

Overview
Express regional technical excellence through prototyping
Operate as a local AFFOA hub
Immerse in Advanced Fabrics technology
Conduit for education and workforce development dissemination
Connect and grow local businesses
Crystallize and excite local entrepreneurs
Agreement allows streamlined project initiation
Vehicle for state/industry/academic funding to upgrade local infrastructure in Advanced Fabrics
Cost share opportunities
Model proven through four FDC’s in three participating states: MA ➔ PA ➔ NC

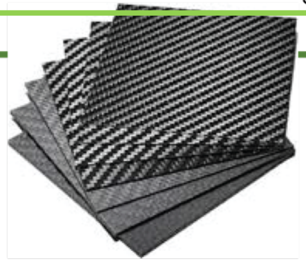


FDC Project & Capability Synergy

affoa	DFDC Defense Fabric Discovery Center	UMASS LOWELL	Drexel University Center for Functional Fabrics	Manufacturing Solutions Center
• Preform Design & Modeling	• Multiphysics fiber design • Fabric system simulation	• Printed electronics design • Custom chip design	• Advanced fiber parameter modeling	• Body scanning • Garment design
• Moore's Law Fibers	• Visible photodetectors • High power LED • PBG fabrics	• Transparent conductive thermoplastics • Moisture barrier film	• Specialty Polymer • Transparent conductive thermoplastics	• Spectral LOOks yarn
• Knitted LED • Woven color-change • Knitted/woven LOOks	• Woven diodes • PBG fabrics	• Crochet knitting	• Weft & warp knit structures • Knitted LOOks	• Stoll LOOks garment • Controlled orientation fabric forming • Nonwovens
• LiFi system • LOOks software integration	• Free space optical comm. • Underwater optical comm. • IFF turret cover	• Fiber and fabric signal testing • Structural health monitoring geo-textiles • Flexible electronics integration	• Warp knit capacitive touch sensors • CTS Makers kit	• Chemical releasing socks • LED composites • Physiological monitorin • Fiber & Fabric testing

NEXTFLEX

Defense Fabric Discovery Center

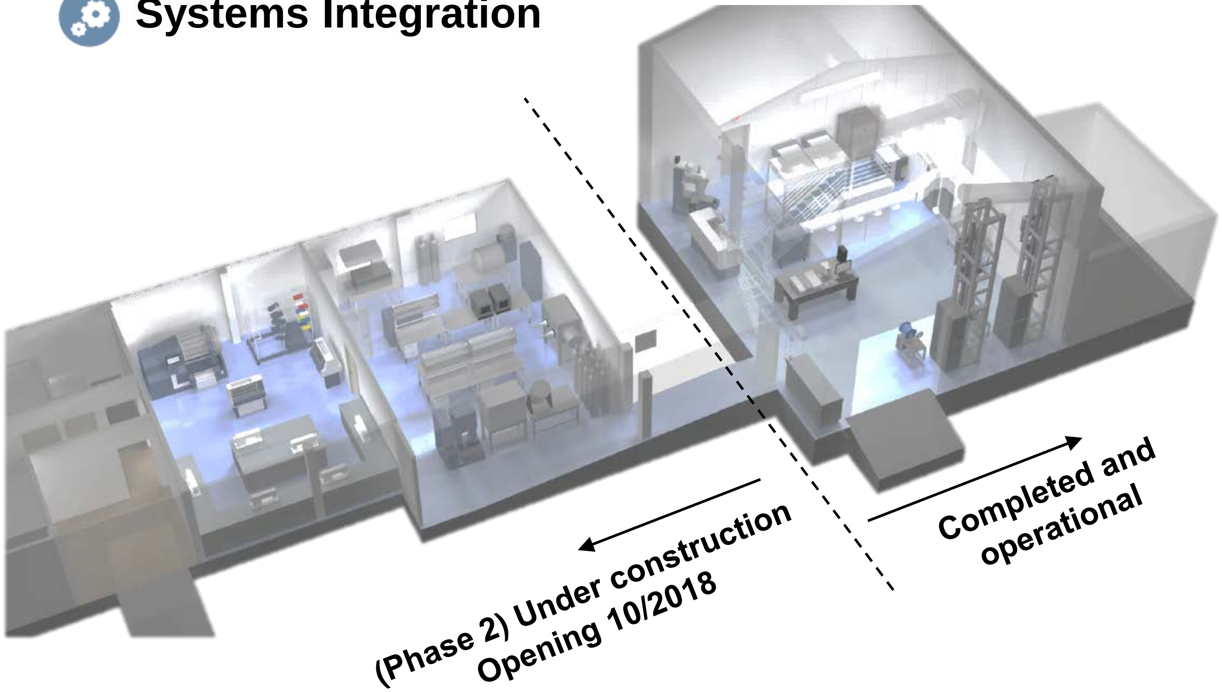
DFDC
Defense Fabric Discovery Center

Q3 2018 Update to AFFOA Board of Directors

Alexander Stolyarov

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

- Computer-Aided Design of Integrated Textiles
- Fiber and Yarn Devices
- Textile Systems and Assemblies
- Systems Integration



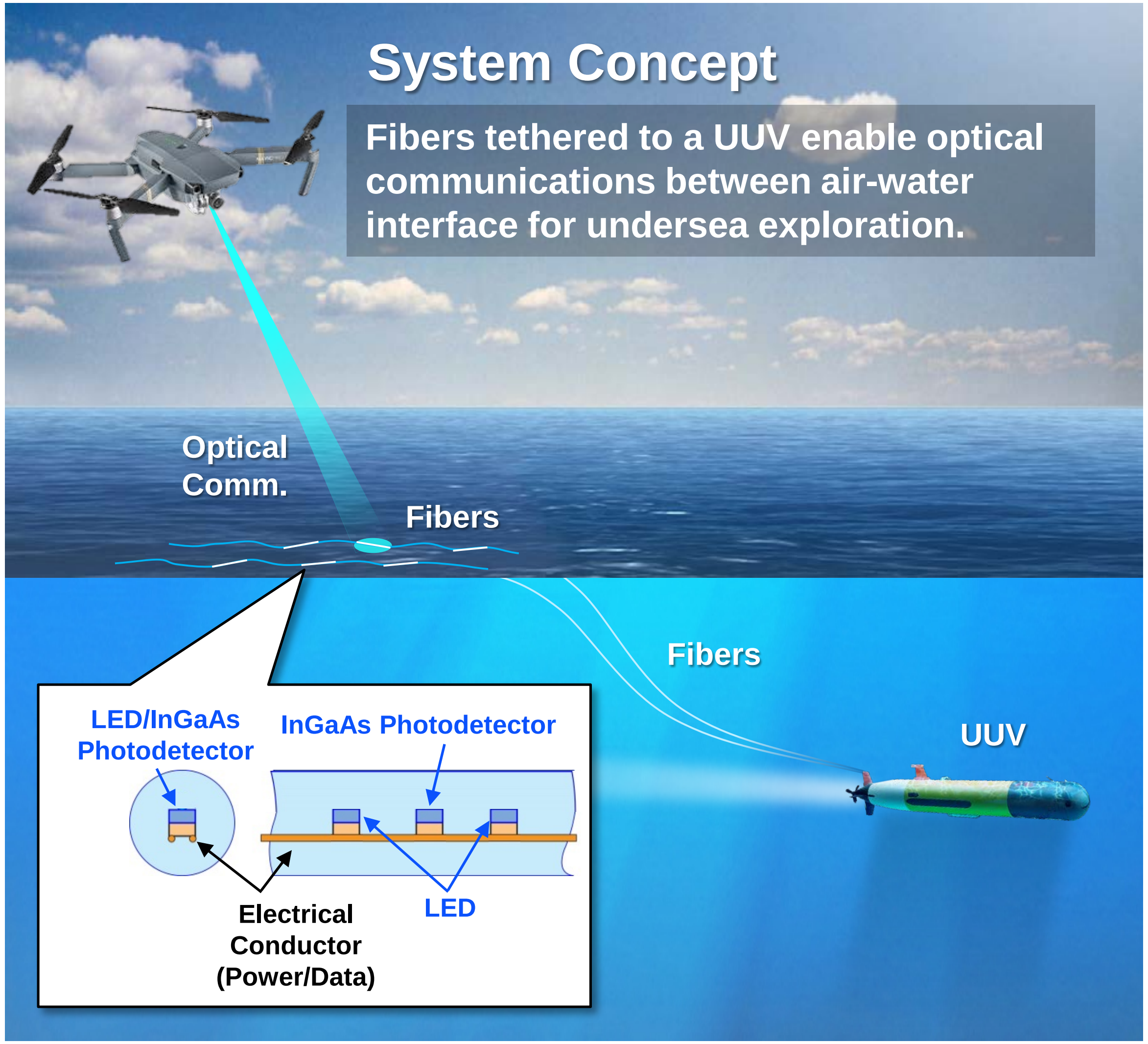
Phase 2 - Under construction (Photo date: 8/28/2018)

Phase 2 space will house:

- Cleanroom for photonic fiber preform fab
- Loom and warp
- Knitting machine
- Assembly and integration space

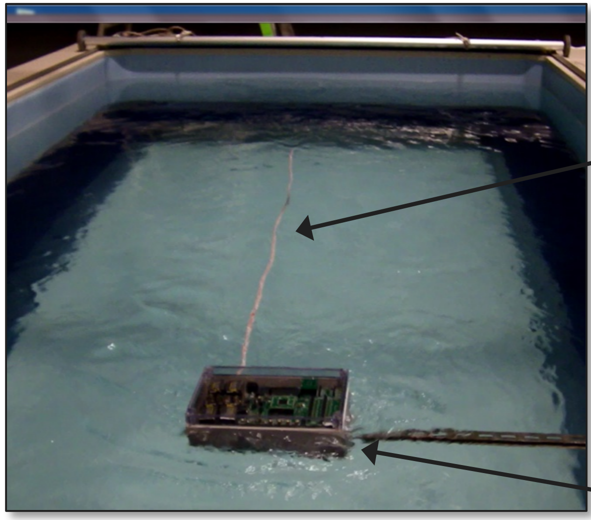
Fibers for Underwater Comm

PI: Lalitha Parameswaran



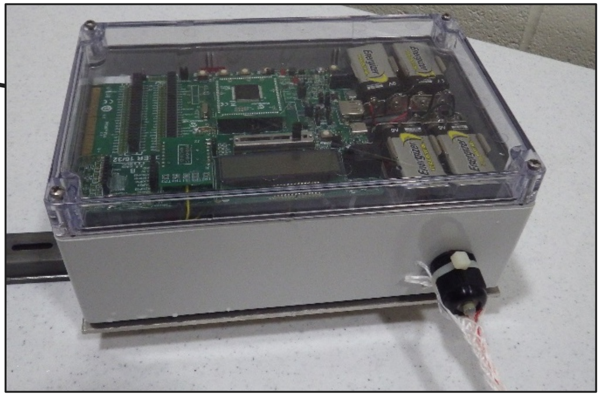
Highlights of Q3, 2018

– Designed, build and tested a self-contained underwater fiber apparatus (SCUFA) for air-water interface comms



Photodetecting fiber woven into rope engineered for positive buoyancy (MIcroAward w/ Teufelberger)

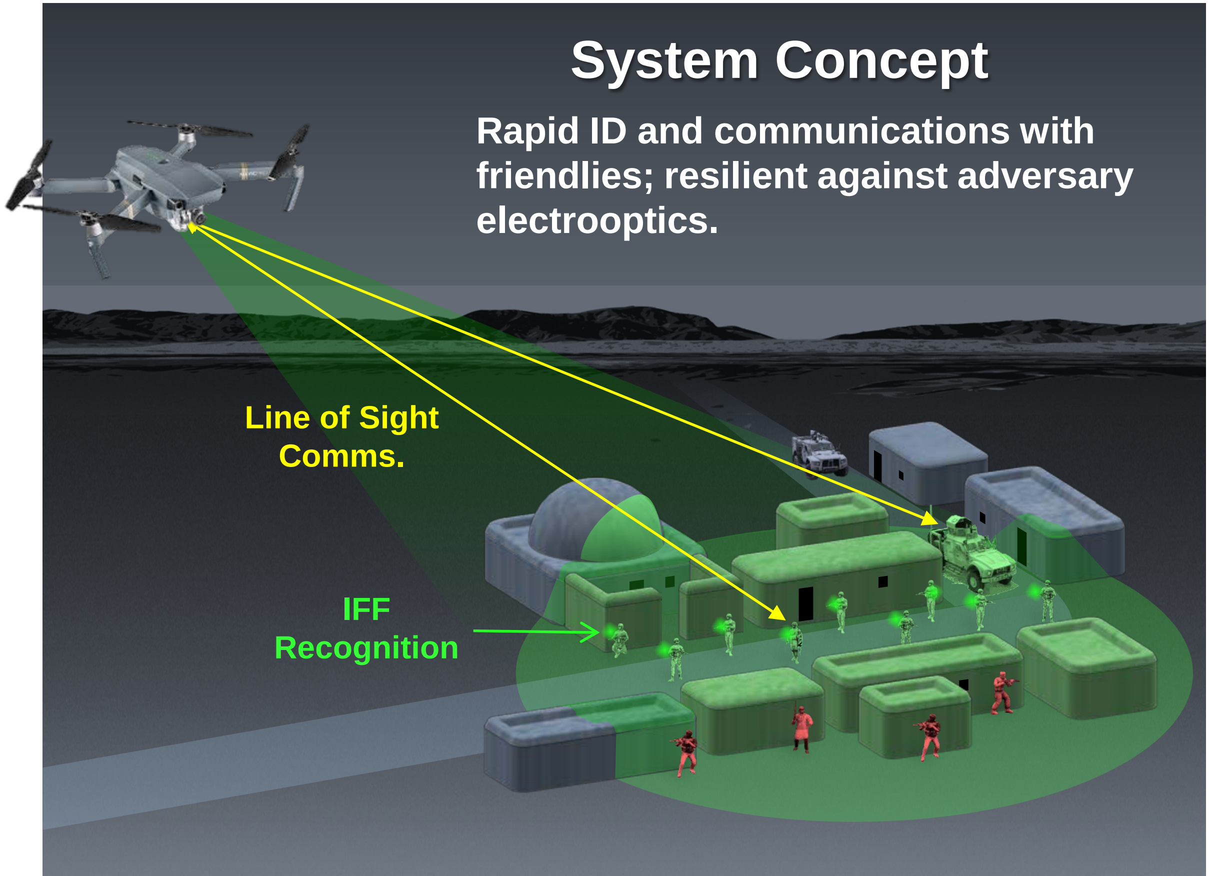
- SCUFA in operation in wavepool with optical transmitter mounted overhead (not in photo)
- Optical communications link from transmitter to rope maintained in flow rates up to 1.7 knots



Development board enclosed in positively buoyant water-sealed container with port for rope/fiber devices

UUV – Unmanned underwater vehicle

Fibers for Free Space Optical Communications
PI: Jeff Chou



- Improve IFF confidence
- Improve situational awareness without adding weight

Highlights of Q3, 2018

– Prototyped soldier tactical vest with integrated IFF and optical comms capability

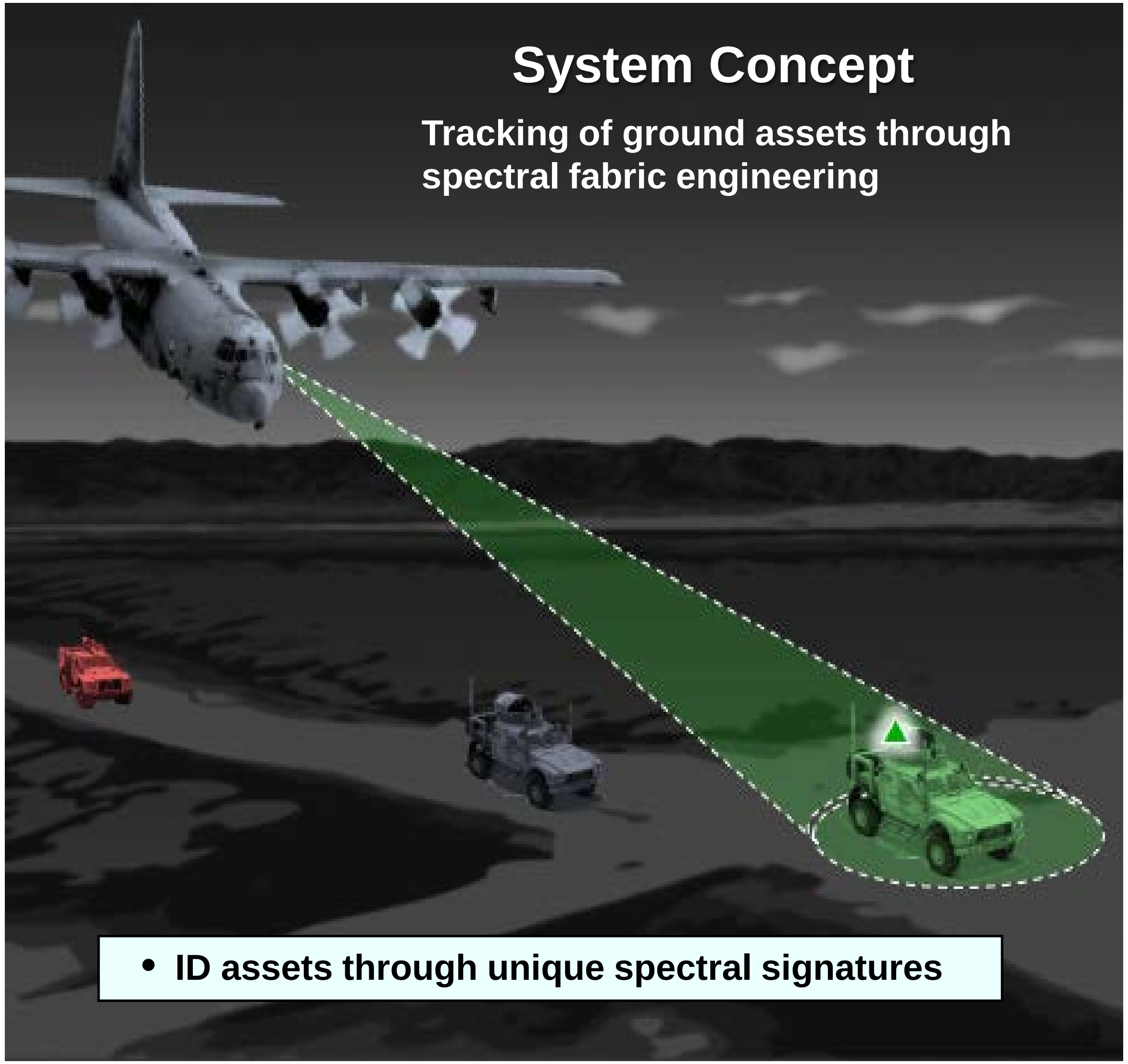
Fiber communications devices woven into webbing (MIcroAward w/ Otex)

- Optical Friend/Foe ID capability integrated into webbing of tactical vest
- Duel mode system enables IFF & voice-over-light modalities
- Redesigned Tx/Tx board for FM (vs AM) modulation scheme for better SNR

Designed & built an optical Tx/Rx module for testing and evaluation of IFF & voice comms

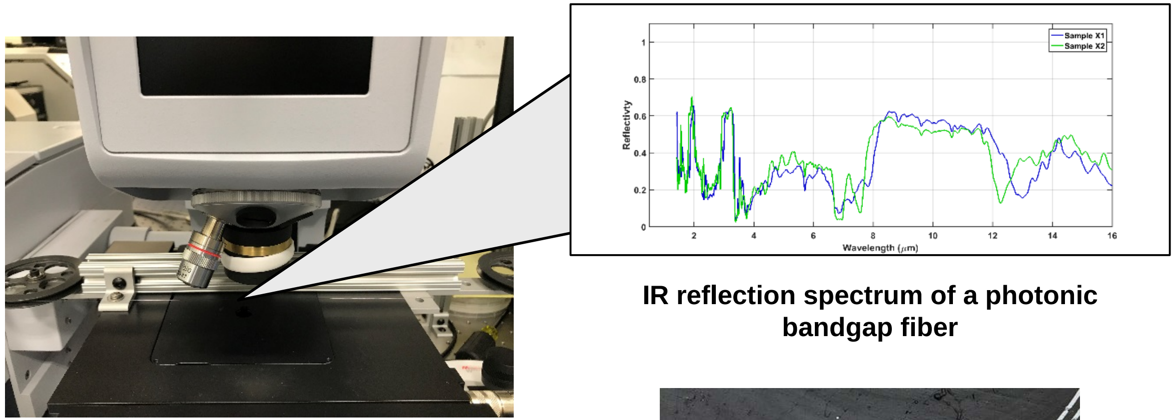
FOR OFFICIAL USE ONLY

(6/10) Fibers for Spectrally Engineered Fabrics
PI: Brad Perkins



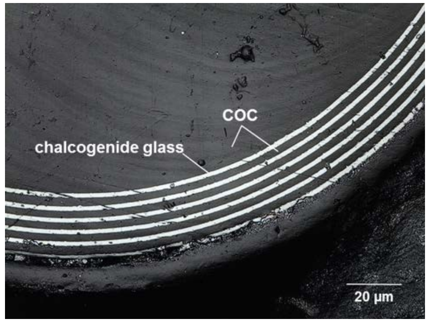
Highlights of Q3, 2018

– **Developed in-line spectroscopic metrology system for measuring fiber reflectivity spectrum during draw**



IR reflection spectrum of a photonic bandgap fiber

- **FTIR measurement on Photonic fiber in-situ during the draw**
- **Enables real time monitoring and on-the-spot tailoring of fiber optical properties**



Designed and setup a fiber cross-section polishing station at the DFDC

Scaling AFEP through FDCs

2018-2019

23 ventures
AFFOA HQ

2019-2020

60 Ventures
UML FDC
PA FDC
AFFOA HQ

2020 → Future

80 Ventures
UML FDC
PA FDC
NC-FDC
AFFOA HQ

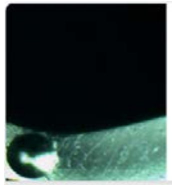
FDC Project & Micro-award Engagements

University of Massachusetts Lowell (UMASS Lowell)

Sensing Textiles for Civil Infrastructure Monitoring

Saint-Gobain Innovative Materials, University of Massachusetts Lowell

$310k + $309k



Fiber to Circuit Interconnect

$50k + $50k

Flexible Electronics for LiFi Hat

Visited AFFOA 08/09

$63k + $63k

Pipeline

Contracting
- Transparent Conductors ($68k + $68k)

Reviewing
- Controller for color change
- Flex circuit for garments
- Die bonding
- Circuit connector

Drexel University Center for Functional Fabrics

Smart Textile Interfaces for Physical Control

Apex Mills, Drexel University

$266k + $267k

3D Knitted Apparel

$26k + $26k

Transparent Conductive Thermoplastics

Visited AFFOA 08/06

$68k + $68k

Pipeline

Contracting
- CTS for automotive interiors ($61k + $25k)

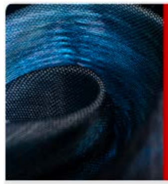
Scoping
- Follow-on opportunity for 3D Knit

NC State University · Manufacturing Solutions Center

Controlled Active Ingredient Delivery via Textiles

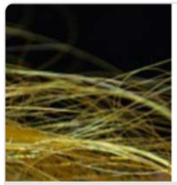
Manufacturing Solutions Center, Textile-Based Delivery, Inc

$114k



Composites with Monofilaments

$35k



Testing and Evaluation of Textile Materials

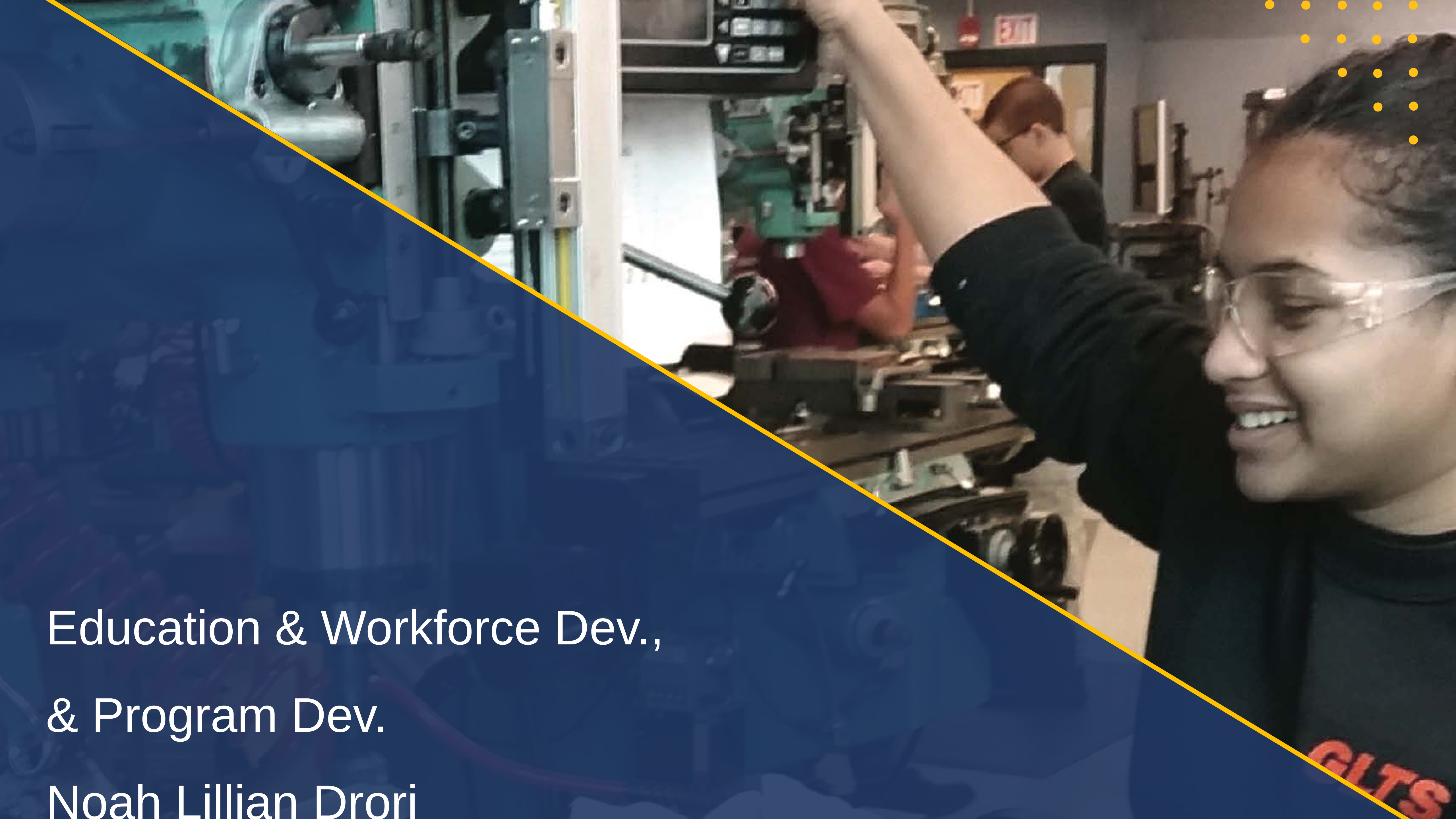
Visited AFFOA 08/27

$11k

Pipeline

Contracting
- Crotchet Knitting ($70k + $0)

Scoping
- Follow-on opportunity for composites
- Overcoating of monofilaments
- Embroidery of monofilaments



Education & Workforce Dev.,

& Program Dev.

Noah Lillian Drori

DO / LEARN / TEACH PORTAL

Support advanced fabric product development by enabling a rapid learning system: building awareness, project execution and learnings, capability sharing

01 Member Capabilities

- Capabilities Redesign
- 202 capabilities listed

02 Project Needs & Collaboration

- Commercial and Government funded projects
- AFEP - 22 teams project pages
- 17 MicroAward Project pages

03 AFFOA Membership, Support With Prototype Development

- GLTS advanced functional fabrics curriculum
- Project Learnings improve domestic manufacturing capability

High Level Portal Stats

48
Projects on Site

80
Project Participants

177
Comments

119
Members on Site

530
Users with Login

108
Average Users On A Weekly Basis

15
Academic Groups

202
Capabilities

MicroAward (MA) Content Drives Usage On Portal

USER BEHAVIOR FLOW

1 EMAIL CAMPAIGN

530
User Logins

2A MICROAWARD OPPORTUNITY PAGE

#1 Clicked Topic:
Fiber to Circuit Interconnect

2B CAPABILITIES

16% of all capabilities

3 MA APPLICATION

Participant by Category:
University (Academic Groups): 9
FIN: 7
Startup: 2
Industry: 3

1 HOMEPAGE

36 Project Participants

2 PROJECTS PAGE

#1 visited
Transparent Conductive Thermoplastics (Drexel)

19 Active MA Projects

3 DELIVERABLE UPDATES

75% of all comments

** All stats about MicroAwards*

Advanced Functional Fabrics Program

The program builds knowledge and skills in the areas of functional fiber production, textile design and integration, and product development through two existing and credentialed interwoven pathways at Greater Lawrence Technical School, in Lawrence MA.

Phase 1

Milestone Completed

Collection of competencies, existing and new, to integrate into units of study

Phase 2

Milestones Completed

- Initial list of relevant units to be integrated into STEAM Academy curriculum due July 1, 2018 (completed)
- Two sample units in Engineering and Machining to test and learn during school year 2018-19 (July 1, 2018)
- MA Capital Equipment Approved and under process (July 2018)

Phase 3

Underway (due July 1, 2019)

Deliver all remaining curriculum units of instruction for Machining, Manufacturing, and/or Engineering Design

Part of a Career Pathway System

Portable & Stackable

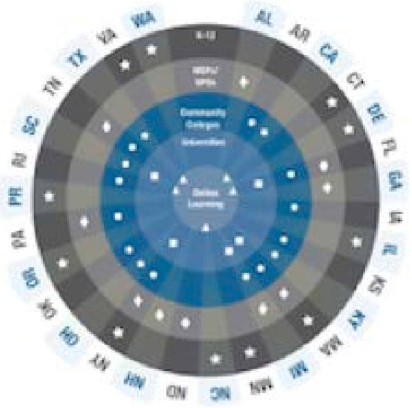
The curricula will offer technical high school students a strong foundation in Advanced Functional Fabrics, and therefore a springboard to:

Jobs in Advanced Manufacturing, Product Design, Machining, Engineering, Software, Textiles

Degrees and certificates:
Material Science, Advanced Manufacturing, Technical Textiles, Design, and Software

Growing the Talent Pipeline

The collaborators are developing a standard for making the program materials available throughout the Commonwealth, in other States, and Fabric Discovery Centers



Transferring Skills to Membership

Capability Gap

Need to develop skills MicroAwardees to connectorize fibers as a result of warp knitting, yarn twisting, and yarn covering of LED fiber.

Skills & Knowledge:

- ❖ Introduction to Electronics: basic components
- ❖ Introduction to LED fiber anatomy

Connectorize Kit:

- ❖ Training Video
- ❖ Digital Manual
- ❖ Equipment, materials, and tools

A few thoughts and actions on Small and Medium Enterprise Engagement at AFFOA

1. Equal access to learning and technology – **Do-Learn-Teach portal**
2. Rapid and directed award program - **MicroAwards**
3. Offer breakthrough technology capabilities – **`"Moore's law for fiber" roadmap**
4. Offer a competitive advantage – **One stop licensing**
5. Lower the barrier to engagements – **MicroAward agreements are no longer than 2 pages**
6. Offer access to product companies – **Proprietary Product Development**
7. National prototyping network – **Fabric Innovation Network**
8. Create local engagements centers – **FDC**
9. Invest in entrepreneurship – **Advanced Fabric Entrepreneurship Program**
10. Make the year 90 days long - **Shot clock innovation**
11. Dedicated investment funds to help accelerate marke