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# The Future of Advanced Functional Fibers and Fabrics

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CEO, AFFOA



Smart Fabrics Virtual Summit  
17 April 2020



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Lowell Mills (circa 1820)

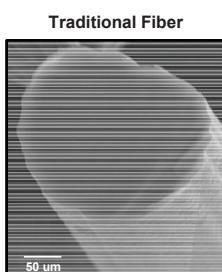




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## Multimaterial Fiber Microsystems



Traditional Fiber



Functional Fiber Microsystem

- Single Material
- No Architecture
- Single Functionality

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

New materials processing approaches are emerging, enabling the development of complex device functionality within a fiber form factor.

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# **affo** From Innovative Technology to Commercial Products

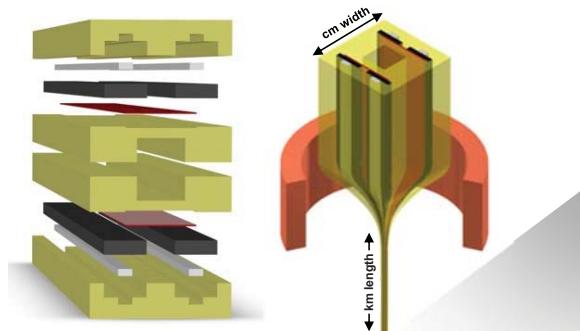
**Necessary (but not sufficient) conditions for Smart Textiles to Impact the Industry**

- Compelling Use Cases
  - Balancing market pull with tech push
- Scalable Manufacturing Processes
  - From component level through final assembly
- Innovative Business Models
  - Fabrics as high tech products
  - Fabrics providing services

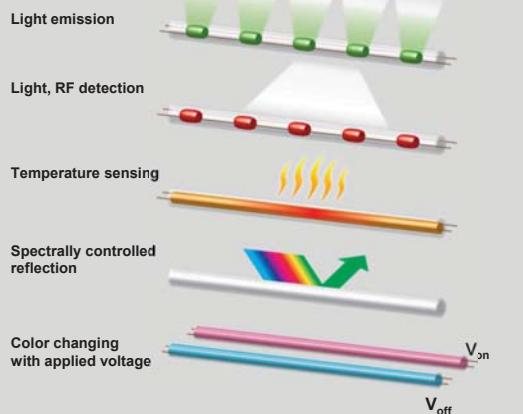
## **affo**

### **Preform to Fiber Drawing A Pathway to Functional Fiber Microsystems**

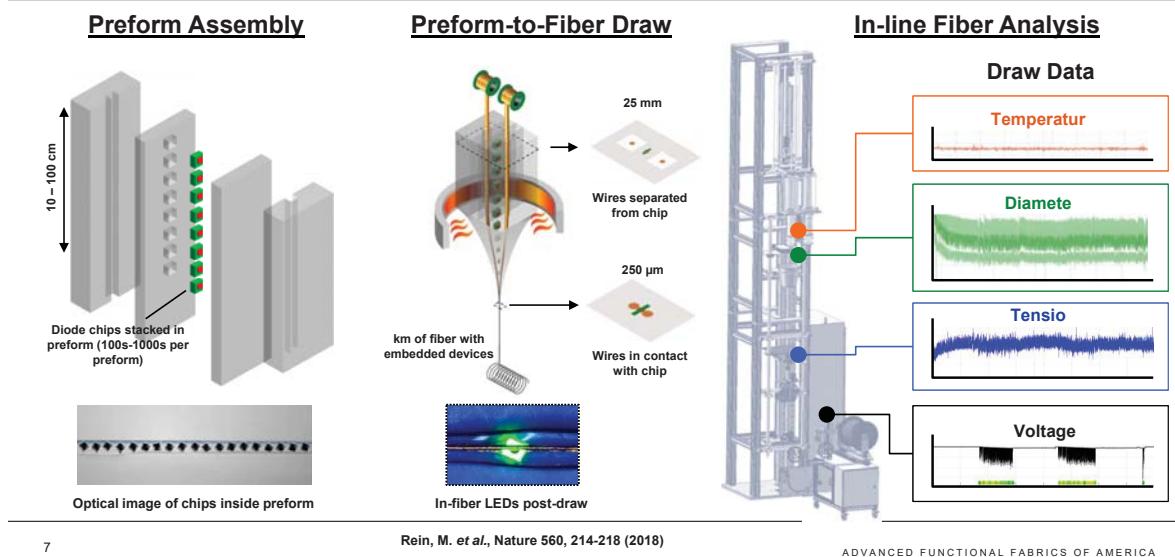
Preform Assembly & Thermal Draw



Example Fiber Applications

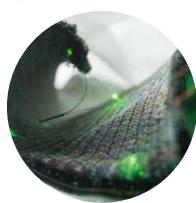


## Example: Microelectronic Chips in Fibers



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## AFFOA – Who We Are

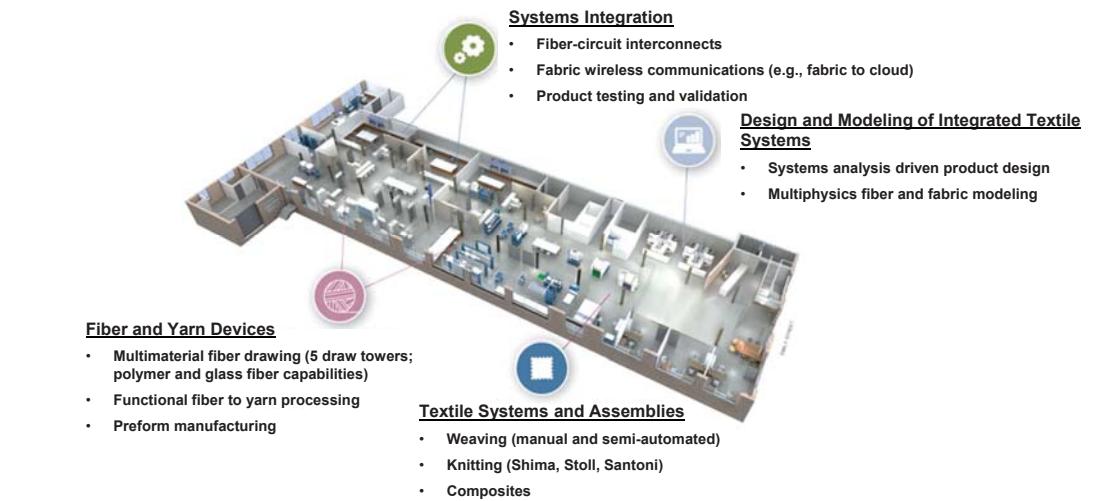


- **AFFOA** is an independent not-for-profit Manufacturing Innovation Institute headquartered in Cambridge, MA focused on rekindling the domestic textiles industry
- **AFFOA's Mission** is to lead a Nationwide enterprise for advanced fiber & fabric technology and manufacturing innovation, enabling revolutionary new system capabilities for commercial and defense applications
- **Dedicated focus on National Security** through a special partnership with MIT Lincoln Laboratory and Natick Soldier Systems Center
- **Founded April 2016** thanks to DoD, State Governments, Academic, and Industry funding commitments totaling over \$200M
- **Over 120 Member organizations** including universities, manufacturers, start-ups, industry, and government partners

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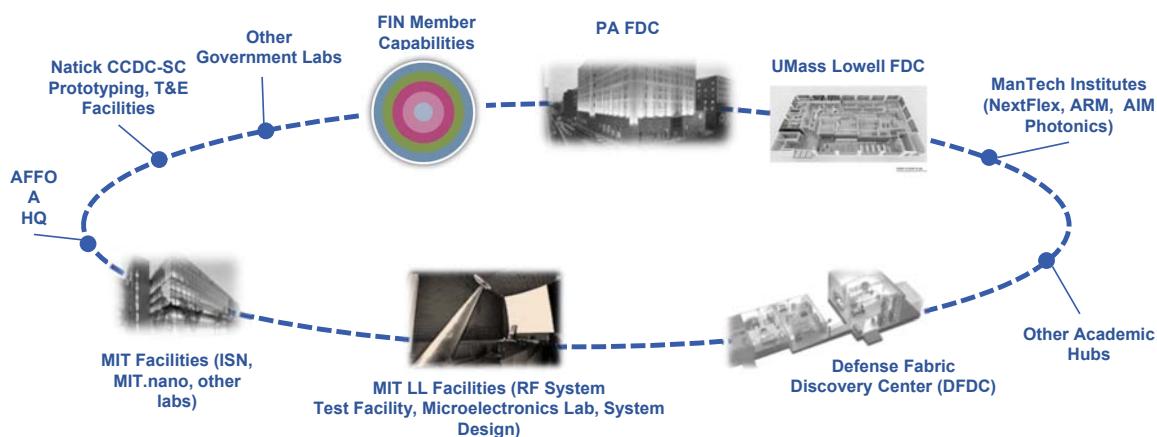
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## AFFOA Headquarters – Cambridge, MA End-to-End Advanced Fabrics Prototyping Facility



## Advanced Fabrics Facilities Enterprise

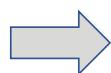
*A connected laboratory enterprise, world-class in its multi-disciplinary R&D and manufacturing opportunities, and supporting the development of advanced fiber and fabric technology and manufacturing process development*





*Advanced Fabrics Enterprise enabled by collaborations across academic, industry and government partners*

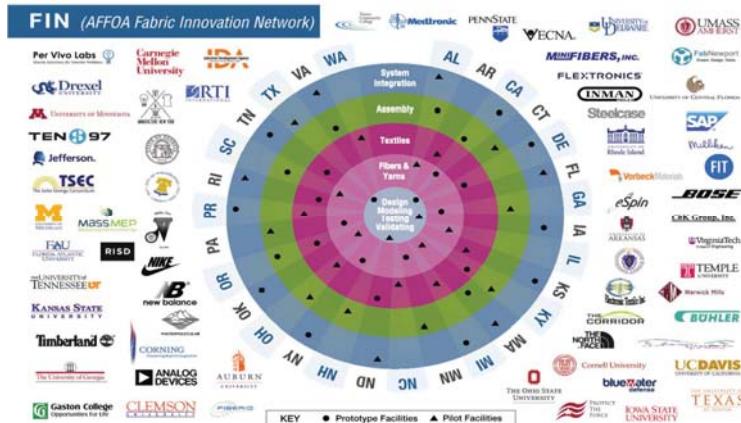
- Research into novel fiber & fabric technology
- Fiber & fabric manufacturing process development
- Novel applications with supporting analysis
- Complementary technologies, expertise and facilities (e.g., Universities, FDCs, Government Labs, other MILs)
- Nationwide fabric prototyping foundry (FIN)
- U.S. defense industrial base & advanced fabric entrepreneurship
- National Fiber Microelectronics Initiative



- Introduction & Motivation
- Fabric Innovation Network
- Applications
- Future of Smart Textiles



## The Fabric Innovation Network (FIN)



The FIN provides an extensive ecosystem for prototyping, capability maturation, and technology transition; leverages industry, academic, and government lab competencies.

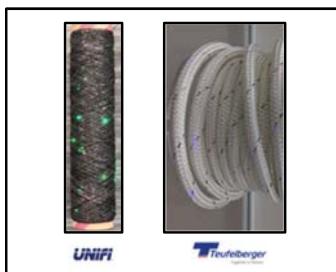
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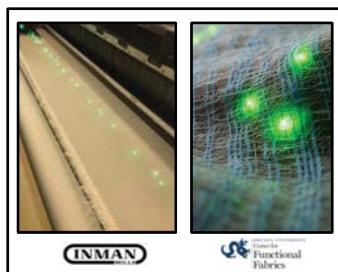
## Examples of Rapid Fabric Prototyping Through the FIN

### Yarns & Ropes



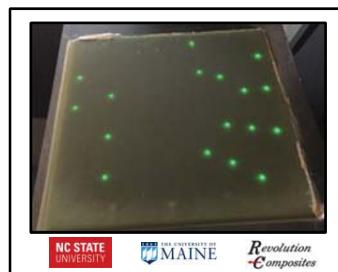
- Natural / synthetic fiber blends
- Multi-filament yarns
- Diameter range: 300 µm – 30 cm

### Wovens, Nonwovens, & Knits



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

### Composites



- Glass fiber
- Carbon fiber
- Advanced thermoplastics

Monofilaments can be integrated into yarns, ropes, fabrics, and composites using industry standard manufacturing processes

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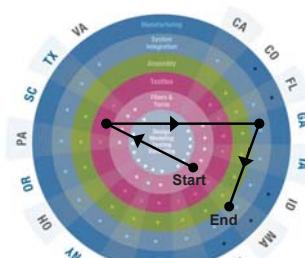
## Towards Integrated Product Prototyping Through the FIN

Prototype Apparel Product



Pants comprised of advanced fiber  
and fabric technology

Made by the FIN



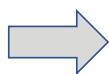
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### Addressing Multiple Challenges and Opportunities

- Chip in fiber scale-up
- Design of functional textile panels and systems for garments
- Fiber integration into wovens
- Cut and sew of functional fabrics
- Integration of apparel with embedded and distributed microelectronics
- Prototyping, capability maturation, and manufacturing maturation for scale-up
- Building the functional apparel supply chain of the future



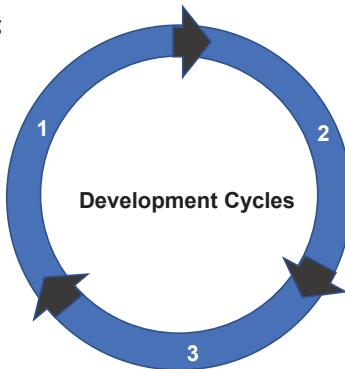
## Outline



- Introduction & Motivation
- Fabric Innovation Network
- Applications
- Future of Smart Textiles

# affoa Application-Driven Approach to Technology Development

- Motivation & Problem Understanding**
  - Understand the problem being solved
  - Develop system concepts together with a potential product end users



## 2. Perform Systems Analysis

- Assess existing approaches to solving the problem
- Perform systems analysis to drive technology requirements
- Assess technology gaps to motivate technology development

## 3. Develop Technology and Prototype

- Develop and harden the technology
- Prototype system concept
- Iterate with user-feedback

# affoa

## Selected Applications and Technologies

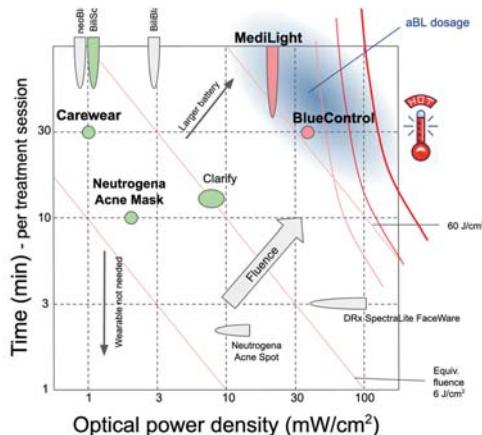
	Architectural / Structural	Apparel / Accessories	Maritime Technologies	Automotive	Aerospace	Medical	Other
AFFOA HQ		<ul style="list-style-type: none"> <li>Wearable health monitoring</li> <li>Fabric motion tracking</li> <li>Thermal sensing</li> </ul>	<ul style="list-style-type: none"> <li>Ocean sensing ropes and cables</li> <li>Advanced sail concepts</li> </ul>		<ul style="list-style-type: none"> <li>Self-monitoring high-performance composites</li> </ul>	<ul style="list-style-type: none"> <li>Light-based therapies</li> </ul>	<ul style="list-style-type: none"> <li>Looks Tape</li> </ul>
AFFOA Members	<ul style="list-style-type: none"> <li>Sensing textiles for infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>Electrically- controlled color changing fabrics</li> <li>Controlled chemical release</li> <li>Shape-shifting climate adaptive garments</li> <li>Cooling textiles</li> </ul>	<ul style="list-style-type: none"> <li>Functional composites for hulls</li> </ul>	<ul style="list-style-type: none"> <li>Smart textile interfaces</li> </ul>		<ul style="list-style-type: none"> <li>Pressure sensing fabrics</li> <li>Self-monitoring filters</li> </ul>	

- Antimicrobial blue light (aBL) therapy has shown promise to eradicate multiple types of common bacteria that infect wounds, presenting an opportunity for innovation
- Working with Doctors\* at MGH Wellman on developing smart bandage product concepts
- Initial systems analysis performed (plot on right) – thermal management discovered as key technical hurdle

\*Dr. Jeffrey Gelfand, M.D., FACP, FIDSA; Dr. Joshua Tam



Many light therapy products on the market. Existing solutions are uncomfortable & cumbersome, and they do not meet the sponsor's needs.  
Total light therapy market about \$1B and growing at 5% CAGR



### System Concept

Fabric integrated motion tracking system for improved comfort and actionable biomechanical data

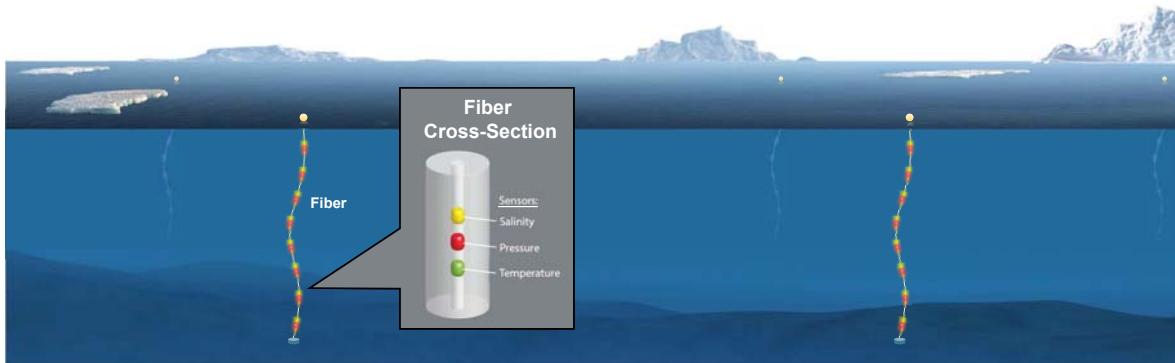


Example existing products on the market today.  
Opportunity for miniaturization of puck-based systems

## AFFOA HQ - Ocean Sensing

### System Concept

**Enable ubiquitous oceanographic measurements such as temperature, pressure, and salinity in a fiber with distributed sensors.**



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## AFFOA Member - Controlled Delivery of Active Ingredients via Fabric

### System Concept

**Textiles with controlled delivery of active ingredients that are persistent through machine washing**



### Key Results

- Product line expansion – sleeves, socks, gloves, base layers
- “Pain relief” labelling – FDA monographs
- Line speed: 120 feet per minute (fpm) (Start of program: 5 fpm)
- Forbes 100
- Domestic manufacturing supply chain

*“I really noticed the warming and cooling effect usually associated with muscle and joint pain creams. I tend to like that soothing feeling (I’ve applied topical creams to my back and shoulders pre- and post-round plenty of times, but never to my feet), so I was a big fan of the results.”*

**Forbes**

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## AFFOA Member – Electrically Controlled Color Changing Fabrics



### System Concept

*Thermochromic fibers for on-demand color change*



### Key Results

- Multifilament fiber production
- Monofilament dress @ NY Fashion Week
- Screen printing for improved contrast
- Semi-automated electrical connections
- Potential spin-out from UCF

"Researchers at the University of Central Florida have developed the first color-changing fabric that can be controlled with a smartphone. Professor Ayman Abouraddy and his team at CREOL, The College of Optics and Photonics, have developed a series of prototypes that includes purses and backpacks. The products change color and pattern through the use of an app or with the click of a built-in button."



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## AFFOA Member – Sensing Textiles for Civil Infrastructure Health Monitoring



*Fiber-optic embedded textile enables significantly improved infrastructure health measurements*



Optical fiber integrated into fabric



### Key Results

- New process developed for integrating optical fibers into textiles
- Field tests completed with ARE
- One of a kind fiber optic to fabric integration machine developed
- Stress mapping of pipe deformation

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ARE – American Railway Engineering

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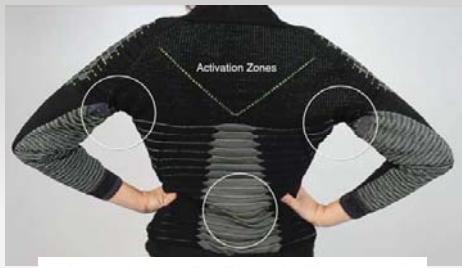
## AFFOA Member – Shape-Shifting Climate-Adaptive Garments



**This project serves as a great example of how passive (not-electrically-powered) fabrics can be functional**

### System Concept

Climate adaptive garments



KNIT STRUCTURE: POROSITY & THICKNESS CHANGE

### Key Results

- Bi-component fiber production
- Bi-directional climate adaptive swatches
- Thermally activated, shape-changing knit structures
- Thermal measurements supporting improved insulation
- Robotic tailoring launched

"Founded by four MIT alumni, the company is now working with the school's Self-Assembly Lab to develop a business-casual sweater that continually adapts to the wearer's body temperature. The material is made up of polymers that react when exposed to heat; its structure contains pores that close up to trap heat when the wearer is cold and open up to let in more air flow when a person is hot."



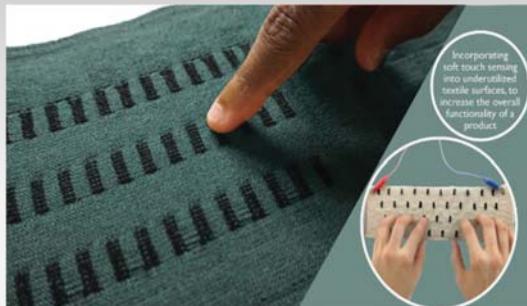
## AFFOA Member – Smart Textile Interfaces for Physical Control



**The smart textile capacitive touch sensor can serve as an interface platform in many applications, from smart automobile consoles to wearable human-device interfaces**

### System Concept

Gesture-sensitive functional textile touchpad interface



Only 2 connections required

### Key Results

- Finishing of warp knit for auto applications
- Weft knit -> fully functional warp knit with cut & connect
- 7 gestures -> On/off, pause, volume up, volume down, forward
- 70 wash cycles

"In another initiative to reduce reliance on foreign made goods, the Pentagon has begun a partnership with domestic textile manufacturers to produce "smart fabrics" for use in military uniforms. Working through the Advanced Functional Fabrics of America nonprofit, the Defense Department has funded a collaborative research venture between the Massachusetts Institute of Technology, Drexel University and Apex Mills."

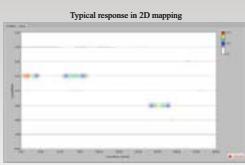
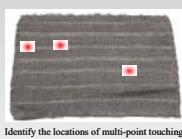




## Other Selected AFFOA Member Technologies

*The examples shown below exemplify the interplay between technology push and market pull*

### Pressure Sensing Fabrics



Identify the locations of multi-point touching

### Advanced Knit Structures



### Passive Cooling Fabrics



- Multi-point, pressure sensing and swipe sensing capabilities developed



- Full car console prototype fabricated
- Laminated touch sensor completed
- Passed OEM inspection

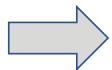


- Woven and knitted fabrics fabricated
- Cooling effect characterized
- Wicking performance characterized



## Outline

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## National Advanced Textile Enterprise Vision



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## National Advanced Textile Enterprise Vision



*Broad set of commercial advancements to revolutionize textile industry*

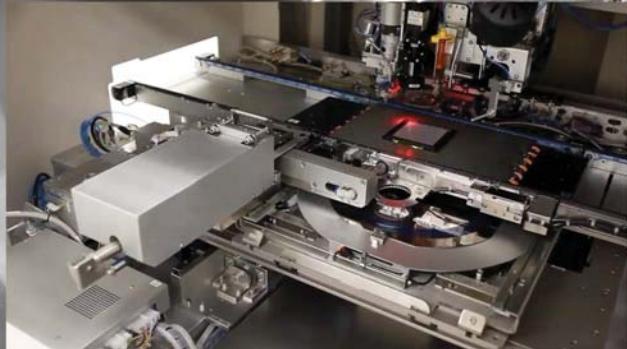
- Advanced fiber & fabric production at scale
- Advanced low-cost microelectronics
- Flexible electronics for wearables
- Continued progress in automated weaving
- Development of robotic cut and sew
- New functionalities in composites
- Transformation of the textile workforce

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## Emerging Flexible Hybrid Electronics

Flexible Hybrid Electronics Development at NextFlex



Key Future Flexible Electronics Needs

- *Integration with functional fabrics*
- *Processing & data storage*
- *Affordable devices*
- *Foundry operations*

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## Emerging Robotic Assembly (Cut & Sew)

Demonstration of LOWRY SEWBOT (18 Oct 2018)



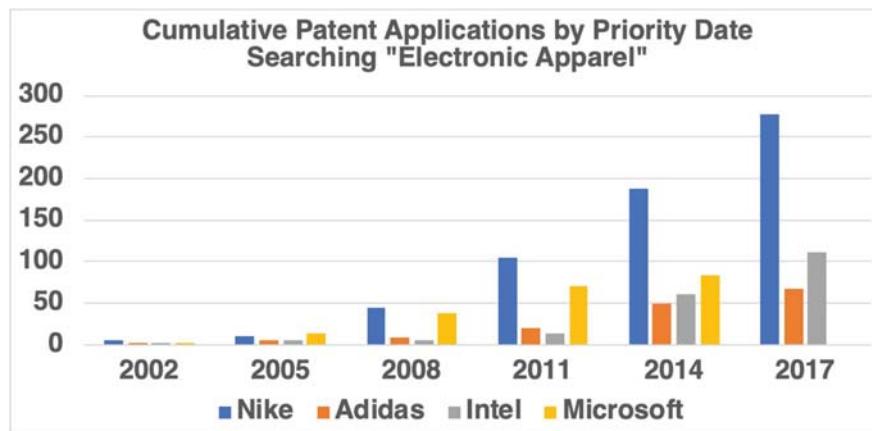
Key Future Robotic Assembly Needs

- *Low-cost manufacturing*
- *High throughput & speed*
- *Complex product assembly*
- *Customization*

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## Patent Activity in “Electronic Apparel”



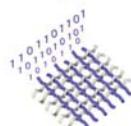
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## A Vision for Smart Fabrics of the Future



**MOORE'S LAW FOR FIBERS** Capabilities of a single strand of fiber advance rapidly in time.



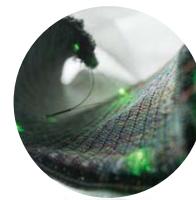
**FABRIC COMPUTERS** Traditional and Moore's law fibers combine to create a sophisticated yet soft fabric computer which senses, stores, processes and communicates information.



**ARTIFICIALLY INTELLIGENT FABRICS** programmed with machine learning algorithms that makes sense of our physiological data, uncovering hidden patterns and deriving health insights.



**FABRICS AS A SERVICE** Transformation of fabrics from goods to a platform for services.



G. Loke et al., Matter 2, 786–788, April 1, 2020

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**Mission**

***Lead a Nationwide enterprise for advanced fiber & fabric technology and manufacturing innovation, enabling revolutionary new system capabilities for commercial and defense applications***

- Advanced multimaterial fibers and fabrics open up entirely new application possibilities
- AFFOA collaborating across government, industry, and academia for advanced fabric prototyping and manufacturing process development
- Significant interest in Smart Textiles emerging from both traditional apparel companies and Tech industry
- Significant opportunity for innovation in Smart Textiles; full future industry will require innovation from devices to assembly automation



*Meeting at 99 Degrees in Lawrence, MA together with  
MITLL & CCDC-SC staff and AFFOA Gov't PM*