IARPA's SMART ePANTS Program: Fashioning Electronics into Textiles

Dawson Cagle, Ph.D. | IARPA Program Manager | October 31, 2023

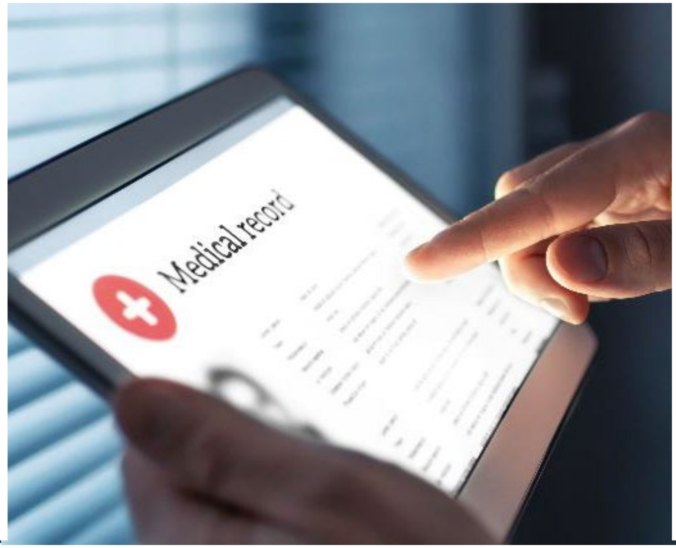
Intelligence Advanced Research Projects Activity

IARPA

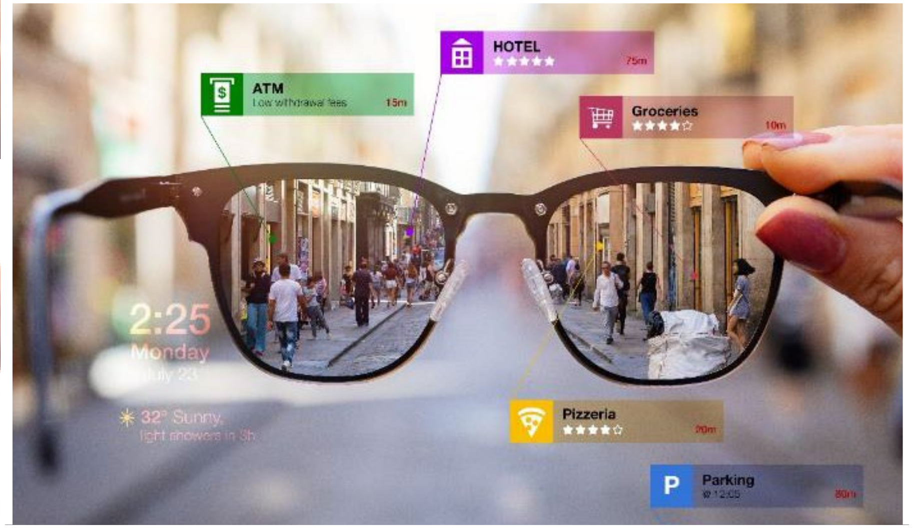
Creating Advantage through Research and Technology

Textiles: One of the Oldest Fields of Engineering

Computation: Engineering that Permeates our Lives



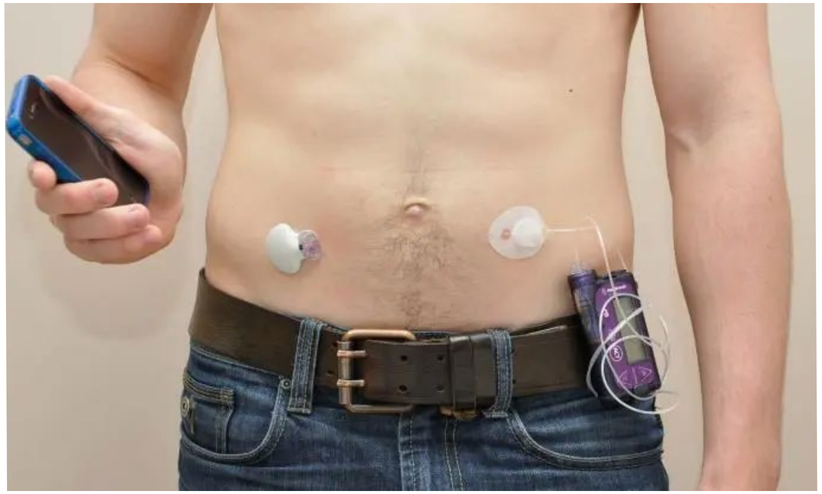
Wearable Computers: An Evolutionary Process



The Need for Computers in Textiles Exists

Military

Medical



Sports Performance

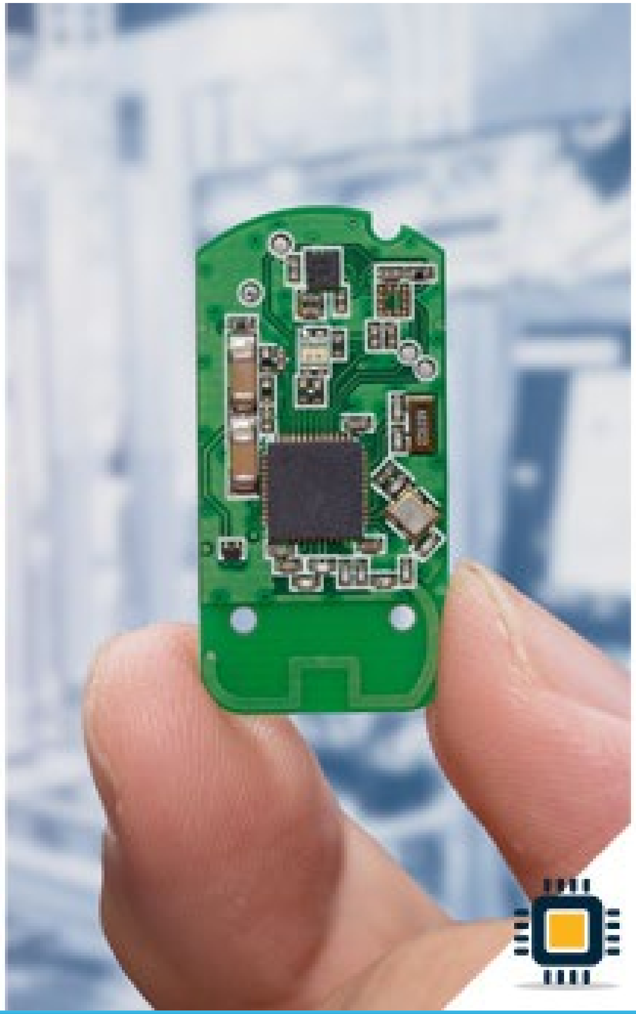
but most regular consumers don't want to buy a $500 shirt that you can't wash

To Expand the Market, We Need Electronics that act like clothing, not "pucks" of electronics

Components Need for Active Smart Textiles (ASTs)

Sensors

Computation and
Data Storage



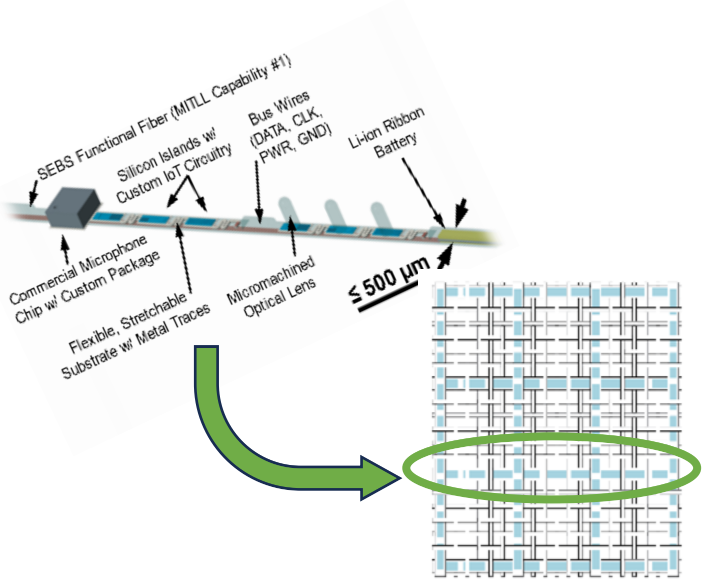
Power Sources

Interconnects
and Haptics

How we can make it happen

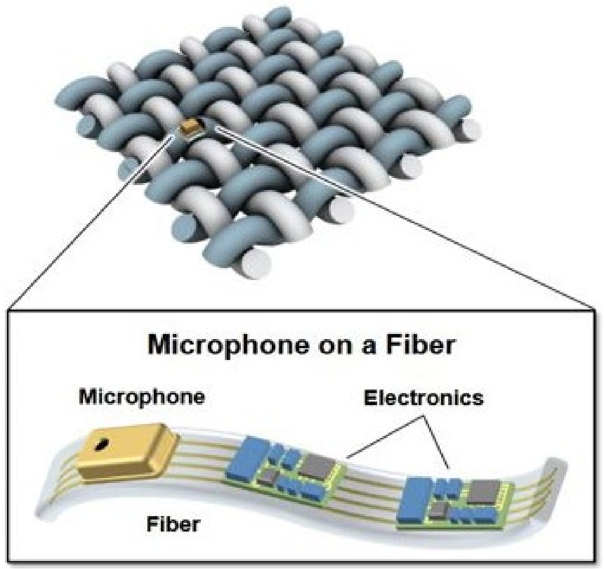
Baseline Designs

- Components Designed to Function Together



Baseline Designs

- Connections for the Textile Environment



Baseline Designs

- Redundancy and Reliability

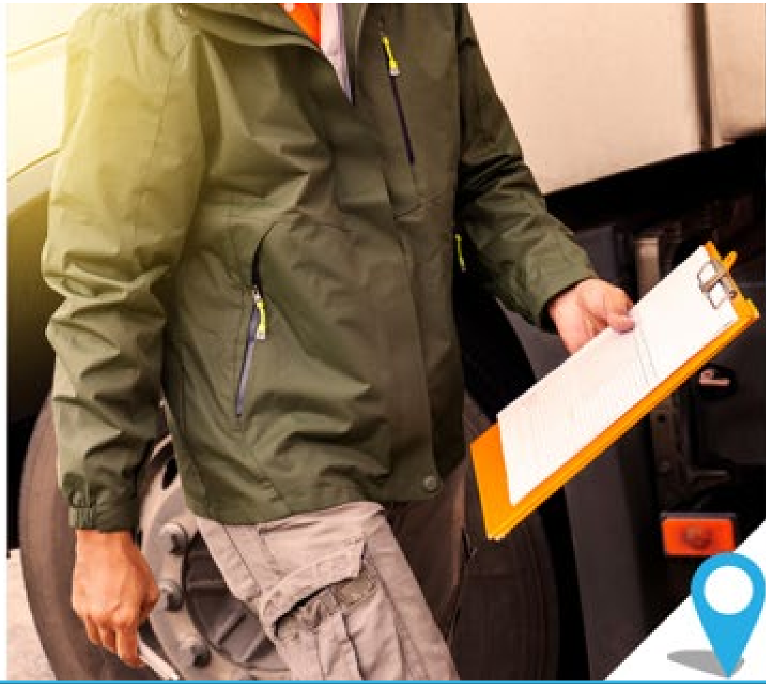
SMART ePANTS

WEAVING ELECTRONICS INTO TEXTILES

Fashioning Electronics into Textiles

The Need

- The Intelligence Community and other US Government agencies need wearable electronics that include effective audio, visual and/or location sensing capabilities
  - Hands–free operation and comfortable wear minimizes errors and accidents
  - Applications in law enforcement and international weapons inspections



Program Goals

Sensing Events

Track 1: **Listen**

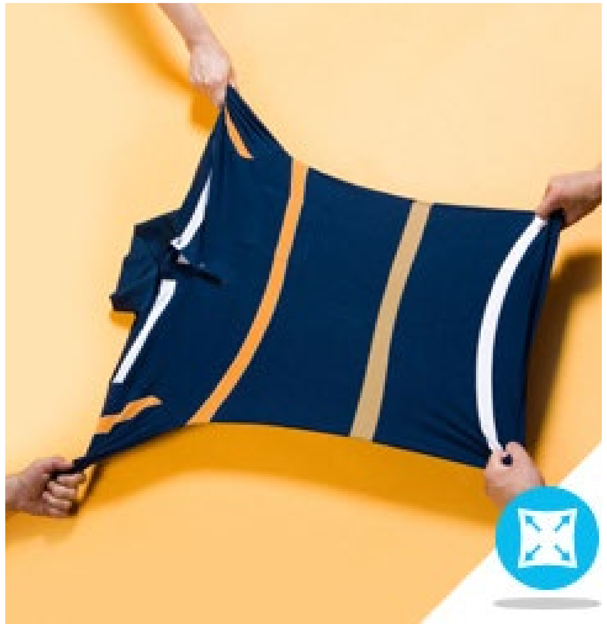
Track 2: **Look**

Track 3: **Locate**

Comfort and Durability

FLEXIBILITY

STRETCHABILITY

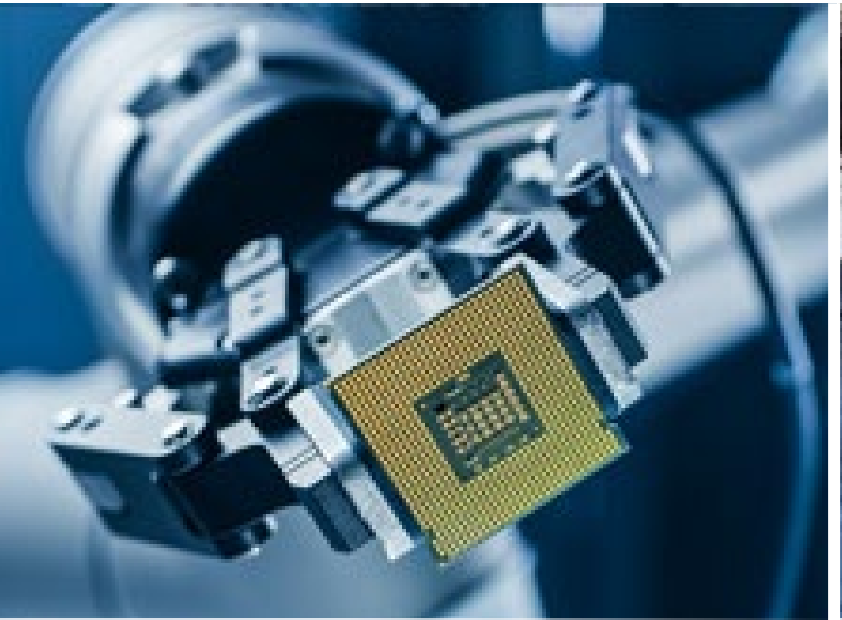


SOFTNESS AND DURABILITY

WASHABILITY

Program Phases

Phase 1: BUILD IT
18 Months



- Performer develops sensor(s) and reference textile
- System is integrated and tested outside textile
- Reference textile is tested to determine durability metrics

Phase 2: WEAR IT
12 Months

- Performer integrates system into garment using reference textile
- AST is tested for performance before/after durability measurements

Phase 3: WASH IT
12 Months

- AST is tested for all performance and durability factors, including washing

Test & Evaluation Teams

affoa

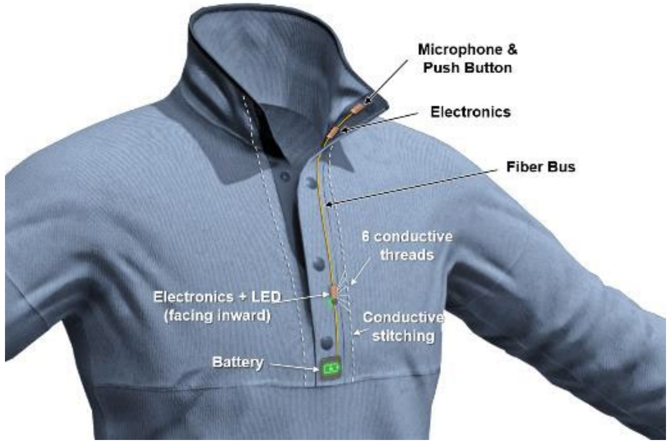
DEVCOM

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Test and Evaluation Team Responsibilities

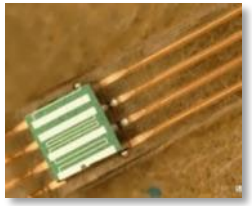
Baseline Designs

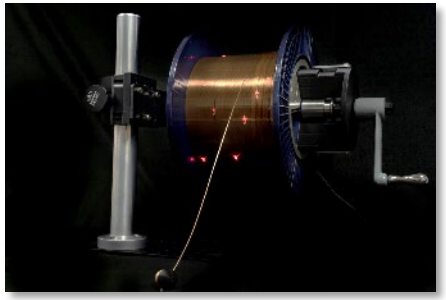
- Built from commercially available sensors and electronics



Government Furnished Capability

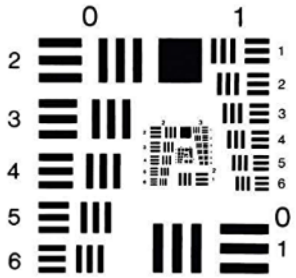
- Made available to all performers





Test & Evaluation

- Systematic evaluation of performer swatches and garments



Sensor Events

Fabric Testing

SMART ePANTS

WEAVING ELECTRONICS INTO TEXTILES

SMART ePANTS Performer Teams

Fashioning Electronics into Textiles

Powerfully Smart Threads (PST)

Areté
DISCOVER. DEVELOP. DELIVER.

WAYNE STATE UNIVERSITY

UNIVERSITY OF MICHIGAN

ASU Arizona State University

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

INTERWOVEN
DESIGN GROUP

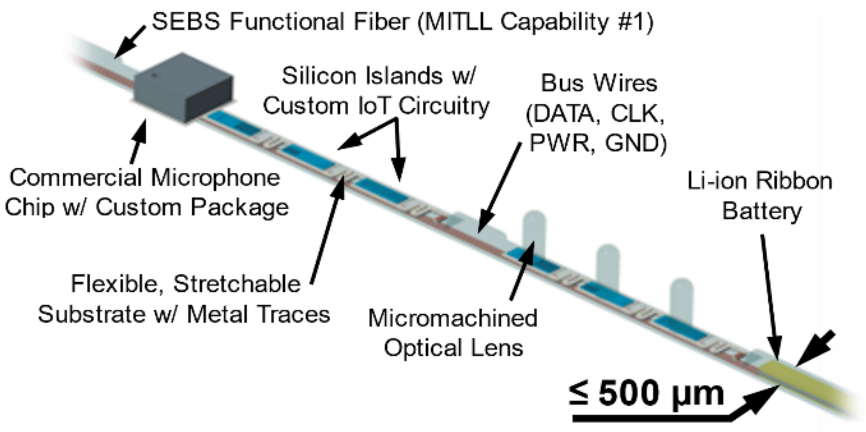
Video

Audio

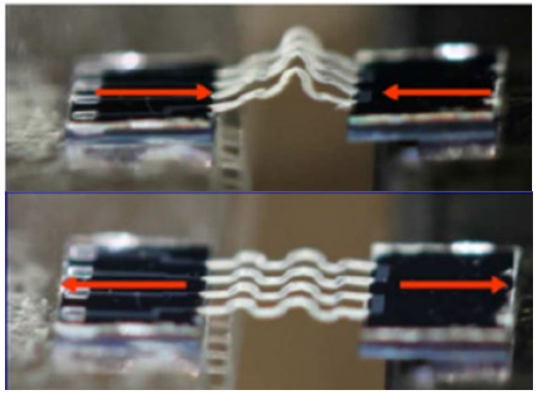
Powerfully Smart Threads

Areté
DISCOVER. DEVELOP. DELIVER.

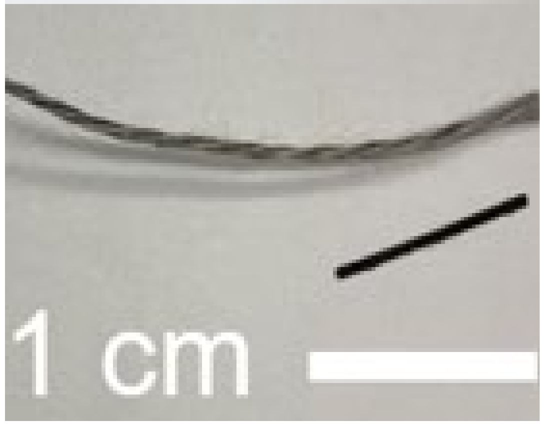
Audio and Imaging system integrated into functional fiber



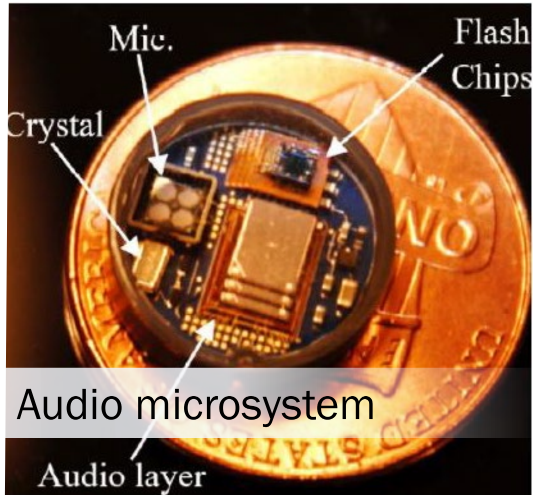
Serpentine micro-cable interconnect structure



Fiber battery



Integration into Ripstop Fabric
100% Cotton Ripstop 6.5 oz, 60" wide



Audio microsystem

Video Audio

Fabric of Things (FoT)

leidos

STM

UNIVERSITY of VIRGINIA

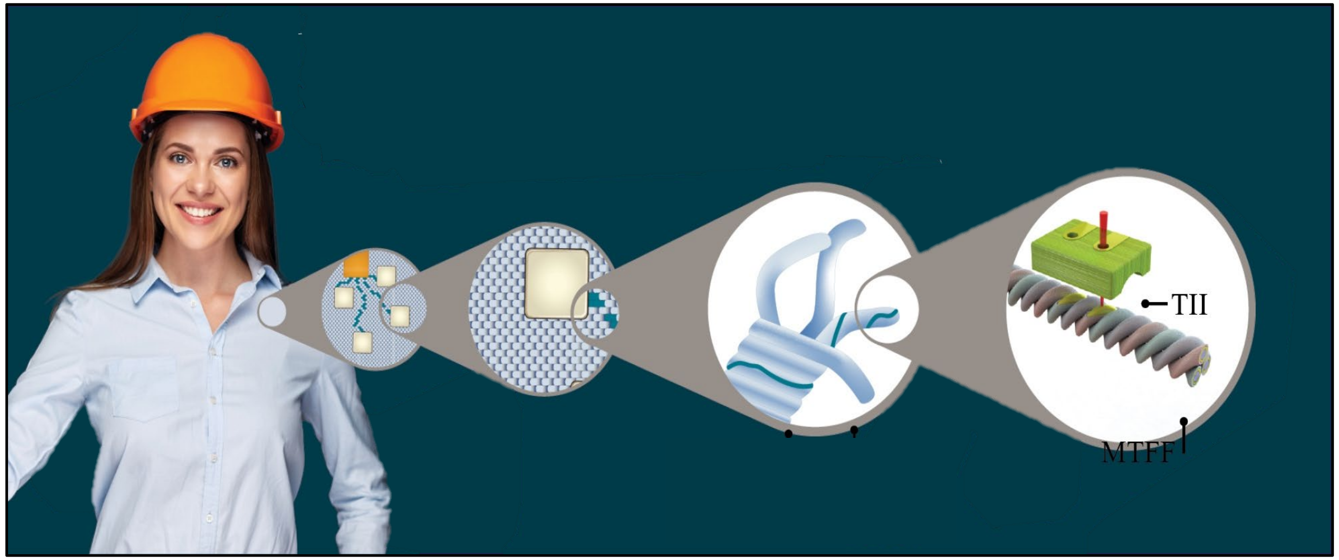
UNIVERSITY OF CALIFORNIA SAN DIEGO
LET THERE BE LIGHT

CLEMSON

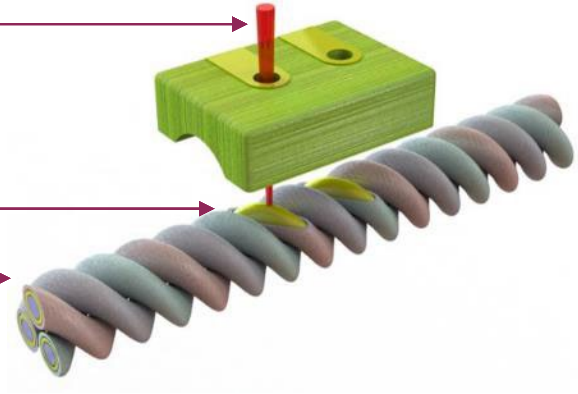
WAVESCIENCES®

Audio

Fabric of Things (FoT)



- TII surface mounts to yarn’s unique conductive pattern using high resolution laser ablation and micro-soldering
- Braided composite yarns comprised of individually insulated, surface metalized textile filaments combined with soft non-conductive filaments



Audio

Fiber Computers & Fabric Networks (FCFN) for Garment-based Discreet Video and Location Services

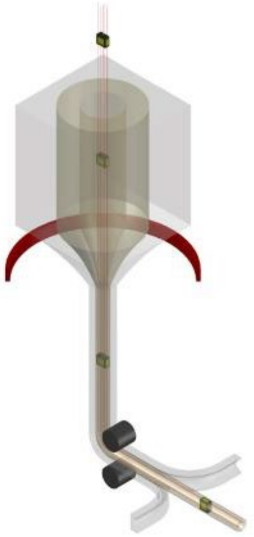
Massachusetts Institute of Technology

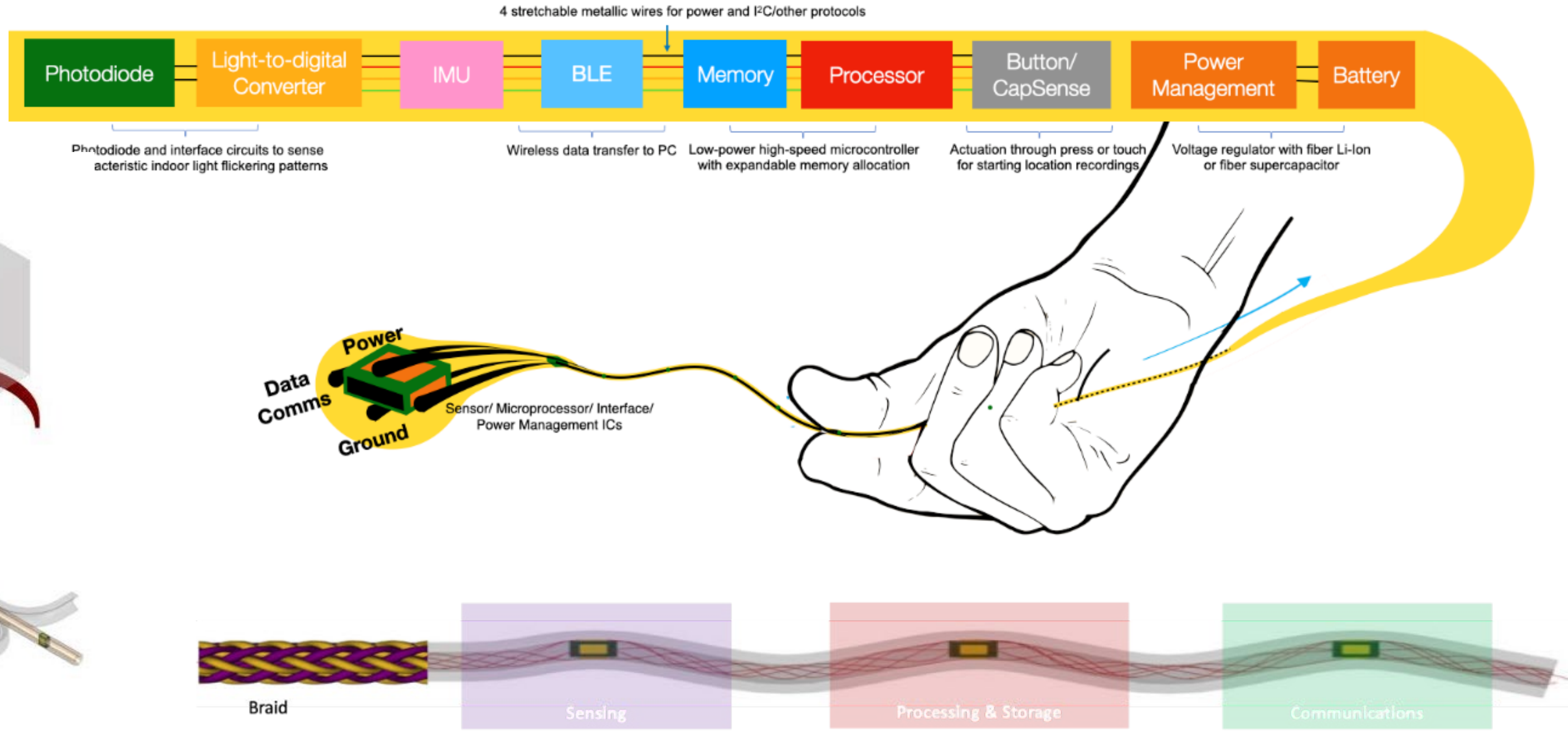
Rhode Island School of Design

Video | Location

*Two additional subcontractors pending

Massachusetts Institute of Technology





Video

Location

Systems Utilizing Intelligent Textiles with Unprecedented Performance (SUIT UP)

NAUTILUS DEFENSE

ANTHRO ENERGY

UNIVERSITY of VIRGINIA

SUNRAY SCIENTIFIC

Centeye

TRX systems

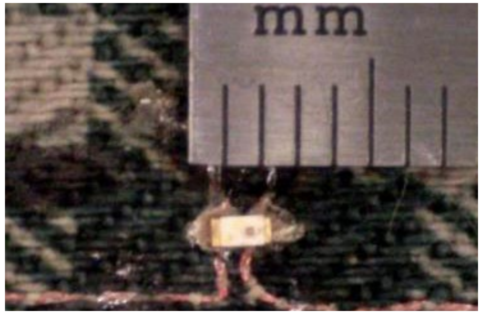
UNIVERSITY OF MICHIGAN

Arachne Labs LLC

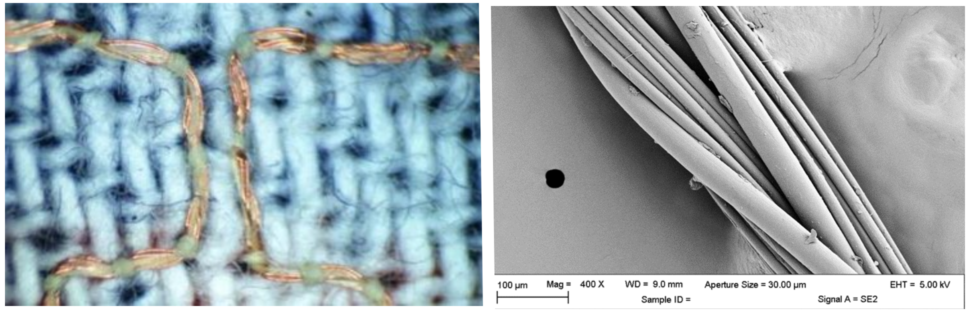
GE Research

SUIT UP

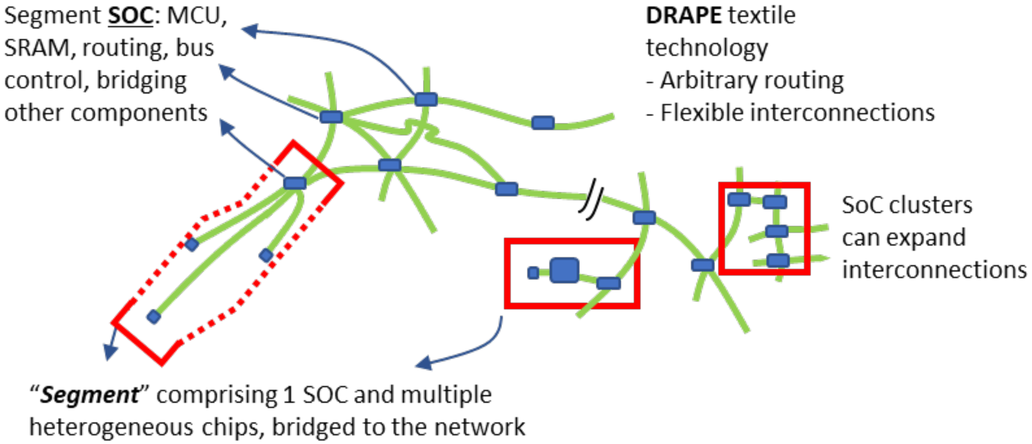
NAUTILUS DEFENSE

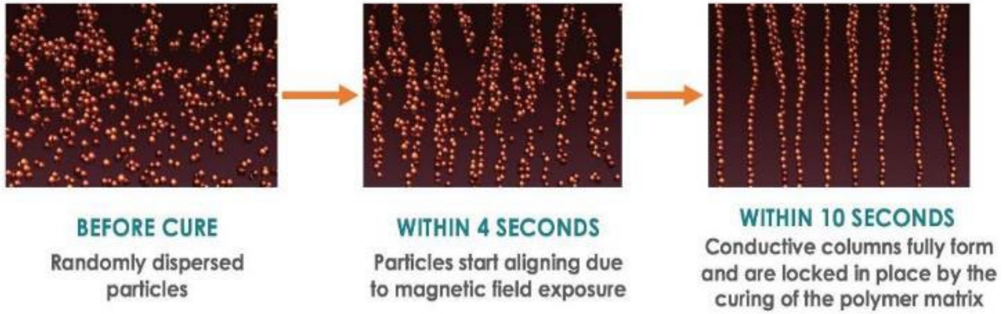


ZTACH Anisotropic Conductive Epoxy enables precisely controlled electrical connections



Braided microyarns are insulated and flexible





Networked system on a chip (SOC) units enable flexible and reconfigurable architecture optimized system performance

Video

Location

Comfortable Outfits from Utilitarian Textiles for Unobtrusive Recording of Events (COUTURE)

SRI International

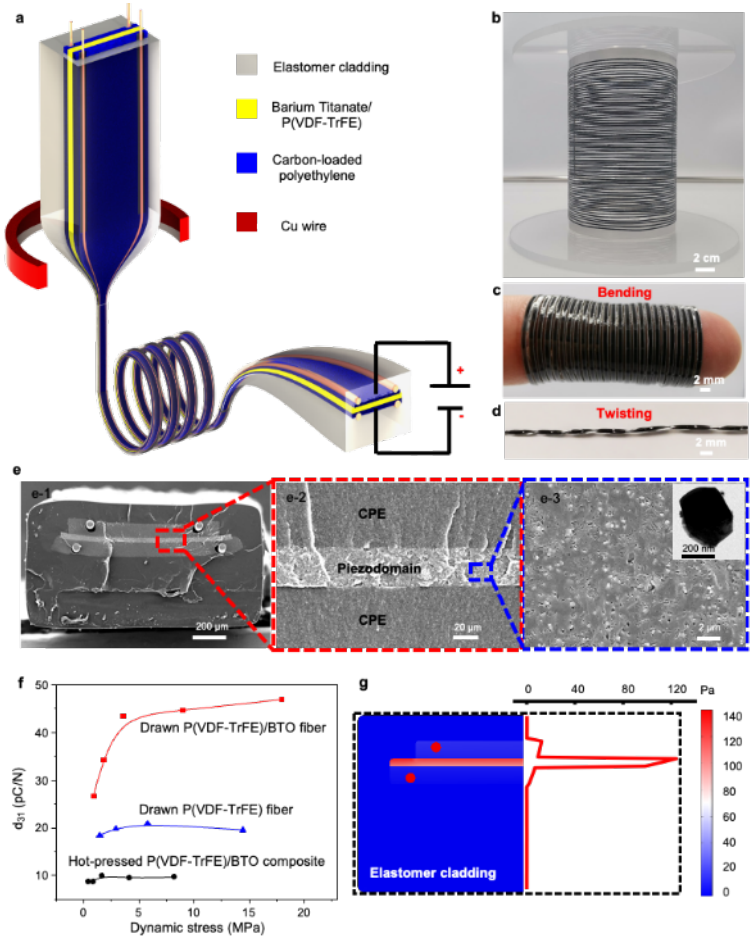
IFM

NC STATE UNIVERSITY

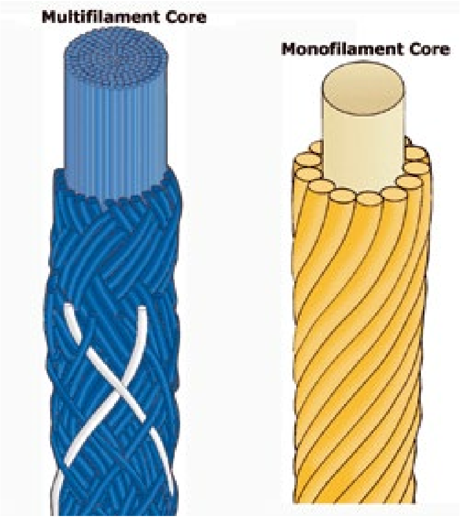
Audio

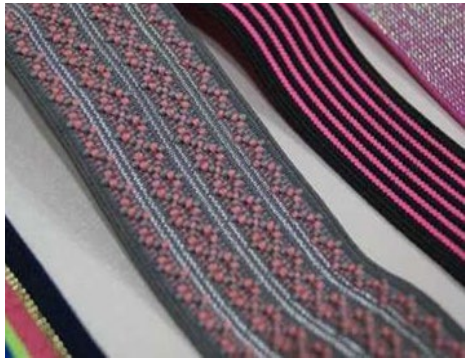
SRI International

Microphone Fiber Draw Process



Examples of Braid, Overstitch, Inlay and Bandaging





Audio

SMART ePANTS Teams

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Massachusetts Institute of Technology

SRI International

leidos

NAUTILUS DEFENSE

SMART ePANTS

WEAVING ELECTRONICS INTO TEXTILES

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Fashioning Electronics into Textiles

Thanks For Your Interest!

Backup Slides

Sensor and Fabric Testing Sequence

Phase 1 Swatch Testing

1. 2 Sensing Event Tests
2. Stored on Shelf for 24 hrs
3. 1 Sensing Event Test
4. Fabric Testing
5. 1 Sensing Event Test
6. Wash Test
7. 1 Sensing Event Test

Phase 2 & 3 Swatch Testing

1. 3 Sensing Event Tests
2. Fabric Testing
3. 1 Sensing Event Test
4. Wash Test
5. 1 Sensing Event Test

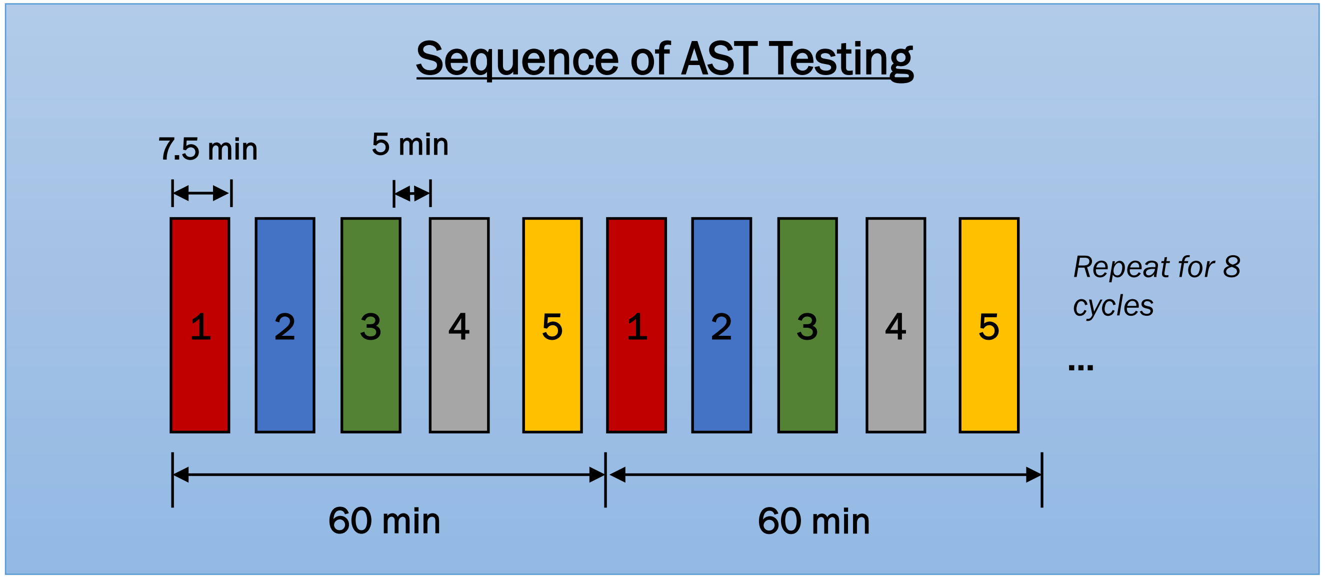
Phase 2 & 3 Garment Testing

1. 2 Sensing Event Tests
2. Stored on Shelf for 1 – 12 wks
3. 1 Sensing Event Test
4. Wash Test
5. 2 Sensing Event Tests

Testing @ AFFOA (grey)
Testing @ MITLL (blue)

Listen Testing

- 7.5 minutes of data collected every hour for 8 hours from each AST article
- Audio data is ported to a PC and converted to line-level analog input to STI meter
- Sound Pressure Level set to 69 dBa in all cases. AST angled at 0° or 45° with respect to the speaker



AST = Active Smart Textile

STI = Speech Transmission Index

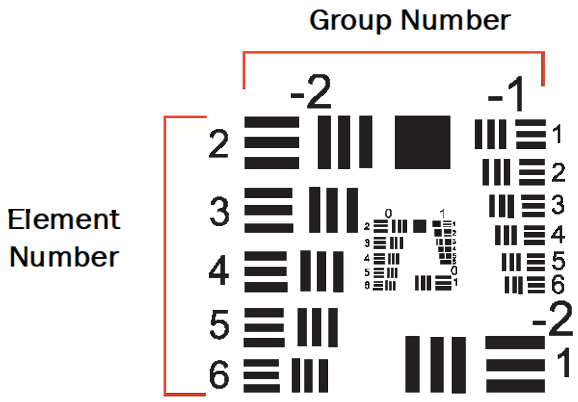
Time (sec)	Signal
0 - 100	STIPA
100 - 200	Female speech, 10 HPB sentences
200 - 250	White noise
250 - 350	Male speech, 10 HPB sentences
350 - 450	STIPA

Speaker at 1m Distance from Manikin

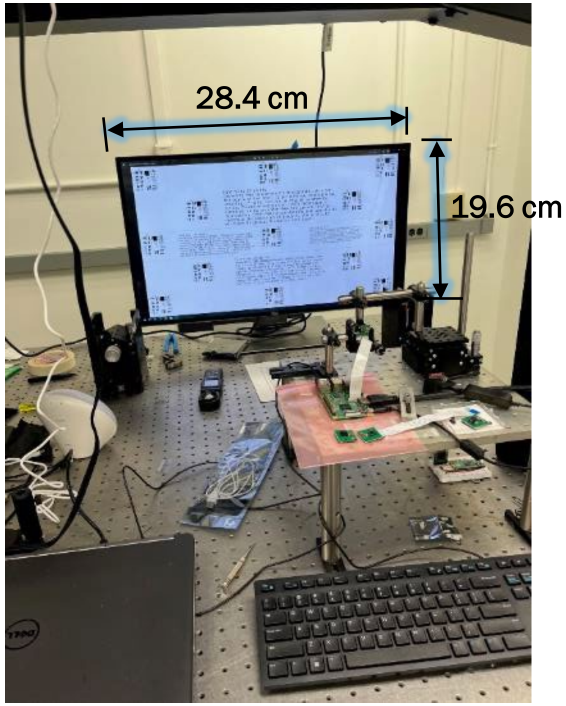
Look Testing

- The camera will take photographs or video of:
  - High-resolution monitor (Dell 8k)
  - 8.5” x 11” paper
- When using the monitor, T&E will vary:
  - Room lights: on vs. off
  - White vs. black background
  - Image centered on middle vs. edge of display

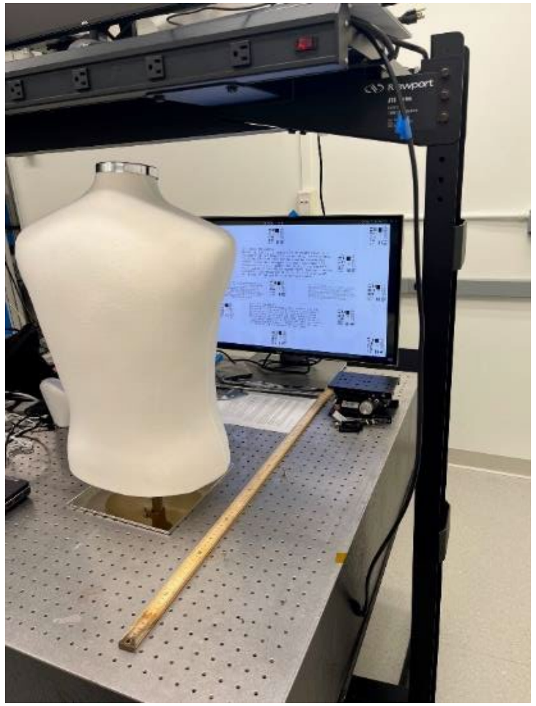
1951 USAF Resolution Chart



High-Resolution Monitor

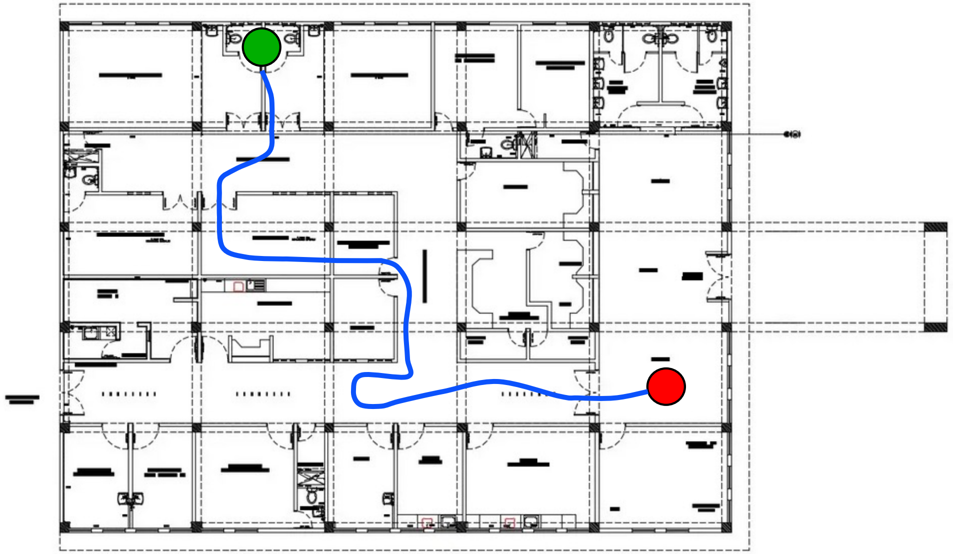


Manikin

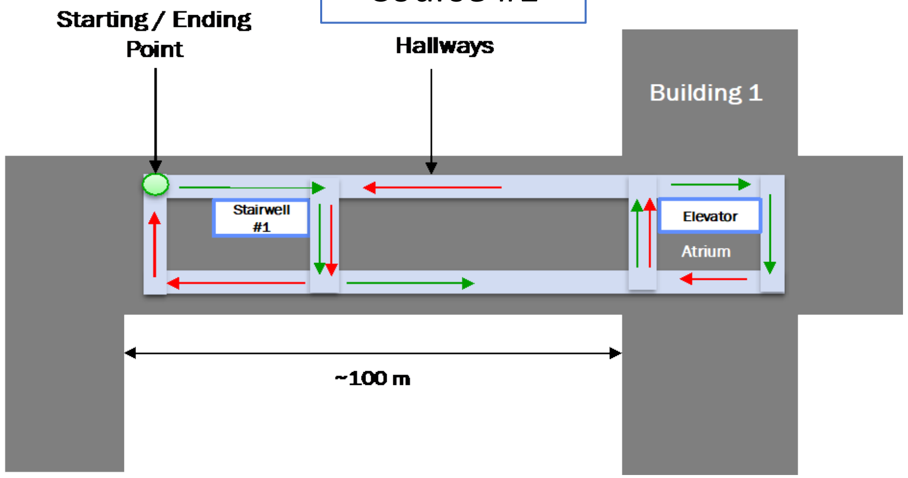


Locate Testing

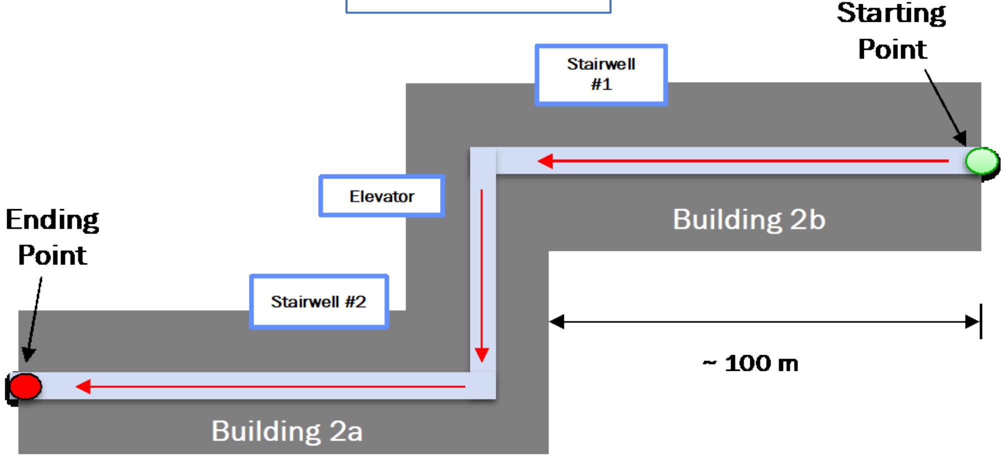
- <u>Not Allowed</u>: GPS or intentional beacons
- <u>Allowed</u>: Onboard cameras or antennas
- T&E will travel with samples around multiple courses
  - Path confined to single floor
  - Path containing a single elevation change of 1 floor using stairs
  - Path containing multiple elevation changes using stairs
  - Path containing a single elevation change of 1 floor elevator



Course #1

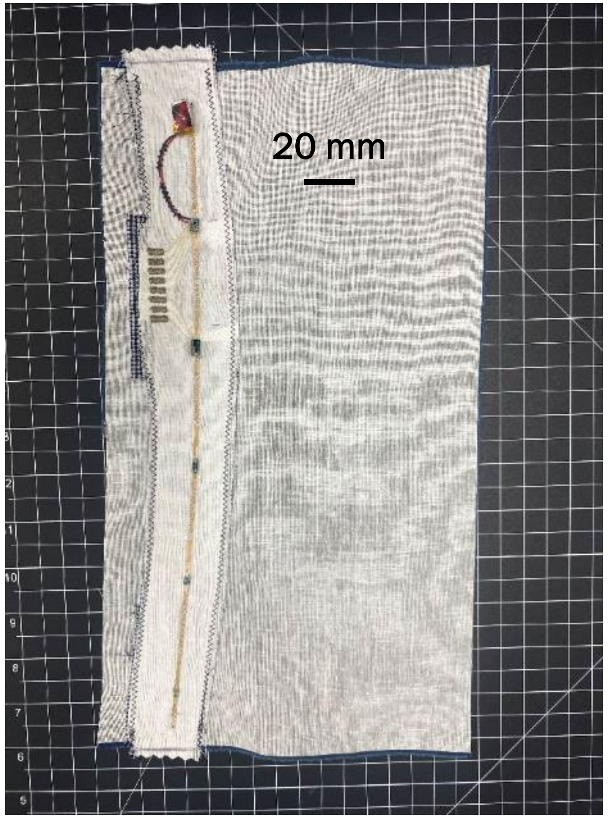


Course #2

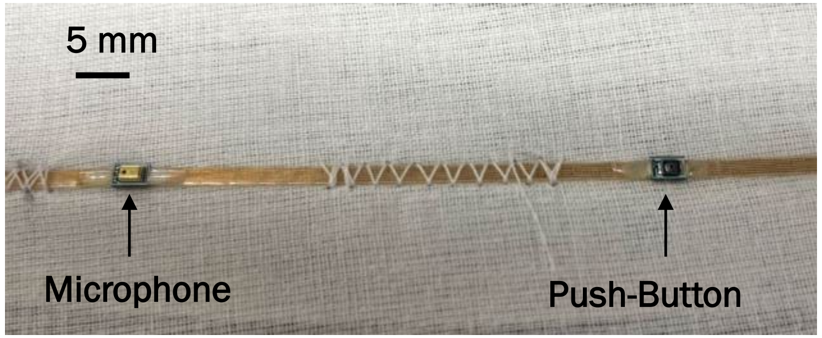


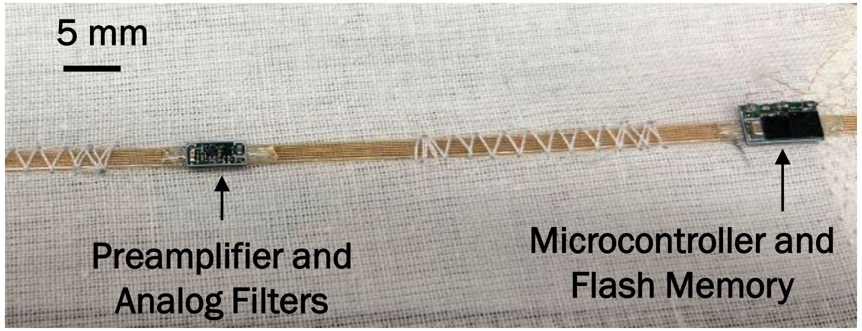
Listen Baseline System

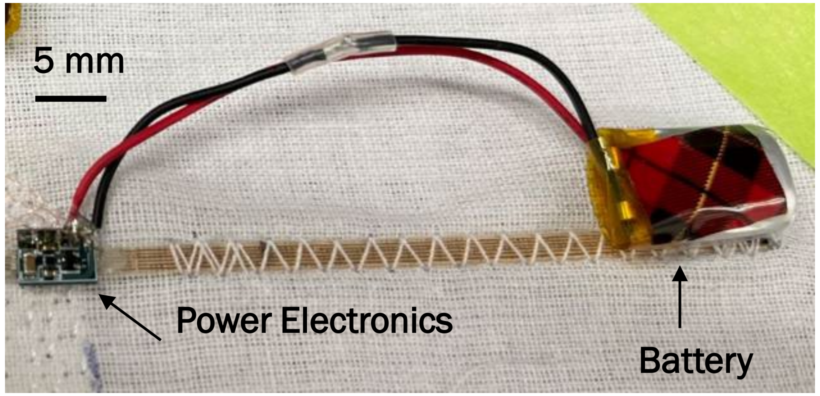
Audio Swatch

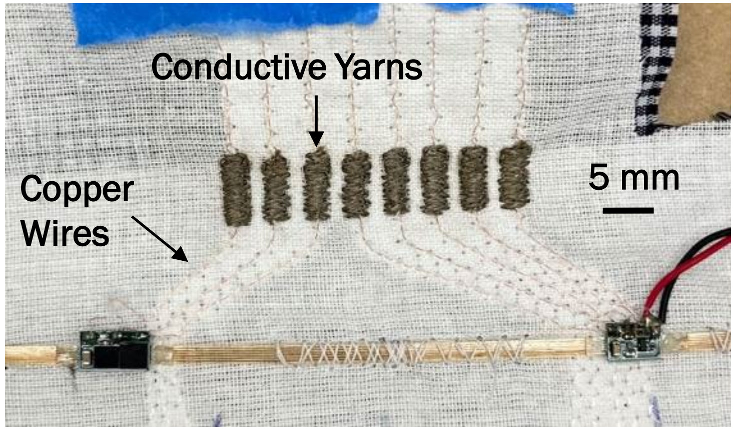


Audio baseline electronics includes five nodes embedded in a polymer fiber





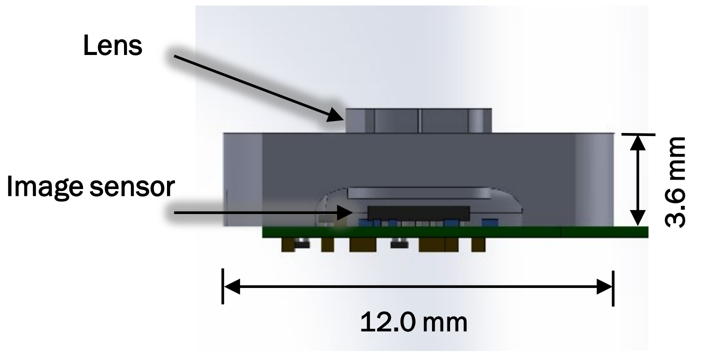




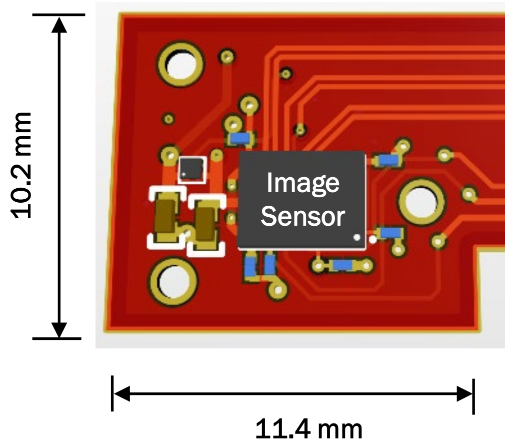
Look Baseline System

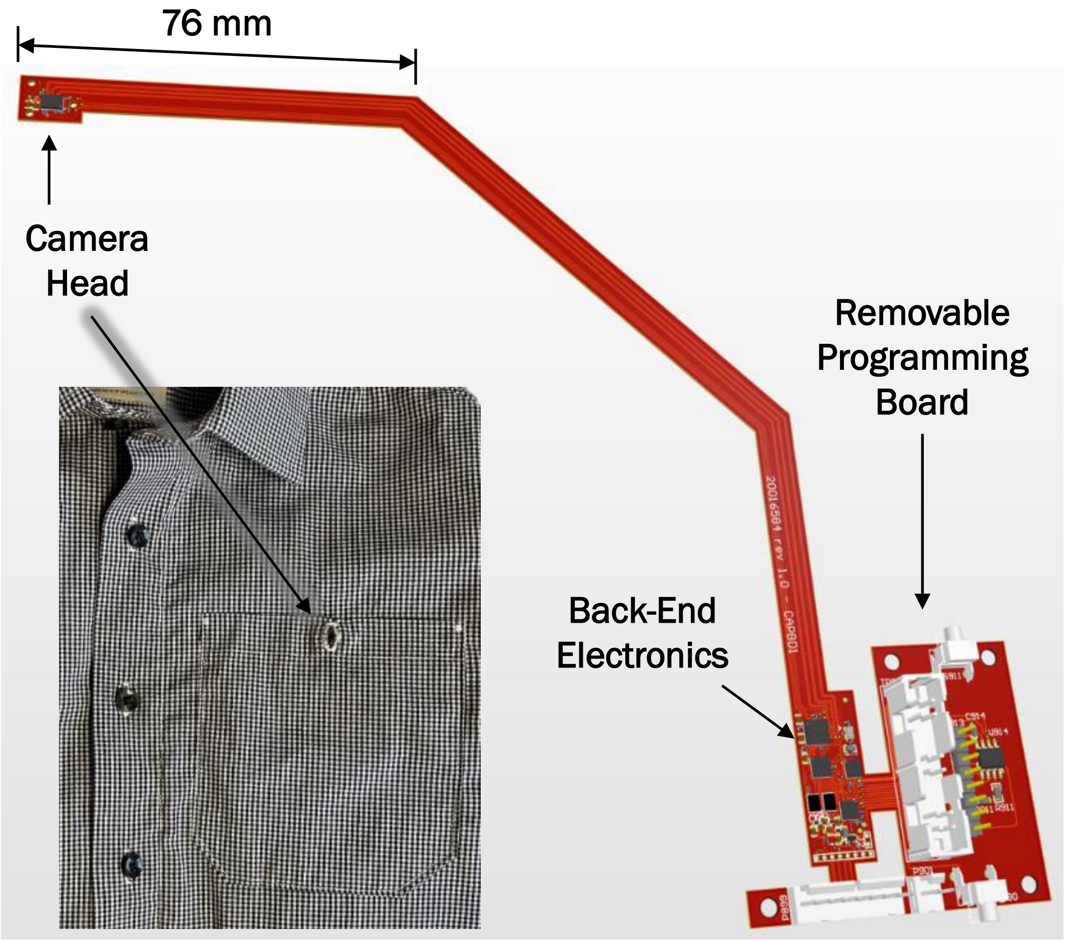
- Still photographs with the ability to store 70 pictures
- <u>Image sensor</u>: Omnivision, 2 MP, 1.4 x. 1.4 µm pixel size
- <u>Lens</u>: 40lens stackup from Arducam
- <u>Backend Electronics</u>: 2-lane MIPI, 160 Mbits/lane, deserializer chip, Flash and SRAM member, FPGS and MCU for processing

Lens Assembly



Camera Head





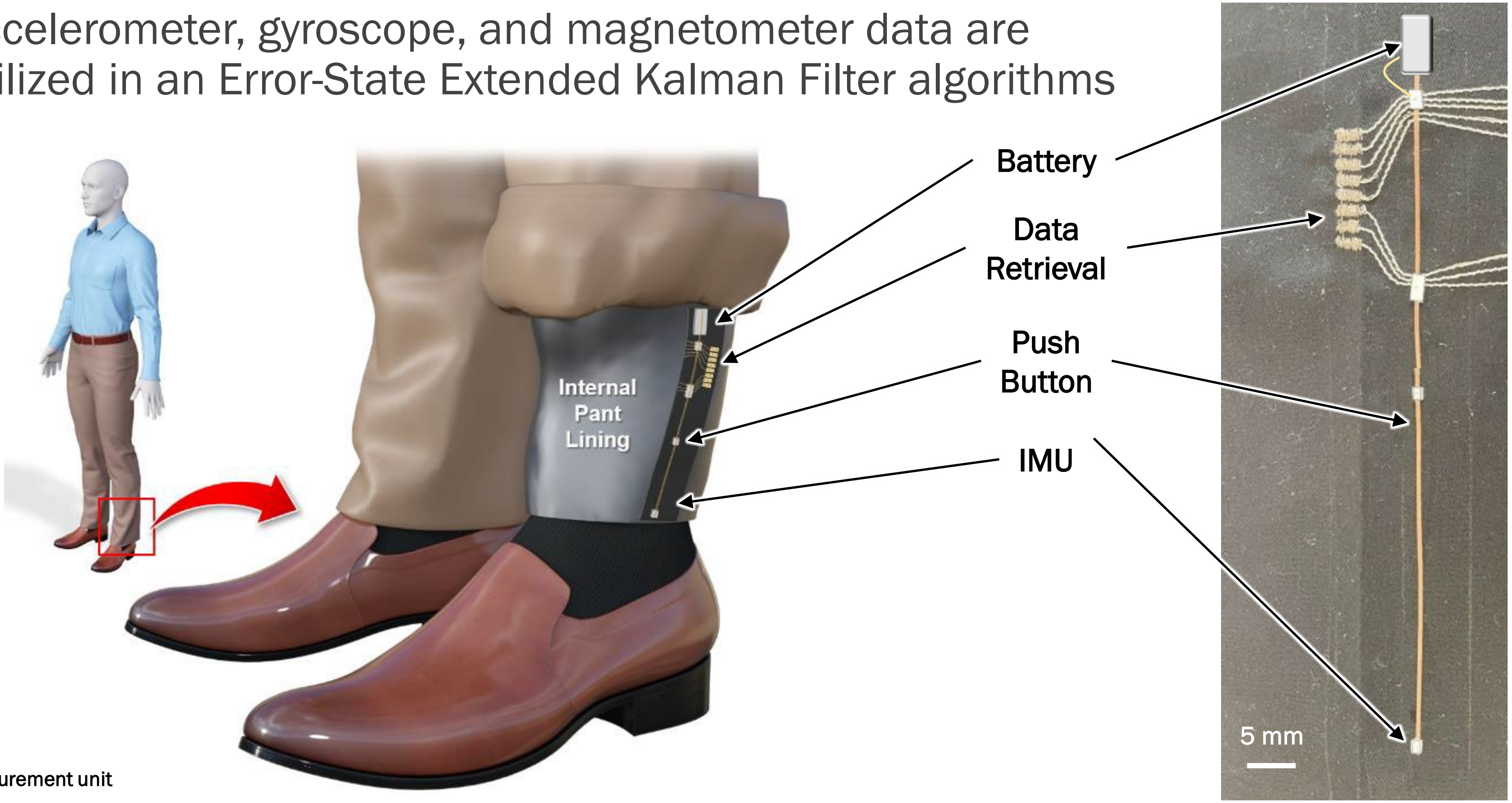
MP = Megapixel
MCU = Microcontroller

MIPI = Mobile industry processor interface
FPGA = Field-programmable gate array

Locate Baseline System

- Fiber-based design built around MEMS IMU for inertial navigation
- Accelerometer, gyroscope, and magnetometer data are utilized in an Error-State Extended Kalman Filter algorithms

Interior of Internal Pant Lining



Exterior of Internal Pant Lining

IMU = Inertial measurement unit
MEMS = Micro-electromechanical Systems