Soldier Electronic Textiles and Revolutionary Fibers and Textiles Manufacturing Innovation Institute

Carole Winterhalter
Chief Technology Officer
The Warfighter is increasingly being equipped with a variety of electronic devices designed to augment their abilities. These include:

- Wearable displays
- Computers
- Radios
- Phones
- GPS & dead-reckoning units
- Sensors
Textile Wearables at NSRDEC

Energy Generation
Photovoltaic Films and Fibers

Functional Fiber and Textile Research & Integration

In-House Basic & Applied Materials Research

Wearable Networks and Connectors

Wearable Antennas

Computer Interface Devices

Heating and Cooling
Active Materials

Embedded Sensors
personal status monitor

Heated Vest
Heated Gloves

Wireless Power Transfer (WPT)

Passive materials

Kinetic Energy Knee Harvester

Heating and Cooling
Active Materials

Wearable Antennas

Combat Identification

Thin Film
Fiber Based

Fabric & Printed Dipoles

microrectenna array

NSRDEC, CERDEC, ARL
• Integrated Soldier Sensor System (ISSS)
• Goal: Provide Squad leader with actionable data concerning probable impending injury based on Soldier physiology and environment
• On-body wireless area network
  – Open system architected
  – Government owned design
  – Low power and ultra-low power
  – Soldier-to-Soldier communication
  – Future integration with Intra-Soldier Wireless (ISW) and Nett Warrior

What is the ISSS
• Stand-alone, intra-soldier only
• Communication Hub
• Physiological status monitor (PSM) watch
  – PPG sensor
• PSM Shirt
  – Army Combat Shirt (ACS) + compression shirt
  – DuPont printable conductive ink
  – COTS data acquisition module
• Washablity
  – Current ink is ~100 hand washes
• Integration
  – “Wires” and ECG leads are printed easily, but what about whole circuit boards?
• Flexibility
  – Data acquisition module is hard plastic
• Comfort
  – Data acquisition module is bulky
  – ECG leads are held still with compression
• Durability
• FR compression + wicking fabrics
• Ongoing development effort with Infoscitex, DCS
• E-textile network for power harvesting
• Additional research option tasks:
  – CNT E-yarns
  – Stretch E-yarns
  – Wireless power transfer
Problem: A new kinetic energy harvesting technology needed a power and data network to communicate between knee braces and to the torso mounted power manager. Cables were created snag hazards and added weight.

Solution: Infoscitex is developing an electro-textile (E-textile) power and data network embedded in the trouser fabric for knee-to-knee connectivity and in a flexible fabric strap for trouser-to-torso connectivity.

Photo Credit: Infoscitex Corporation Staff
Knee-to-knee E-textile network

Connector stowage pockets

ISPDS-compliant connectors

Photo Credit: Infoscitex Corporation Staff
Trouser E-textile Network

Photo Credit: Infoscitex Corporation Staff
Trouser E-textile Network Path in Blue
Selectively Enabled Wiring in textiles (SEWit)
E-textile Yarns

- E-textile yarns, consisting of extremely fine insulated wires wrapped around a core yarn, were developed.
- By blending such fine conductors with conventional textile yarns it is possible to produce E-textile fabrics that are indistinguishable from conventional fabrics.
- The electrical and mechanical properties of these yarns can be tailored based on:
  - Core yarn size and material
  - Wire AWG and material
  - Wire/yarn blending process
Weaving

• The E-textile yarns are woven into a fabric along with textile yarns in the desired pattern (i.e. in the rip-stop portion of an ACU fabric)

• The weaving process can use any loom as has been demonstrated on equipment ranging from prototype units to 68” wide production looms.
• Once woven, the E-textile can be printed and finished using established methods.
• Samples of an ACU-based e-textile fabric were sent to a printing and finishing plant for treatment and evaluation.
• These samples were inserted into a production run and subjected to normal printing and finishing processes including a Quarpel water repellent finish.
• Finished samples were evaluated for:
  – Electrical continuity: Passed
  – Enamel integrity: Passed
  – IR reflectance: Passed

Printed sample with Quarpel water resistant finish
Welding and connectorization techniques were developed for:

- Connecting warp and fill e-yarns to create the desired network topology.
- Forming connections that bridge seam boundaries to form continuous network paths between pattern pieces.
- Providing EMI shielding for network paths.
- Connecting external electronic devices with the fabric network.
Importance of Seams in E-textile Products

- Throughout our research it was observed that bridging seam boundaries in a reliable manner required a detailed understanding of the seam construction, the e-textile pattern, and the welding parameters.

- Without this understanding connections may either not be formed or undesired connections may be formed in their place.
System Inputs:

- E-yarn spacing (T)
- Angular shift ($\alpha_s$)
- Seam angle ($\beta$)
- Seam width (w)
- Horn length (hd)
- Seam type
• The SEWit Toolkit can be used to create a variety of complex power and data networks for wearable applications.

• Power networks;
  – Networks capable of supporting power loads of up to 64W at 4A have been demonstrated
  – Voltage ratings of ~ 1 kV are typical for most E-yarns

• Methods for utilizing this technology include:
  – Integration of panels containing SEWit networks into existing products
  – Construction of new garments using SEWit fabric

• In both scenarios the fabric can be designed to have the required structure:
  – Distributed: A grid-like pattern ideal for sensor networks and ad-hoc reconfigurable networks where fault tolerance is required.
  – Dedicated: Point to point networks ideal for applications where high performance is required (i.e. high-speed USB, high power capacity, etc.)
Data Networks

- Demonstrated the feasibility of supporting a variety of network protocols:
  - analog audio/video
  - Serial (RS-232, etc.)
  - 1000BaseT (Gigabit) Ethernet
  - high-speed USB 2.0
- Validated that transmission rates were identical to analogous conventional cables
- Able to handle streaming video
- Able to transmit across seams
- Various shielding approaches developed
- Compatible with many COTS and ruggedized connectors
- Approach can be readily adapted for different fabric types and end uses
Revolutionary Fibers and Textiles
Manufacturing Innovation Institute
Overview

Ms. Carole Winterhalter
Government Chief Technology Officer
26 June 2016
• National Network of Manufacturing Innovation (NNMI) led by Department of Commerce
  - Dept. of Defense: 6
  - Dept. of Energy: 2
  - More to come

• What is a Manufacturing Innovation Institute?
  - Led by a non-profit (501c3 or 6)
  - Public/private partnership with Federal investment + cost share requirement
  - Supports an end-to-end ‘ecosystem’ in the U.S. that includes industry, universities, community colleges, federal agencies, and states.
  - Acts as an innovation engine for advanced manufacturing and design, and a demonstration platform for industry
  - Invests in industrially-relevant manufacturing technologies (MRL 4 – 7) with broad applications
  - Project determination, execution performed by members of the Institute
Institute Major Activities

Applied Research & Demo projects for
- reducing cost/risk on commercializing new tech.
- Solving pre-competitive industrial problems

Tech Integration - Development of innovative methodologies and practices for supply chain integration

Small/Medium Enterprises
- Engagement with small and medium-sized manufacturing enterprises (SMEs).

Institute

Workforce Training
- Real options, real jobs, real life.
RFT-MII Fast Facts

• Announced on April 1 by Secretary of Defense, Ash Carter

• Revolutionary Fibers and Textiles Manufacturing Innovation Institute (RFT-MII) is the 6th of the DoD-led institutes

• Awarded to the Advanced Functional Fabrics of America (AFFOA), a non-profit led by MIT. Provisional leadership team includes:
  ▪ Chairman of Board: GEN (R) Paul Kern
  ▪ Executive Director: Dr. Yoel Fink
  ▪ Chief Operating Officer: Dr. Tairan Wang
  ▪ Chief Marketing Officer: Mr. Eric Spackey
  ▪ Chief Technology Officer: Dr. Aimee Rose

• Total contract award is nearly $320M; $75M of which is Federal funding over 5 years

• Total of 89 companies, non-profits, universities, and 5 State and other organizations – spread across 28 states
  ▪ 16 companies make up the 3 tiers of membership
  ▪ Small to medium-sized manufacturers and academia make up the Fiber Innovation Network (FIN)
AFFOA making great progress standing up:

- **Board of Directors**: Identified 7 of 11 members
- **C-Level Officers**: Identified and recruiting Exec. Director, COO, CMO, Program Manager; Engaged with possible CIO; still looking for Workforce Officer
- **HQ Facility**: 12 Emily Street, Cambridge, MA
  - Undergoing renovations
  - Developing equipment list to meet 30 June deadline for MA state funding
- **Membership**:
  - Finalizing membership agreement
  - Actively recruiting members, including non-selected team members
  - Planning to host prospective members meeting - TBA date
- **Much more being done in parallel**

- [www.affoa.org](http://www.affoa.org), #AFFOA
Organization Chart

- AFFOA NPO Board of Directors
  - All Members Council
    - Economic Impact Council
      - Workforce Development Council
        - AFFOA NPO CWO
        - AFFOA NPO COO
  - AFFOA NPO CEO and Award PM
    - Gov’t. PM
      - Technical Advisory Council
        - AFFOA NPO CMO
        - AFFOA NPO CTO
          - Gov’t. CTO

- AFFOA Stakeholders Council
AFFOA Governance Plan

AFFOA NPO:
AFFOA NPO is governed by a Board of Directors. The AFFOA NPO Board will have eleven members and include representatives of participants in AFFOA. The composition of the Board will be as follows:

- one representative appointed by MIT;
- the CEO of AFFOA NPO;
- one representative of the Tier 1 Industry Members of AFFOA;
- one representative of the Tier 2 Industry Members of AFFOA;
- one representative of the Tier 3 Industry Members of AFFOA;
- two representatives of the industry participants in AFFOA's FIN Foundry;
- one at-large representative of the Members and participants in AFFOA;
- two representatives of AFFOA Member States; and
- one representative of the academic institutions participating in AFFOA, exclusive of MIT.