

Improving Wearable Electronics Durability by Design

Presented by H. David Rosenfeld

2019-06-05

ASTM Workshop on Smart Textiles for Workwear Applications, Denver CO

DuPont Advanced Materials





DUPONT™
INTEXAR™

Performance ready.

DuPont™ Intexar™ is pushing the boundaries of on-body textile technology.

Fitness insights through biometric monitoring

Conquer cold environments with powered Heat.

Intexar™ Health includes medical grade ECG, mobile heat and e-stim therapy



INTEXAR™ **FITNESS**



INTEXAR™ **HEAT**

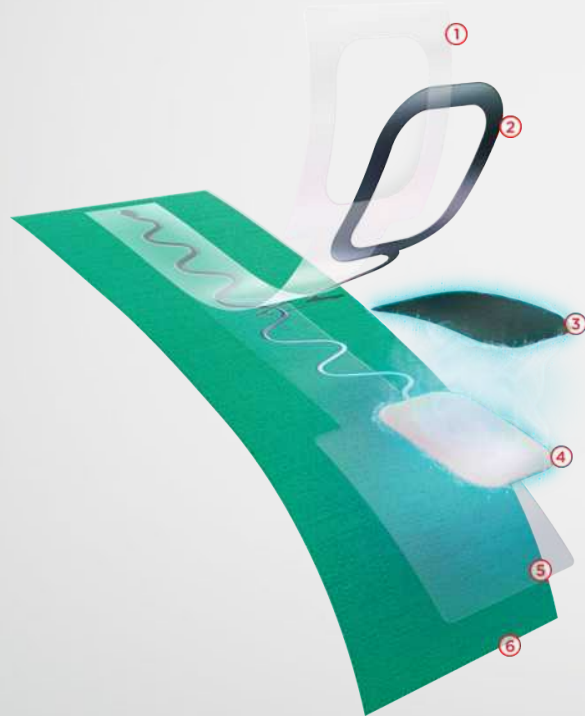


INTEXAR™ **HEALTH**

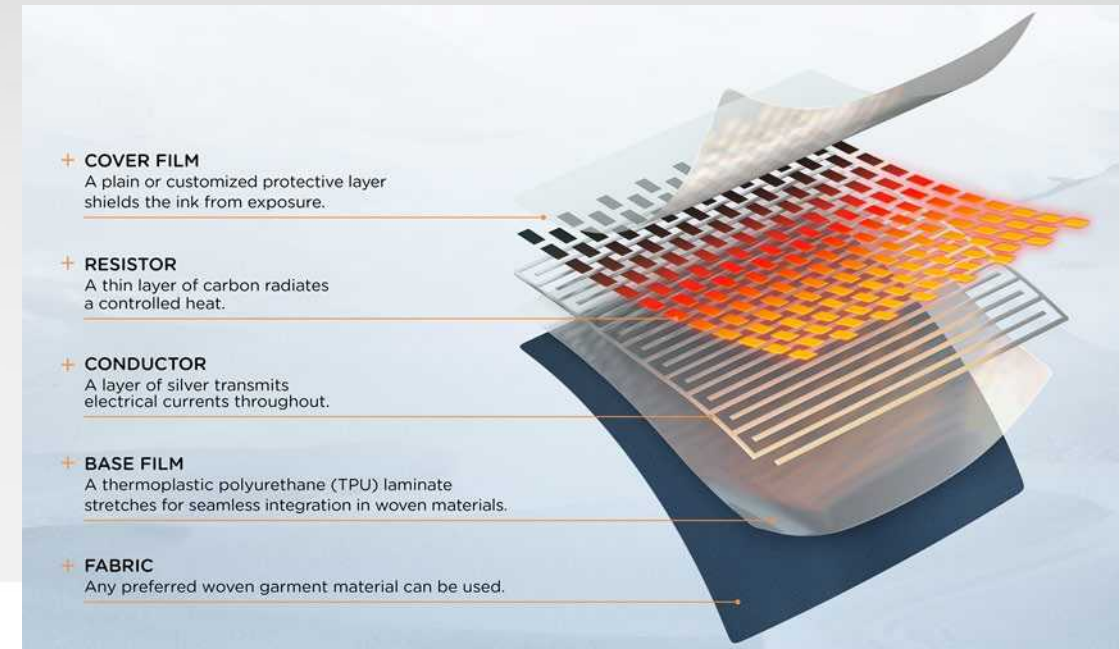
Outline

1. Examples of Intexar™ wearable electronics applications.
2. Intro to the materials set.
3. How design and application of the materials set influences electrical durability in stretch and wash testing.

Examples



Health Monitoring



Therapeutic Heating

Pregnancy monitoring

- + Intexar™ team proud to have collaborated with Owlet on The Owlet Band, which connects expectant mothers with their children- before they are born.
- + The Owlet Band has won 'Best Innovation in Wearable Technologies' and 'Tech to change the world' awards at CES 2019.



Heated down jacket



THE WALL STREET JOURNAL.

STYLE & FASHION | FASHION

These Heated Jackets Actually Work—And Charge Your Phone, Too

Toasty, battery-powered parkas have been growing ever more clever—and you can even use them to juice a dying smartphone

By *Jacob Gallagher*

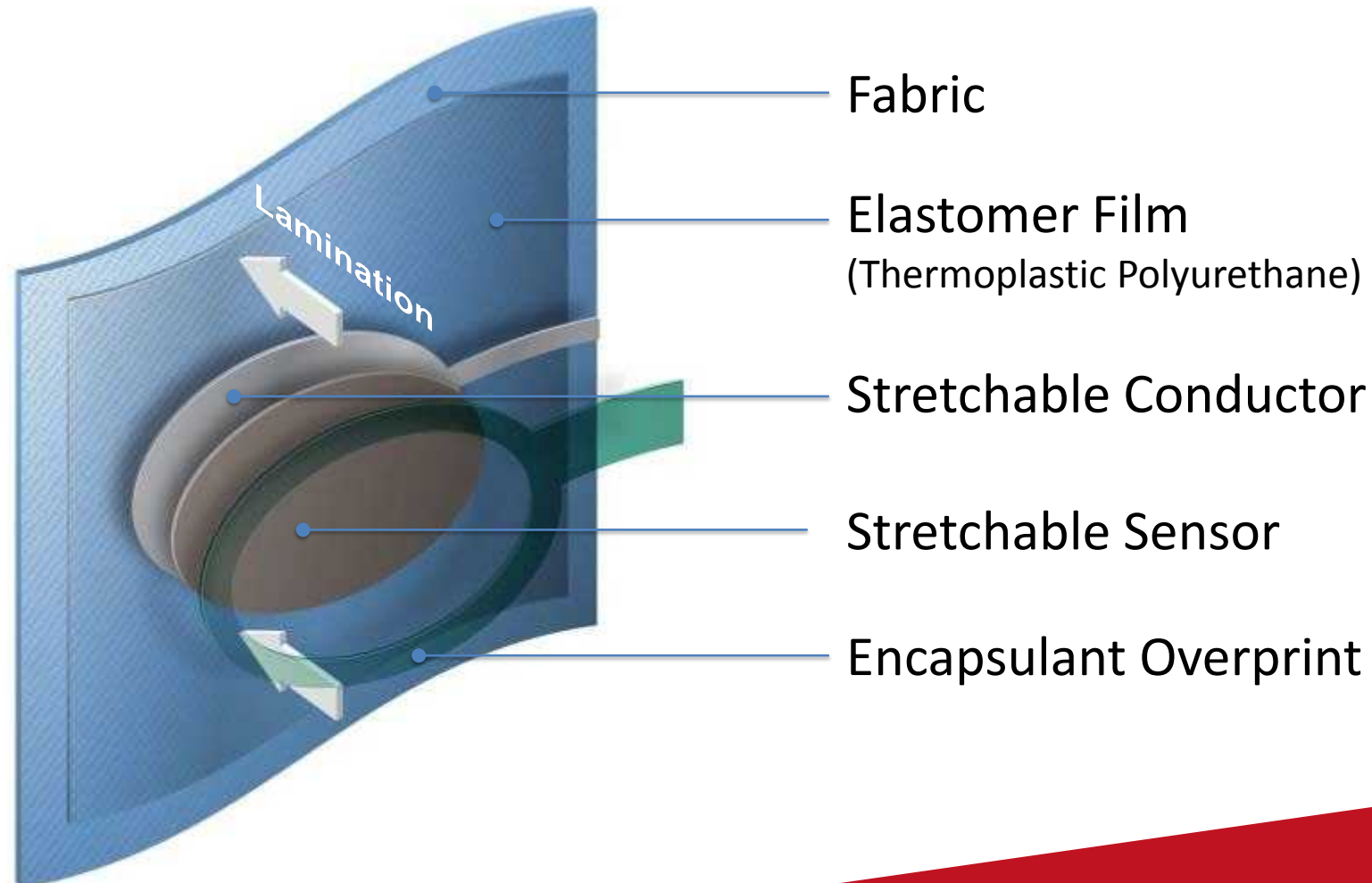
Jan. 30, 2019 11:46 a.m. ET

System introduction

- DuPont introduces Intexar™, game changing performance in smart clothing technology
- Fitness and biometric sensing are exciting growth markets. What is needed is smart clothing technology that has the comfort, performance, and durability to answer this demanding application.
- The DuPont approach was to look holistically at the opportunity and create a robust solution that considers the fabric, the processes, and the materials together. The solution is a system of elastomeric films and stretchable electronic inks designed to be bonded to fabric.
- Wash and durability are basic fundamental requirements of the target application, what really stands out for the Intexar™ system is comfort and it's high recovery. The ability to withstand stretch easily and continuously come back to the original shape. All while providing high conductivity.

How smart clothing is made using Intexar™

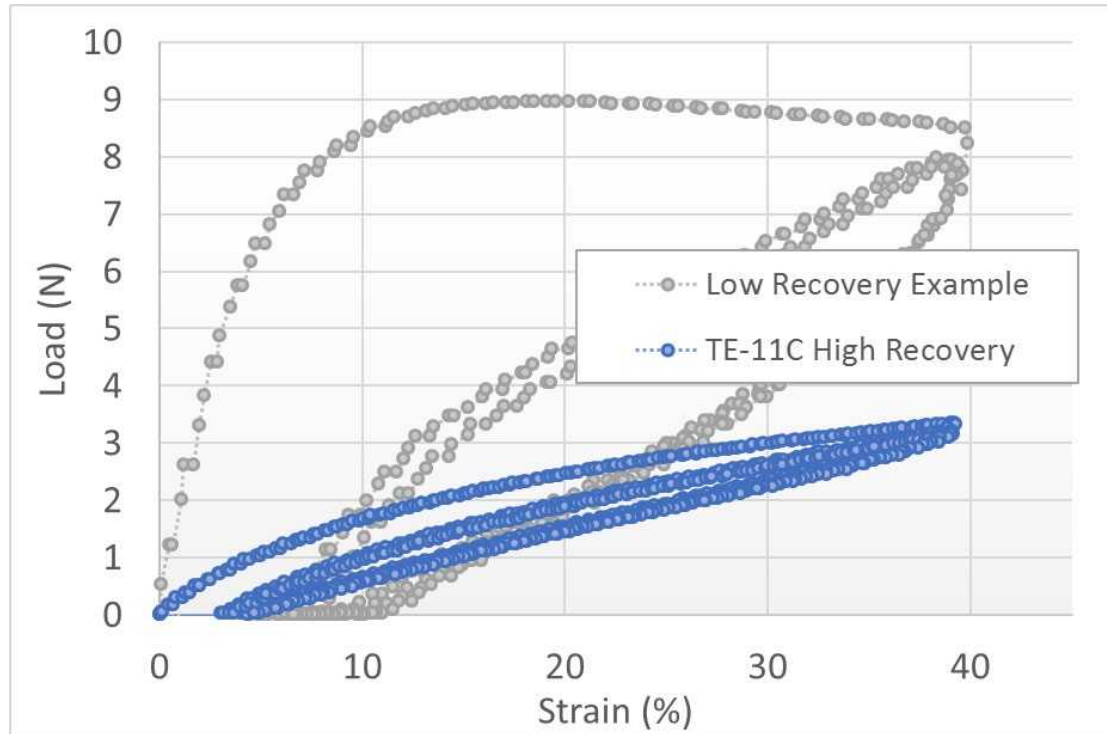
PROCESS: SCREEN PRINT, CUT OUT PARTS, LAMINATE TO FABRIC



Intexar™ product set

	Material	Product ID	Description
High Recovery System	Silver Conductor	PE874	Stretchable conductor for signal transfer • Best stretch recovery
	Silver Conductor	PE876	Stretchable conductor for signal transfer • Best washability
	Base Film / Cover Film	TE-11C	Polyurethane film designed for stretchable printed electronics
	Cover Film	TE-21C	Melt adhesive film designed for part packaging
Basic System	Silver Conductor	PE873	Stretchable conductor for signal transfer
	Encapsulant	PE773	Stretchable encapsulant for wearable applications
	Carbon Sensor	PE671	Biopotential sensor and overprint

Base film stress strain characteristics

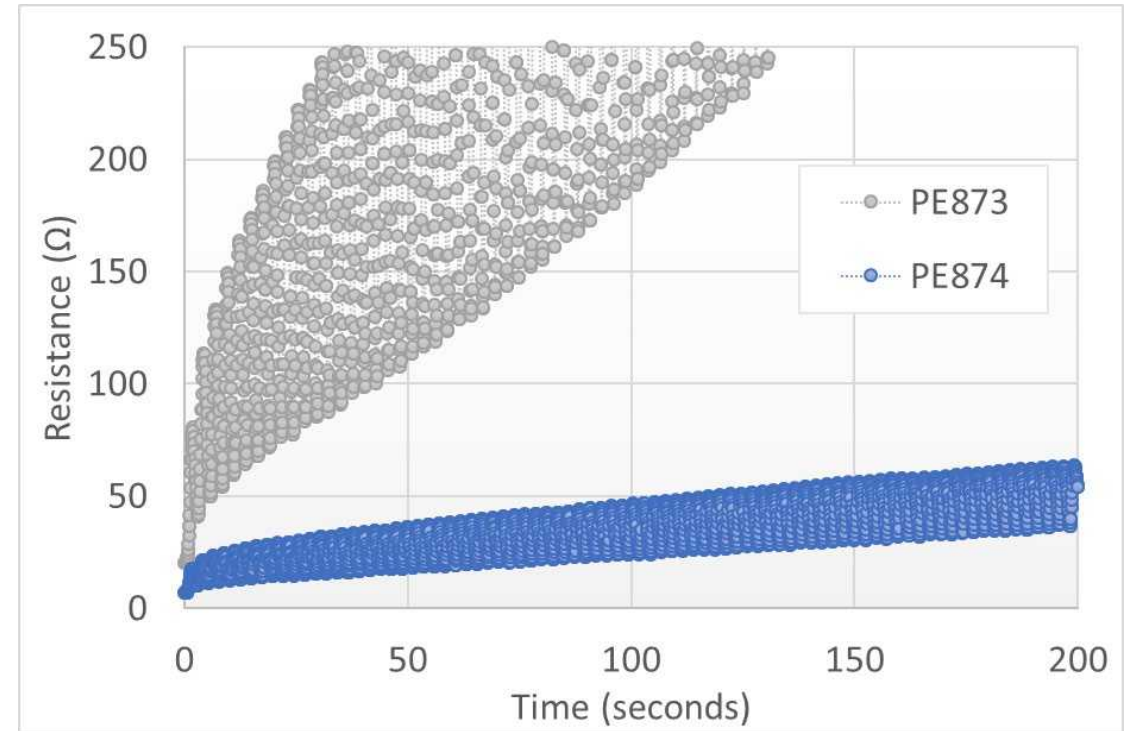
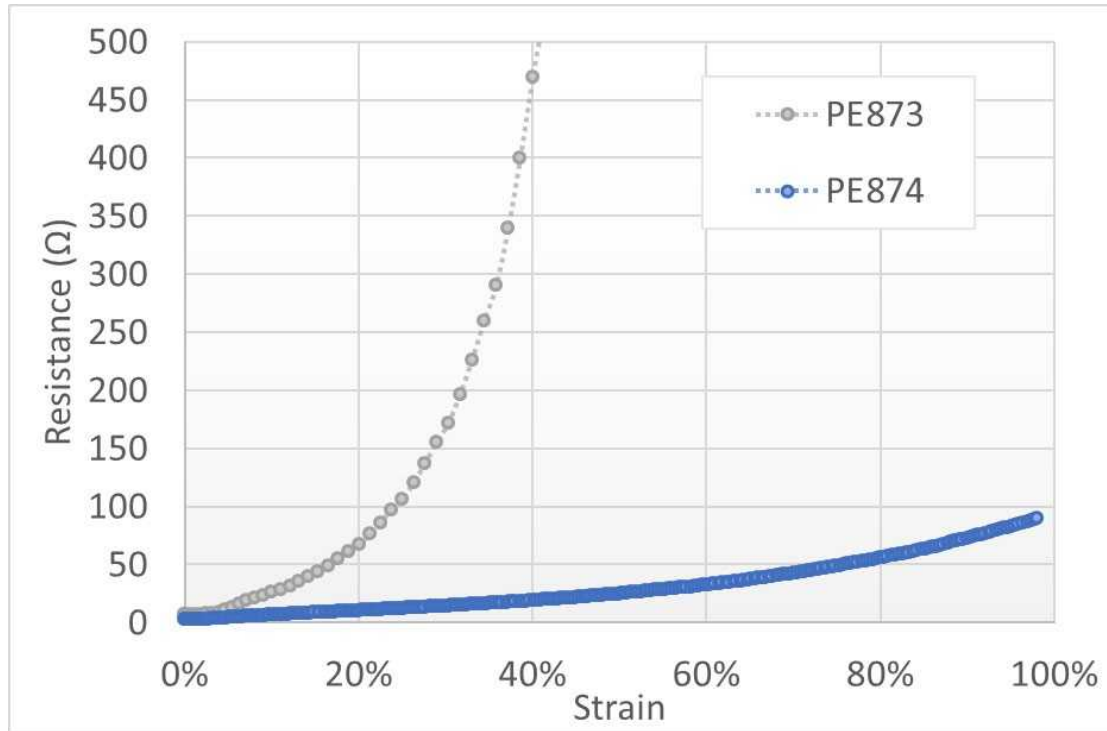


Strain	Recovery* TE-11C	Recovery* Low recovery film example	Modulus** TE-11C	Modulus ** Low recovery film example
20%	99 %	97 %	3.0 N	3.5 N
40%	97%	94 %	4.0 N	6.0 N
60%	96 %	89 %	5.4 N	10.0 N

*Recovered strain after 40% strain at 508mm/min, 1 second rest.

**Force required to pull 2cm wide 100um thick film to specified strain after first cycle.

PE874 mechanical & electrical performance

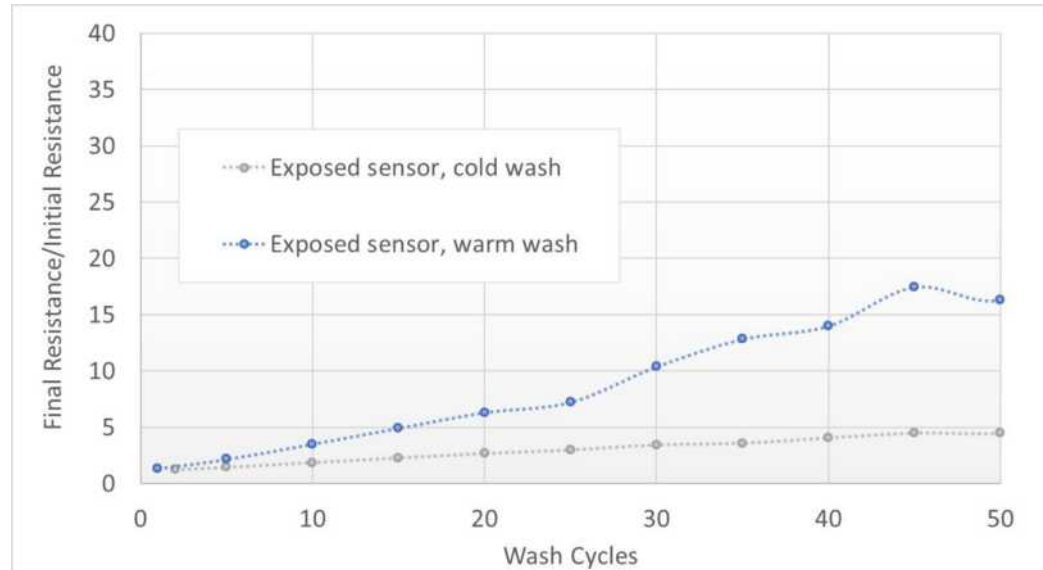


PE874 sets new standard in stretch electrical performance

- Max initial strain – PE874 withstands 100% stretch maintaining low resistance
- Cyclic strain 0 – 10%, 80 cycles – PE874 resistance in narrow and well controlled band.

Test description: Ink printed on TE-11C base film. 10cm x 0.2cm conductor. Strain rate 508 mm/min

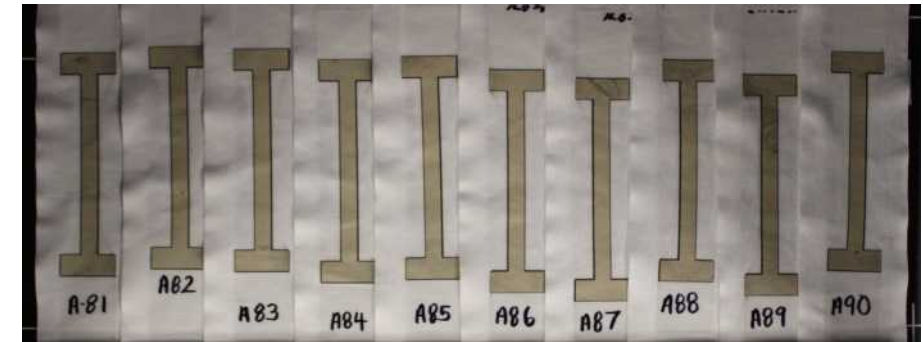
PE876 exposed sensor wash durability



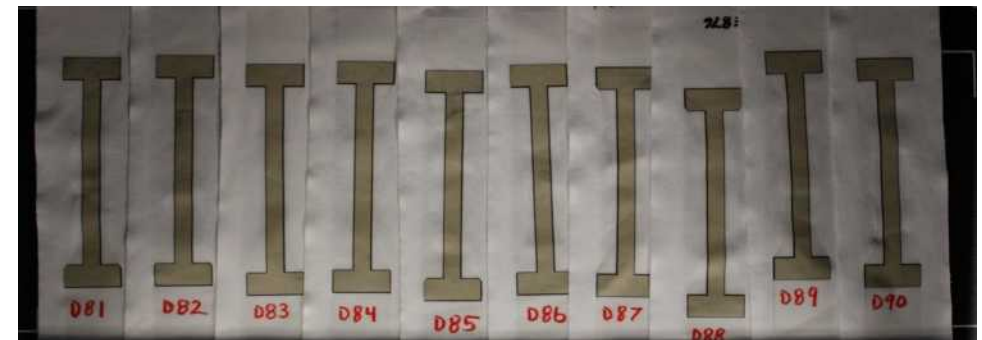
High conductivity, wash durable sensor
Ag-based sensor material designed for wash fastness
Exposed sensor not compatible with hot tumble dry

Test description: Ink printed on TE-11C base film. 10cm x 0.7cm conductor. All washed top loader per standard AATCC/ISO 135 wash protocol. Air dried.

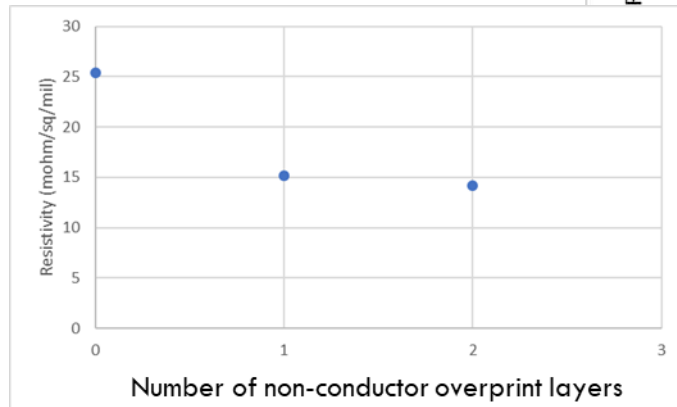
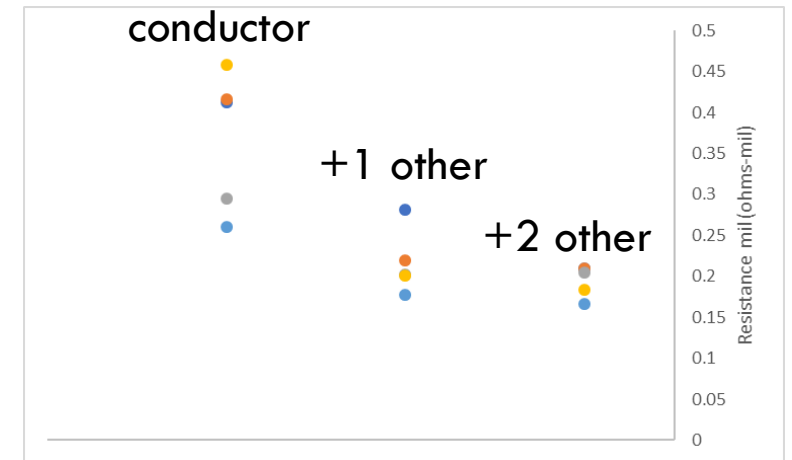
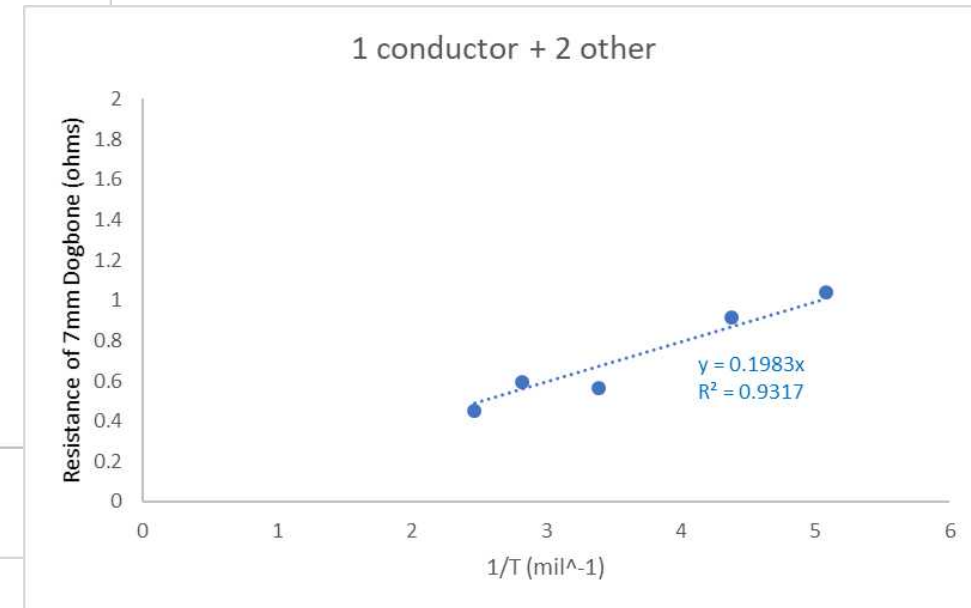
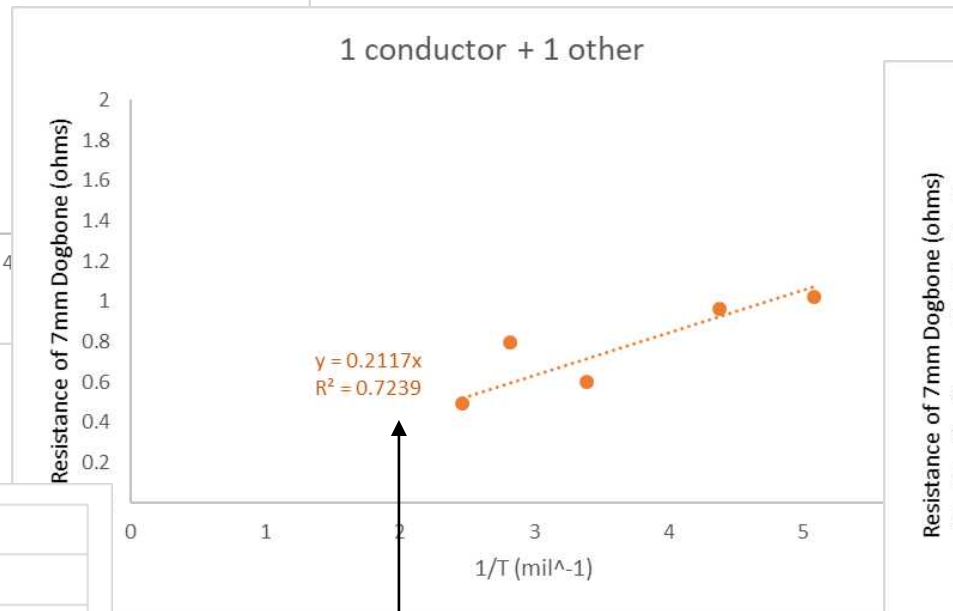
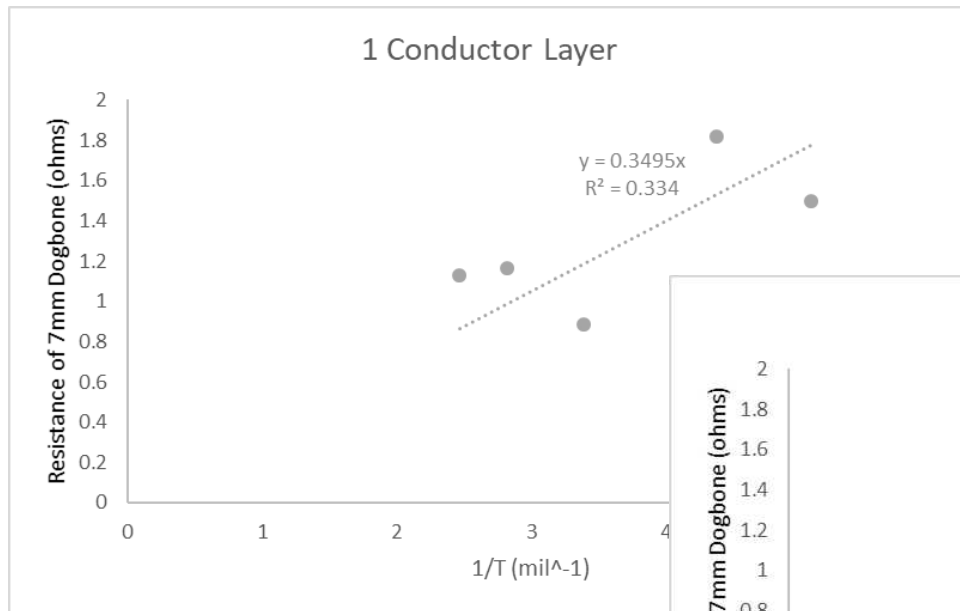
Cold Wash, 25th cycle



Warm Wash, 25th cycle



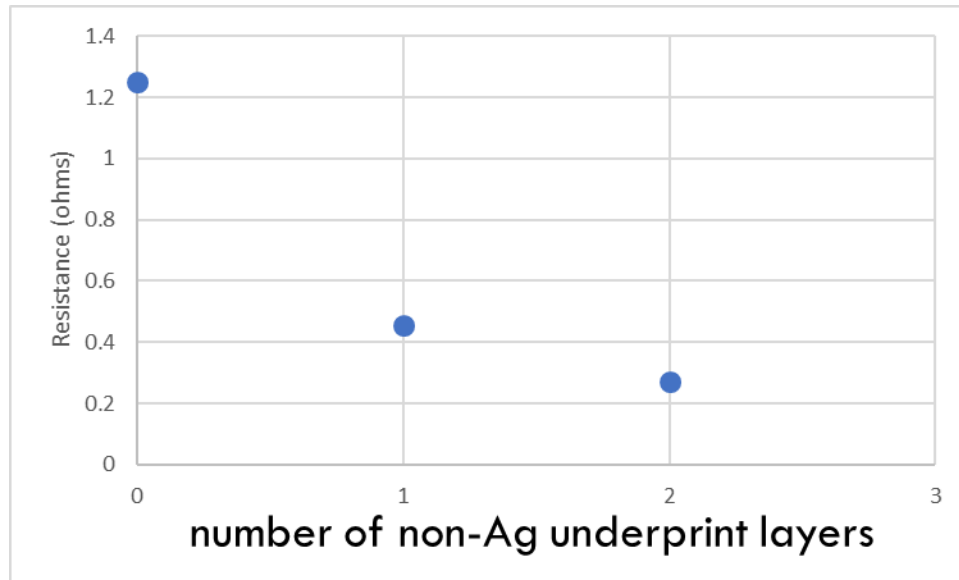
Build affects resistivity- overprints



Slope of trend line is
proportional to resistivity

Build affects resistivity- underprints

PE876 Top Layer

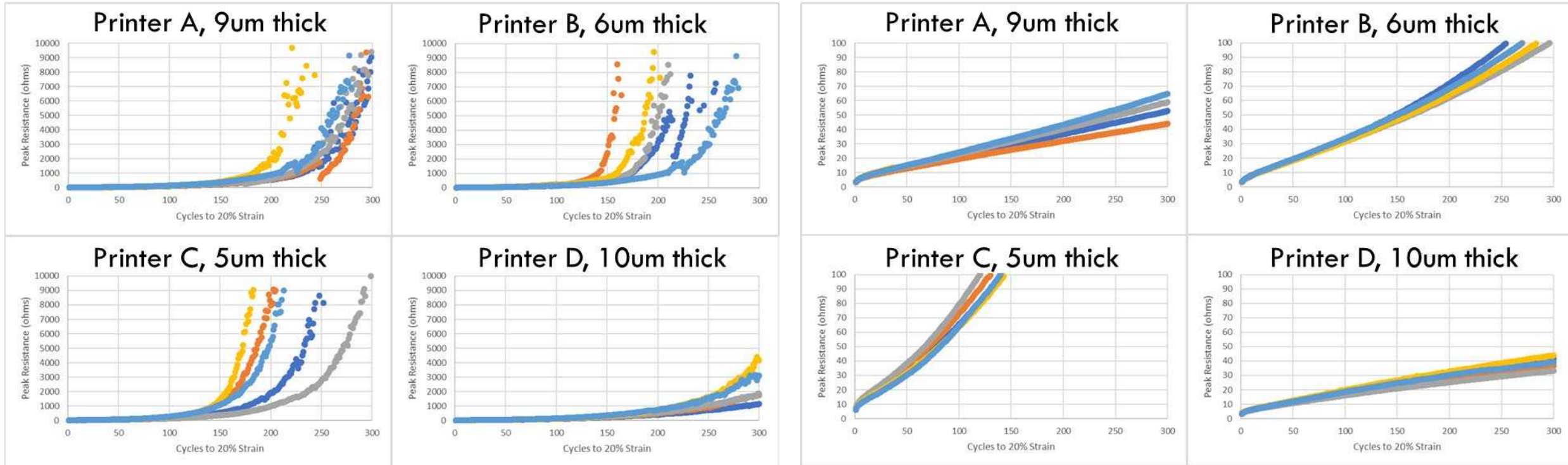


PE876 is desirable as an exposed sensor, so we do not want to overprint it. But we see that underprint layers also have a beneficial impact on as printed resistance (left). Even when those carbon layers are on top of a PE874 silver base layer (right).

Impact of overprint on stretch/electrical response

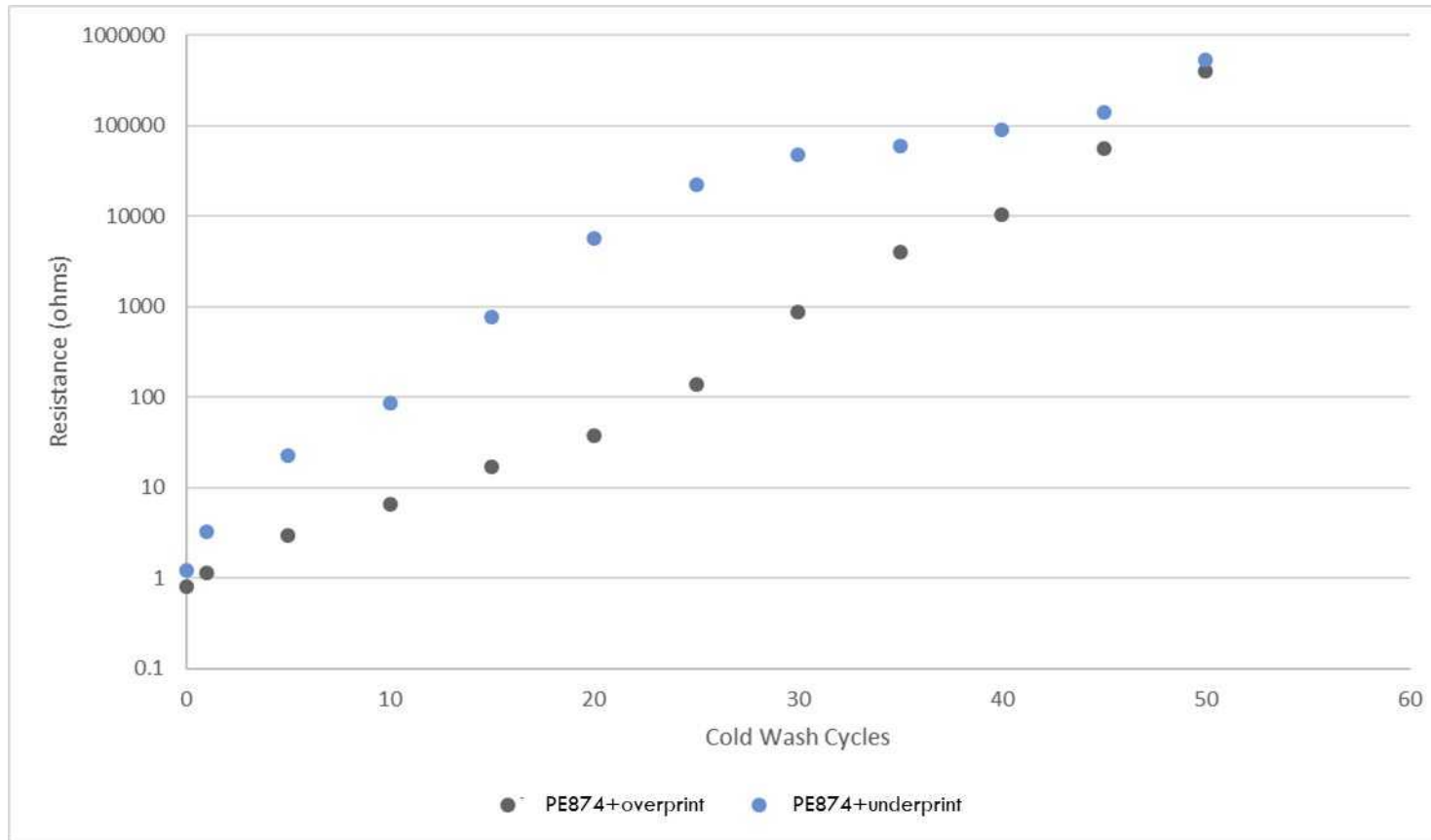
1 print pass silver conductor (PE874)

Add 2 additional non-conductor print layers



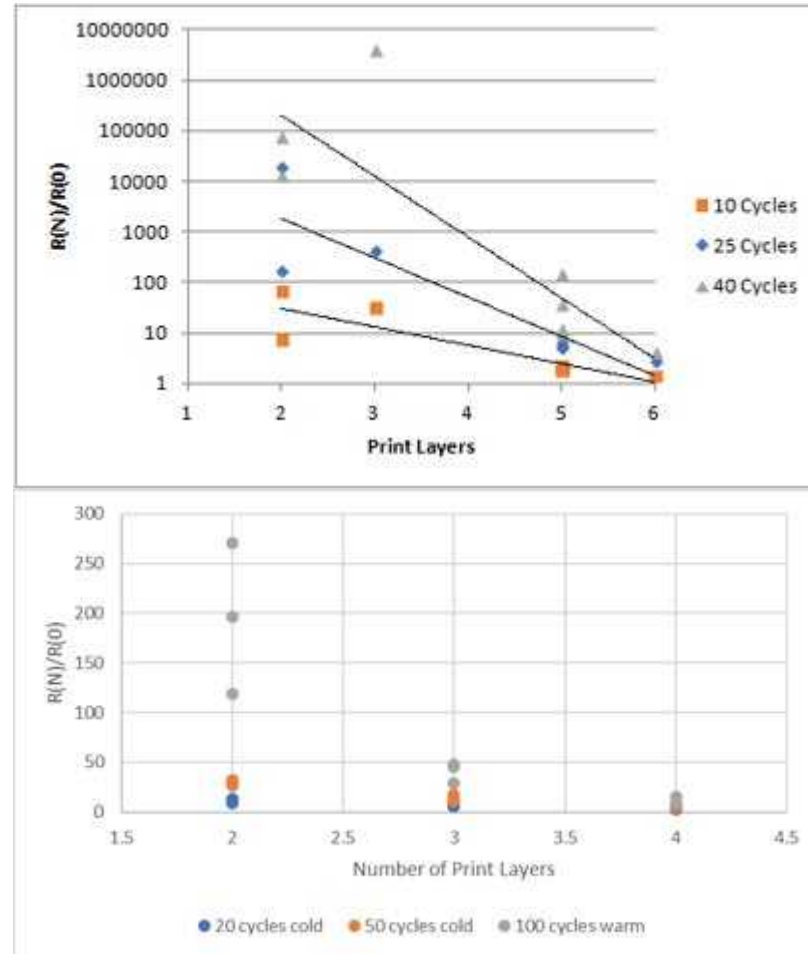
20% strain, 20in/min, strain control, 7mm dogbone on TE11C substrate

Build affect on wash – underprint vs overprint



Build affect on wash – number of print layers

Increasing print layers results in exponential improvement in wash durability regardless of what those print layers are.



PE874 with overprints

Some single and some double conductor prints with the balance of layers being non-conductors

PE876 with underprints

Summary

Build (number of print layers and paste combinations) impacts durability in a complex way. Finished article size and shape impacts durability.

Knowledge of stretch/electrical response and wash durability for various builds guides design

Optimize performance and cost to needs of application

Durability and performance testing needs to be done at or near the finished article stage



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■ Smart textiles, from lab scale
to commercial products

Wednesday, June the 05th

Presented by Justine Decaens

- AGENDA:

1. Research orientations
2. Prototyping steps
3. Toward commercialization
5. The need for standardization



■ 1. RESEARCH ORIENTATIONS:

■ Smart textiles : market overview

• A few figures:

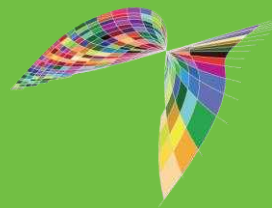
- Smart textiles = 300 Billions of US Dollars in 2012
- Smart textiles = 1 500 Billions of US Dollars in 2020
- Annual growth of 36%

• Key sectors:

- Protection
- Sports and Leisure
- Medical

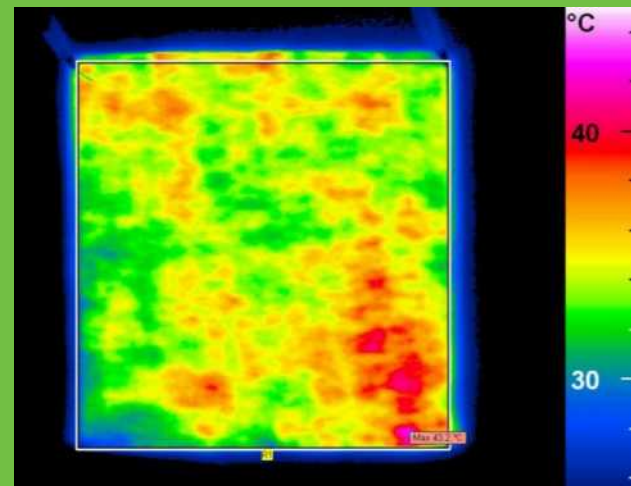
Source : Dalsgaard, R. Sterrett. 2014. "White paper on smart textile garments and devices: a market overview of smart textile wearable technologies".
Market Opportunities for Smart Textiles 2014. 11pages.

1. RESEARCH ORIENTATIONS:

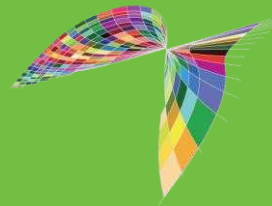


Smart textiles : thermal fabrics

- Heating or cooling
- Joule or Seebeck effect
- Conductive fibers & yarns
- Example of projects :
 - Heating orthosis for thermo-therapeutic applications
 - Heating base layers for workers in cold environment
 - Active cooling vest for deep-mines workers

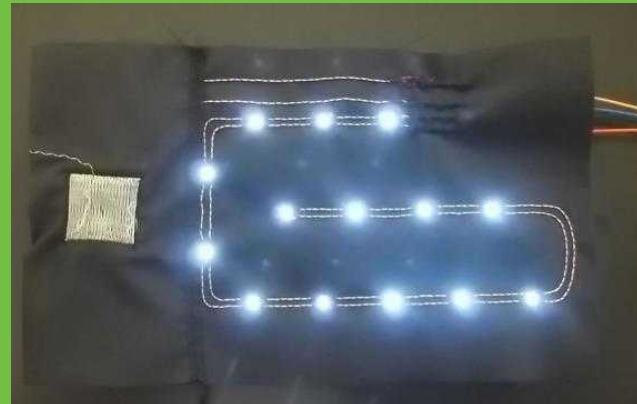


1. RESEARCH ORIENTATIONS:



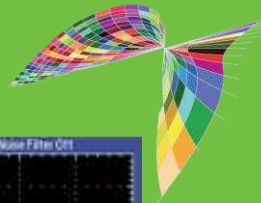
■ Smart textiles : lighting fabrics

- LEDs integration,
 - Electroluminescent panels,
 - Optical fibers
-
- Example of projects :
 - Lighting vests for constrution workers
 - New generation of illuminated purses



www.fptt-pftt.gc.ca

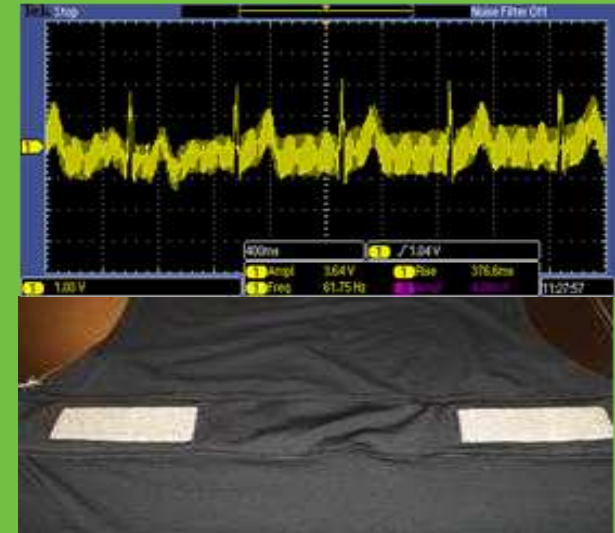
1. RESEARCH ORIENTATIONS:



Smart textiles : sensing fabrics

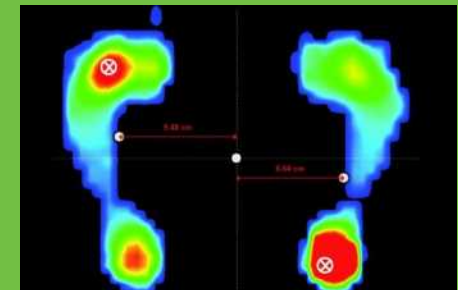
Bio-monitoring : conductive fabrics

- Muscular activity sensors
- ECG sensors
- Respiration sensors



Pressure sensors : piezoresistive membranes

- Smart insoles to measure the plantar pressure
- Pressure sensors network to monitor aircraft structure



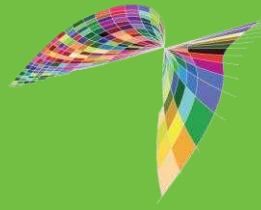
Humidity sensors : conductive fabrics

- Electro-conductive geosynthetics to detect leaks in landfills

- AGENDA:

1. Research orientations
2. Prototyping steps
3. Toward commercialization
5. The need for standardization

■ 2. Prototyping steps:



■ Defining the integration level:

1st Generation

- After final assembly and finishing.



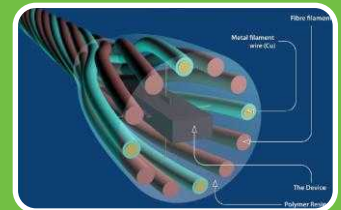
2nd Generation

- Manufacturing of the fabric.

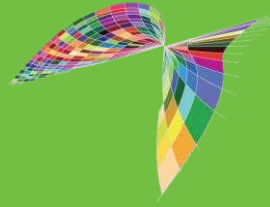


3rd Generation

- At the level of the fibers and yarns

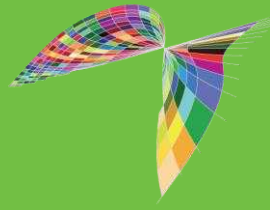


■ 2. Prototyping steps:



- Identifying the appropriate materials
- Selecting the right application process
- Determining the most suitable design
- Testing the prototype performances

■ 2. Prototyping steps :



■ Identifying the appropriate materials

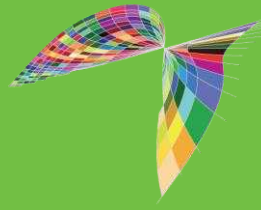
● **Metallic conductive yarns :**

- **Composition :** Silver, copper, stainless steel
- **Structure:** Core/sheath or multifilaments
- **Diameter**
- **Hairiness**



■ 2. Prototyping steps:

■ Identifying the appropriate materials

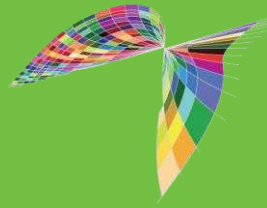


- **Conductive polymers:**
- **Polyaniline, Polypyrrole, etc. → doped polymers**
 - Level of conductivity
 - Ease of manufacturing
 - Performance stability
- **Carbon charged polymers**
 - Graphite or carbon nanoparticles dispersion



www.plastic-lemag.com

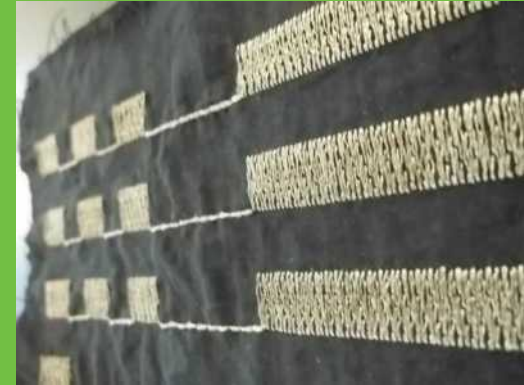
■ 2. Prototyping steps:



■ Selecting the application process : metallic conductive yarns

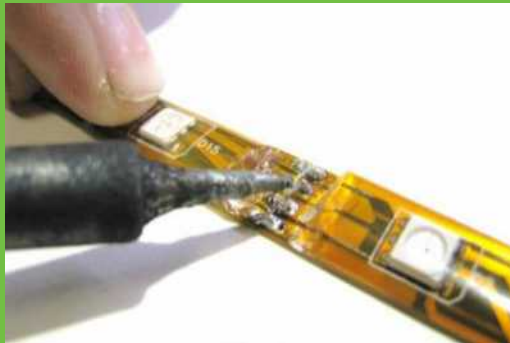
- **Structure choices**

- Weaving
- Knitting
- Embroidering



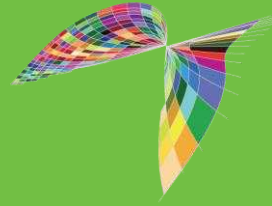
- **Connection methods**

- Soldering
- Glueing
- Snap connectors



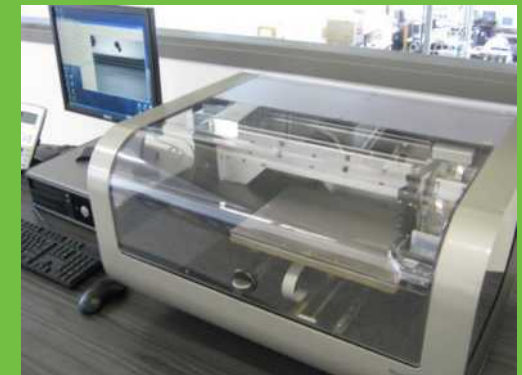
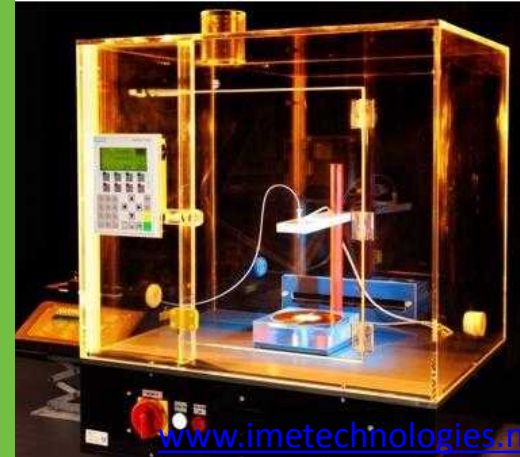
www.usledsupply.com

■ 2. Prototyping steps:

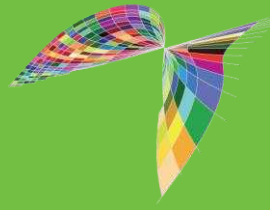


■ Selecting the application process : conductive polymers

- **Yarns transformation:**
 - Electrospinning
- **Surface application:**
 - Spin coating
 - Screen printing
 - Inkjet printing



■ 2. Prototyping steps:

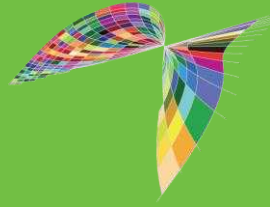


■ Determining the design:

- **Consideration of the wearer's comfort**
 - Freedom of motion despite the addition of new functions
 - Protection of these functions against premature degradation
- **Preparation of the patterns**
- **Conception of the diverse components**
- **Final assembly**



■ 2. Prototyping steps:



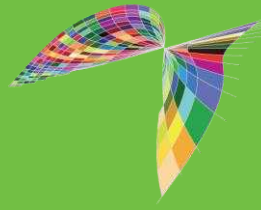
■ Testing the prototypes performances

- **Standard testing:**
 - Resistance to washing
 - Resistance to ageing (Xenon light)
 - Mechanical resistance (tensile strength, cut or abrasion resistance, etc.)

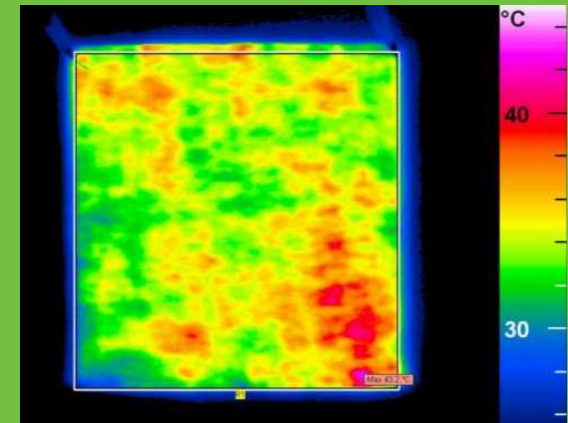
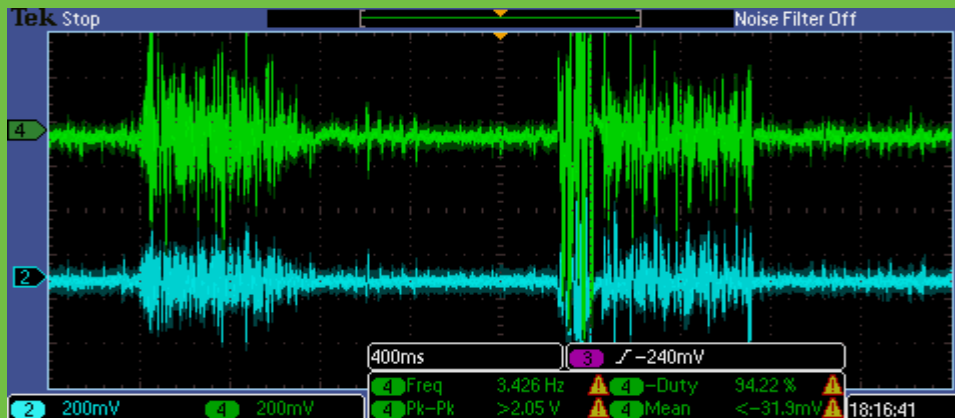


■ 2. Prototyping steps :

■ Testing the prototypes performances



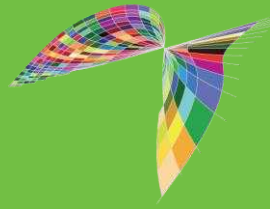
- **Specialized testing:**
 - Development of test methods based on the needs
 - Electrical resistance testing
 - Infrared thermal imaging
 - Synthetic sweat spraying
 - Oscilloscope data visualization



- AGENDA:

1. Research orientations
2. Prototyping steps
3. Toward commercialization
5. The need for standardization

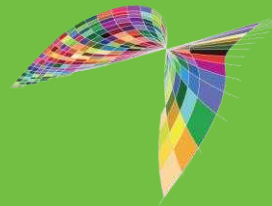
■ 3. Toward commercialization:



■ Major considerations:

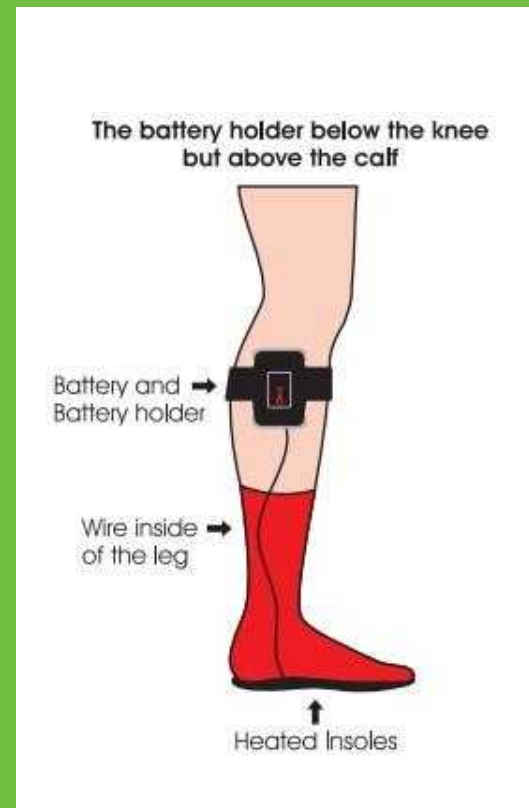
- **Productivity : notion of speed**
 - Dependence on the manufacturing method
 - Ex : Embroidery VS Knitting
 - Assembly : Least number of steps possible
 - Automation : Reduction of manual inputs
- **Cost control**
 - Choice of raw materials
 - Optimization of raw materials consumption
 - Optimization of the productivity
 - Set up of quality control process

■ 3. Toward commercialization :

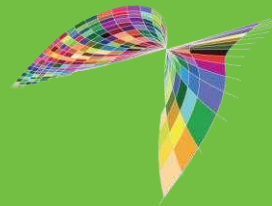


■ Example of commercial products: Thermastrom™

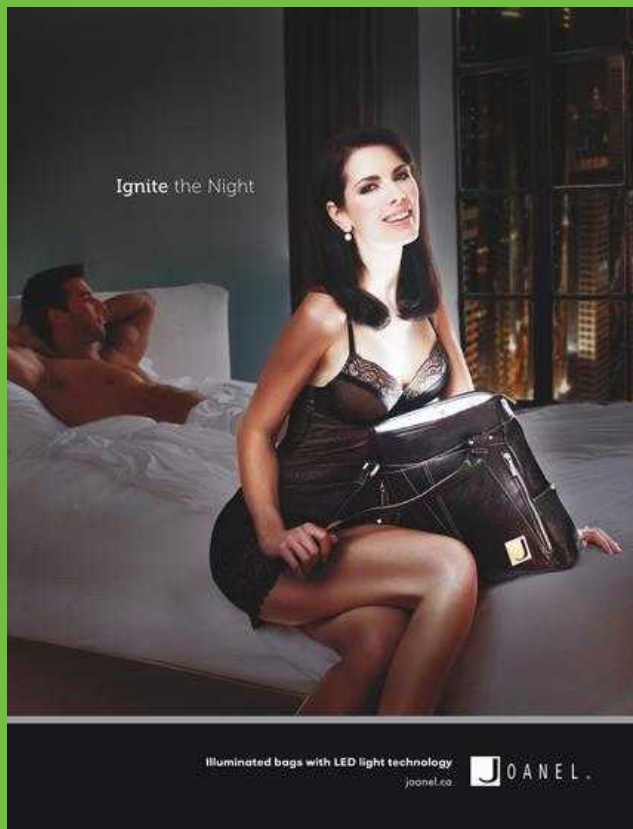
• 1 Technology → Several applications



■ 3. Toward commercialization :



■ Example of commercial products: lighting purses Joanel™



■ 3. Toward commercialization :



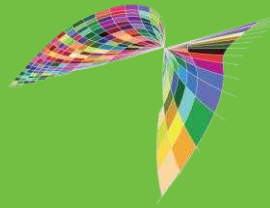
- Example of commercial products : Vital signs monitoring shirt :Tex-Life™



- AGENDA:

1. Research orientations
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4. The need for standardization

■ 4. The need for standardization

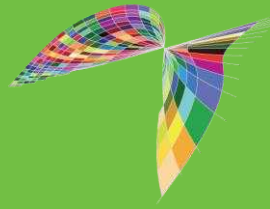


■ SUSTASMART initiative



- Lack of standards for smart textiles
- Brake for their development on the market
- SUSTASMART = Supporting Standardisation for Smart Textiles
- International partners
- Objectives :
 - Organizing and defining smart textiles categories
 - Establishing the need for standards
 - Working on the elaboration of test methods

■ 4. The need for standardization



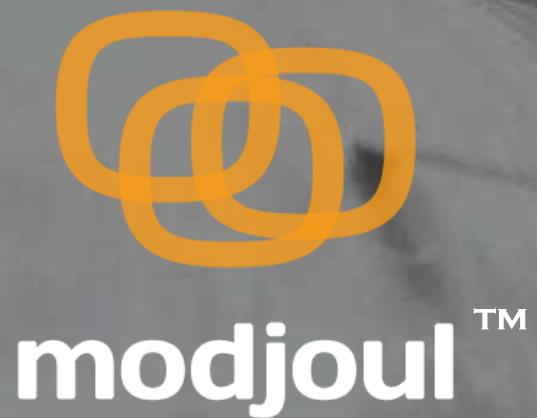
■ CTT Group developments

- Guided by the need to test our prototypes
- Elaboration of internal test methods
- Some examples:
 - GCTTG 4001-07 : Measure of conductive fibers electrical resistance
 - GCTTG 4002-09 : Measure of nonwoven electrical conductivity
 - GCTTG (en cours) : Measure of heating textiles thermal resistance



■ Questions ?

Thank you for your attention !



Let data drive TM

TECHNOLOGY THAT IMPROVES THE WAY COMPANIES FUNCTION



Why Use a Wearable



Individual: Point Issue for Correction



Groups of Employees: Compare to known thresholds, or set thresholds for improvement; Work site management



Organization: Change the way an organization is managed



We Keep Employees Safe



The SmartBelt Features

Easy to Use

The wear and go model of SmartBelt means **all you need to do** is put it on to start seeing data.

Common Article of Clothing

The SmartBelt is worn exactly like a normal belt – through the belt loops, snug enough to hold your pants up, and with the buckle in the center of the body.

5 Sizes

The SmartBelt can fit a wide range of body types and sizes ranging from a 30" waist to a 44" waist.

1GB of storage

With a 1GB SD card that can store up to 2 weeks of data, the SmartBelt was designed to handle connectivity challenges from Wi-Fi dead zones to use cases where workers are not connected for extended periods of time.

Vibration Motor

The onboard vibration motor provides real-time haptic feedback to a user when an at risk movement is performed.



Our Customers

Adecco

Amick Farms



BRIDGESTONE

CATERPILLAR



CINTAS



Eby-Brown



Gulfstream



HONDA
The Power of Dreams



meijer



NORTHROP GRUMMAN



Raytheon



STÜKEN



The Modjoul Platform

Multiple Personas

From a single individual to an entire enterprise, data is accessible so risks can be eliminated.

View all Locations at Once

Easy to understand map views that will let you know when there are any alerts for safety related events.

APIs

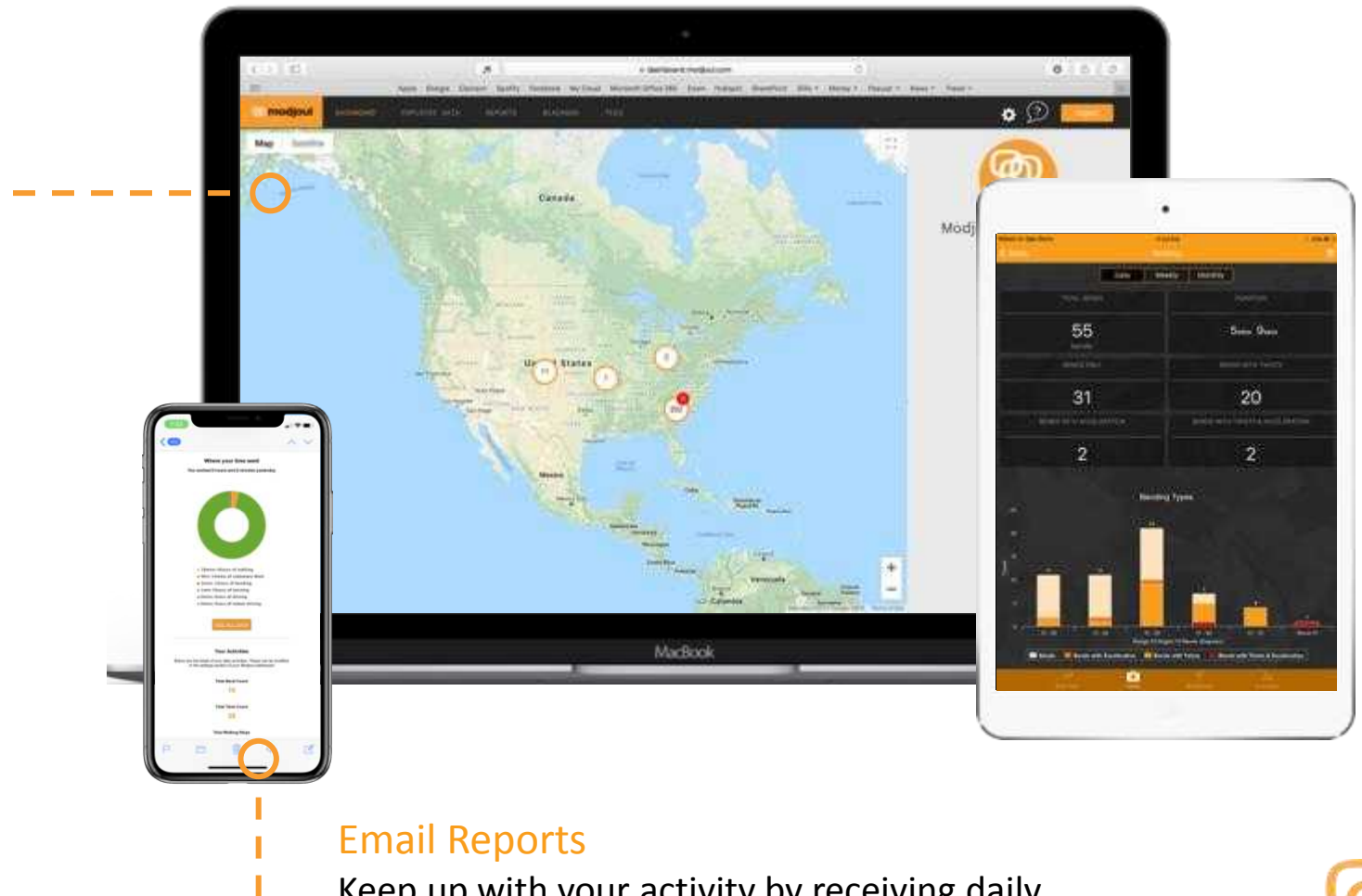
All the data collected by Modjoul is available via APIs allowing it to be used by the customer for any unique applications.

Benchmarking

Individual and organization data can be compared to the entire modjoul data ecosystem in order to see how you compare.

Email Reports

Keep up with your activity by receiving daily, weekly, or monthly activity updates





5 Steps in Building a Safety Wearable



Step 1 – Business Case

Event Type	Annual Loss \$ (Billions)	% of Pie
Overexertion Involving Outside Source	\$ 15.08	24%
Falls on Same Level	\$ 10.17	16%
Falls to Lower Level	\$ 5.40	9%
Struck by Object or Equipment	\$ 5.31	9%
Other Exertions or Bodily Reactions	\$ 4.15	7%
Roadway Incidents	\$ 2.96	5%
Slip or Trip Without Fall	\$ 2.35	4%
Caught in/Compressed by Equipment	\$ 1.97	3%
Struck Against Object or Equipment	\$ 1.85	3%
Repetitive Motions Involving Micro-tasks	\$ 1.82	3%
	\$ 51.06	

Source: Liberty Mutual Analysis on **Workplace Safety**

Key Considerations:

- Size matters
- How to protect the models....
- How much data does your model or use case need?
- How to protect the electronics – abuse, environmental and the part of the body?
- No one cares if your battery life lasts past a typical shift UNLESS it lasts a week





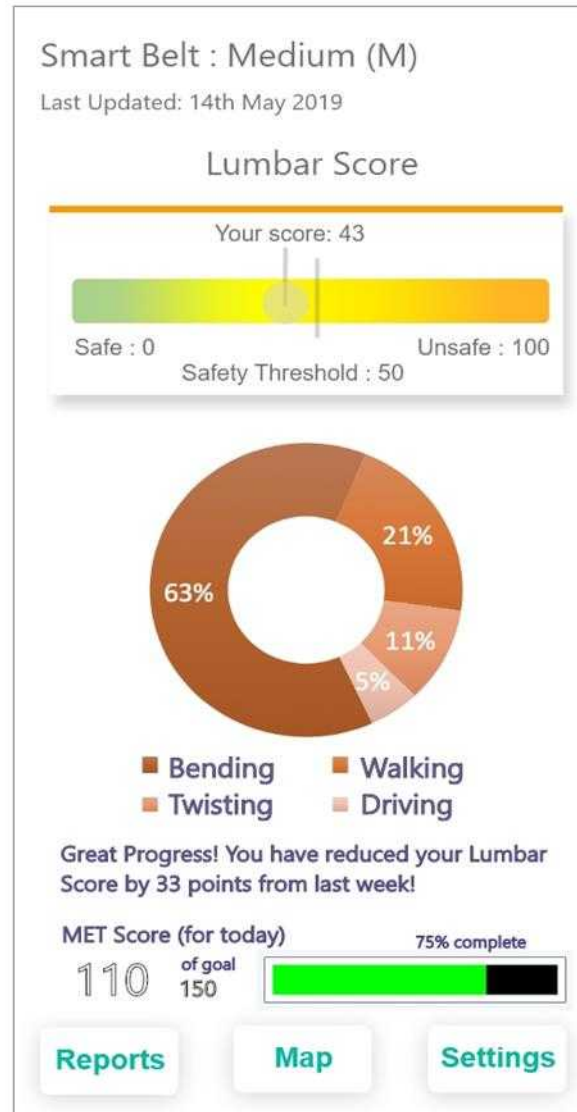
Step 2 – All the Coding You Will Want to Do

Firmware

- Software that operates the hardware
- Runs the processor and the components
- Primary purpose is to collect and send data from the sensors
- Battery management and conservation

Cloud Software

- Operates the IoT engine
- Displays the persona data – employee, supervisor, leader, administrative
- Device Management



IoT

- Payload Ingestion – Sets up multi-tenancy and security certificates
- Computing Power – How much processor will you need to handle thousands of calculations at one time
- Data Storage and Archival – drives the overall latency in the UI

Mobile Application

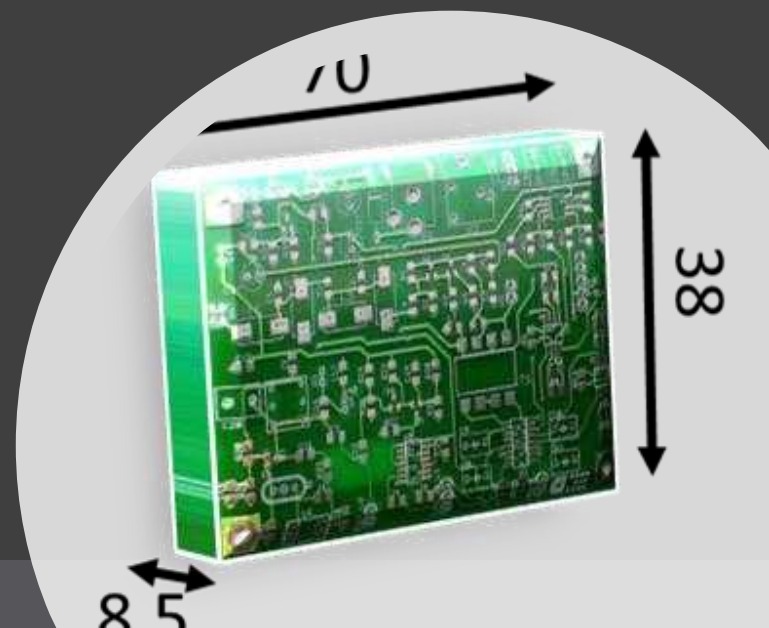
- Two Main Purposes for the mobile application
- Send and receive the data from blue tooth if applicable
- Display the employee data



Step 3 – Design Hardware

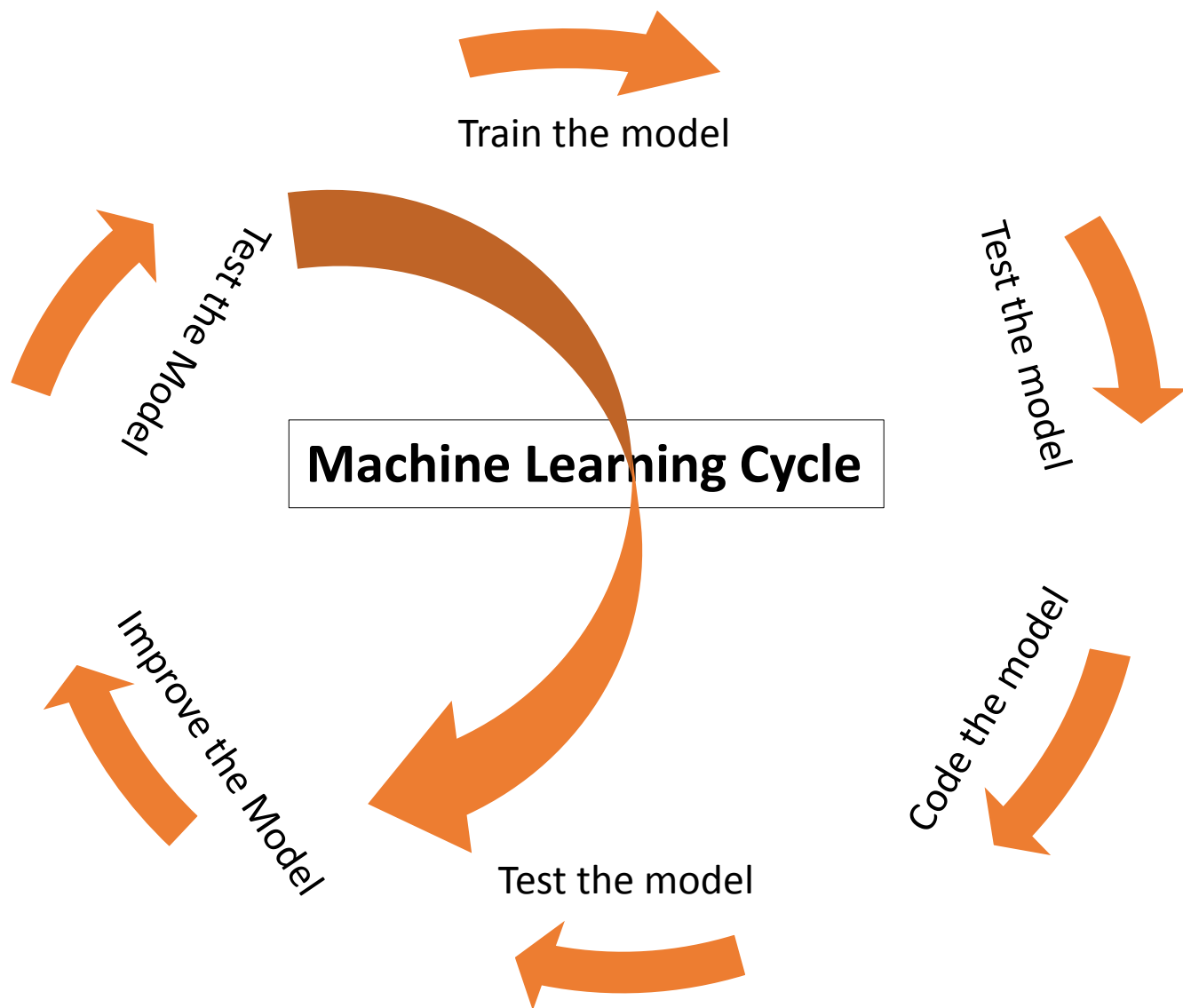
- Sensors
 - Detect location, motion, environment, and biometric data
- Processor
 - Determines how fast data is sent to the radio and runs firmware code
- Data Storage
 - Provides short-term storage and allows for inconsistent radio signal
- Radio
 - Three basic types of radio: Wi-Fi, Bluetooth, and Cellular
- Battery
- Mechanical
 - Attachment to equipment or clothes

Then you will need to test!





Step 4 – You are now part of the AI Revolution



We need people to test a
wearable IOT product
Make \$40 for showing up plus \$10
for every person you get to show up.
Takes 45min - 1 hour.

You + 10 friends= \$140
You + 50 friends = \$540

Contact:

Nick@Modjoul.com

206-605-5883

Limited Availability Act Fast



modjoul

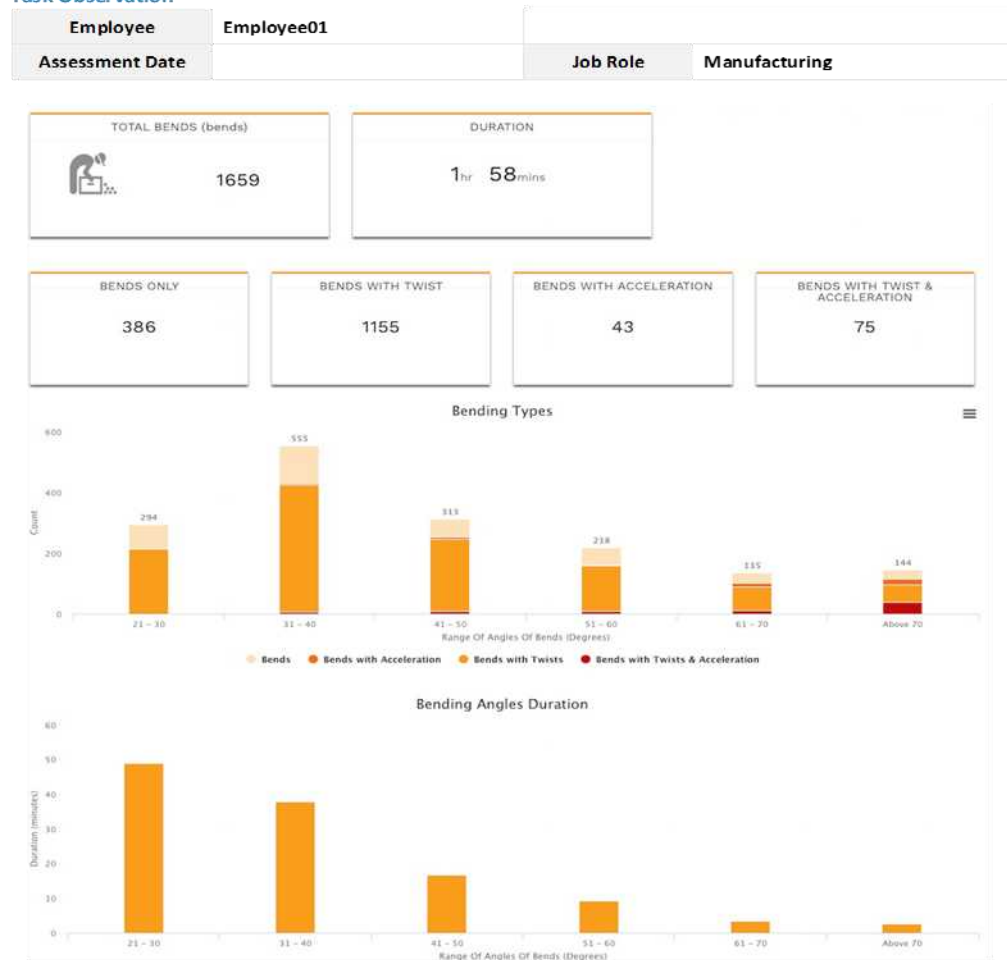
**398 College Ave.
Clemson, SC**





Step 5 – Implementation

Task Observation



- Companies have a process for implementing new technologies
- Business cases and uses develop over time
- Liberal warranty process
- Customer Success Specialist
- Reports showing utilization

Metric	Individual	Position	Supervisor	Company
Dynamic Lumbar Score	130	120	125	110
Static Lumbar Score	340	290	300	255
Total Lumbar Score	470	410	425	365
MET	1.85	1.75	1.81	1.65
Bends > 60 degrees	15	8	10	10
Twists > 45 degrees	32	30	28	20



Employee Feedback

Employee Engagement is one of the biggest indicators for deployment success and ultimately positive behavioral based change

"After wearing the belt at work all day, I move differently when I am at home because I forget I'm not wearing the belt."

"It is more comfortable than the belt that I normally wear to work."

"It was really cool getting to see how much I move from day to day and how far I have walked."

"I forgot I had it on until it buzzed me."





SmartBelt as a Portal

Wearables



Non Wearables



Modjoul Can

Build A Wearable

to collect information on how people move, where they are, and what the environment is like.

Create Data Models

to interpret the output of digital signatures with the use of artificial intelligence and present in an actionable way.

Provide a Software Platform

for any wearable device that can deliver actionable insights, benchmark organizations, and reduce risk.



modjoul



Contact Us

Contact Us

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Clemson, SC 29631

Eric Martinez

Email: Eric@Modjoul.com

Phone: (206) 291-5708

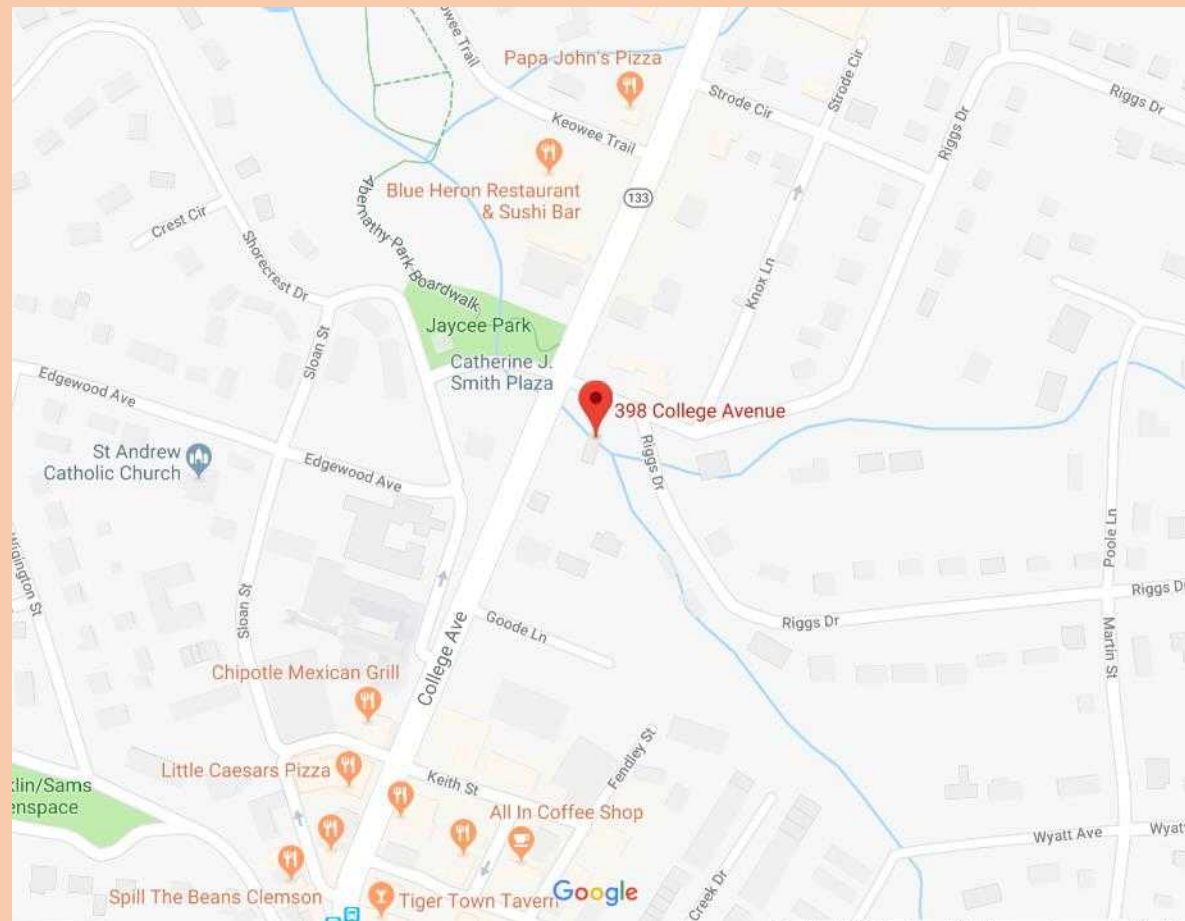
Jen Thorson

Email: Jen@Modjoul.com

Phone: (973) 868-8319



<https://twitter.com/modjoul>





U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – SOLDIER CENTER

Electronic Textiles for Soldier Networks and Sensors – ASTM Workshop on Smart Textiles for Workwear Applications 5 June 2019

Carole Winterhalter

Textile Technologist

Soldier Protection and Survivability Directorate

DISTRIBUTION STATEMENT A.
Approved for public release.



ELECTRONIC TEXTILES FOR SOLDIER NETWORKS AND SENSORS



Overview:

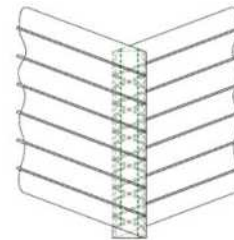
- Army Soldier Power
- Developmental Networks
- Novel Ultrasonic Sewing Technology: SEWiT Etextiles
- Etextile Connectors and Connections
- Standardization Activities



Wearable Cables



Wearable Connectors



*Novel Ultrasonic
Sewing Technology*





ARMY SOLDIER POWER OVERVIEW



- Power is required by Soldiers operating in austere environments where there is no power infrastructure.
- Soldier Power is a key enabler for operations, essential for patrols and required for Soldier sustainment.
- Reducing fuel and water demands reduces the number of convoys and allows Soldiers protecting convoys to accomplish other tasks.
- Goal is to reduce dismounted Soldier's energy loads, increase mission duration and reduce logistics.
- The Army is aggressively deploying Soldier Power solutions to include advanced power management devices, fuel cells, energy efficient generators, and alternative energy sources.



<https://www.asaie.army.mil/Public/ArmyPowerEnergy/SoldierPower.html>



SOLDIER POWER OPERATIONAL ENERGY TRENDS



Energy requirements are rising exponentially, causing a challenging trend for increased power duration for the dismounted Soldier.





PROBLEM STATEMENT

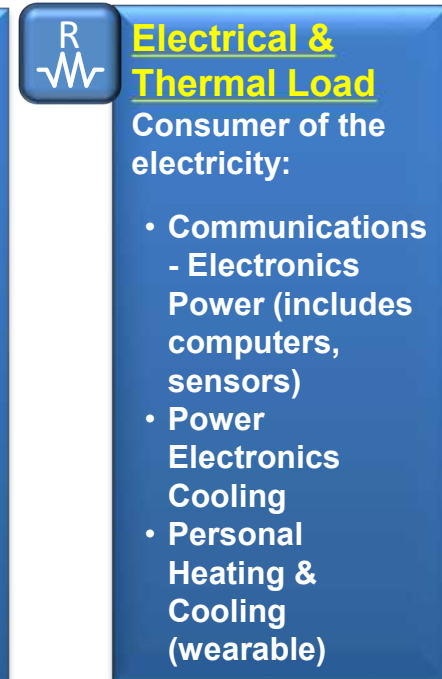
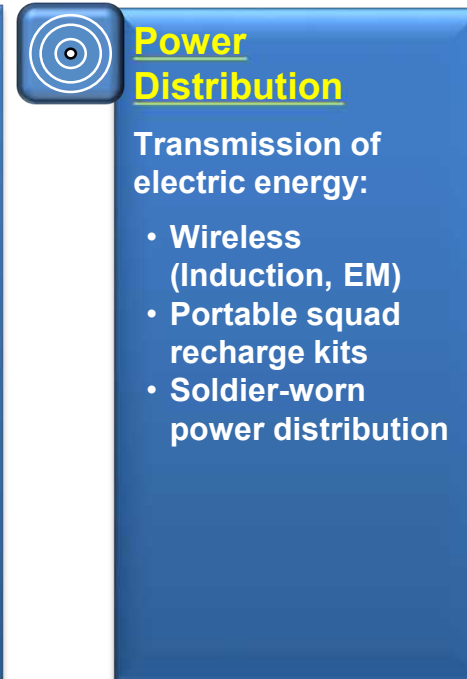
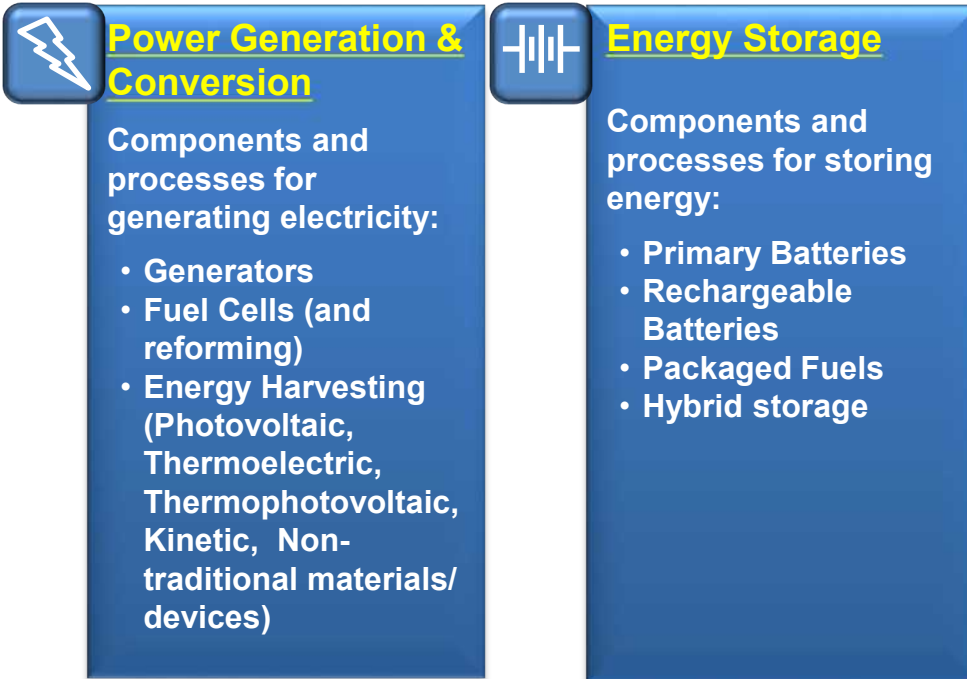


- Future infantry mission durations will be longer and more isolated from supply lines.
- Soldiers use more technology which act as force multipliers enhancing their capabilities.
- These technologies and power solutions must be carried.
- Capabilities = Batteries = Weight Burden = Ineffective Soldiers

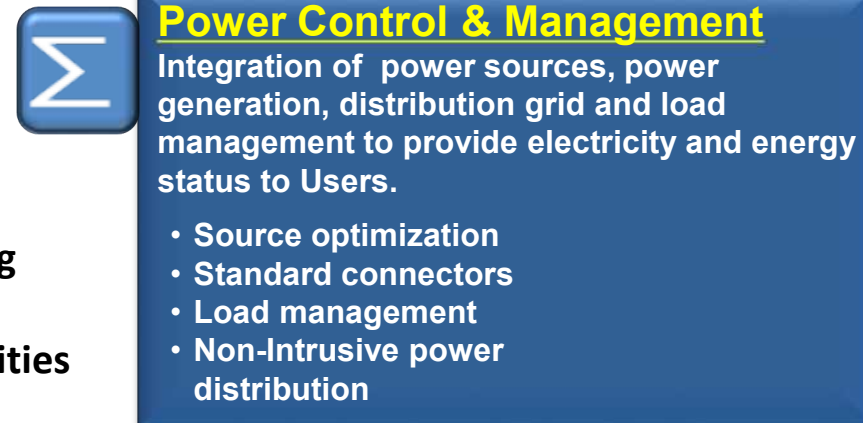
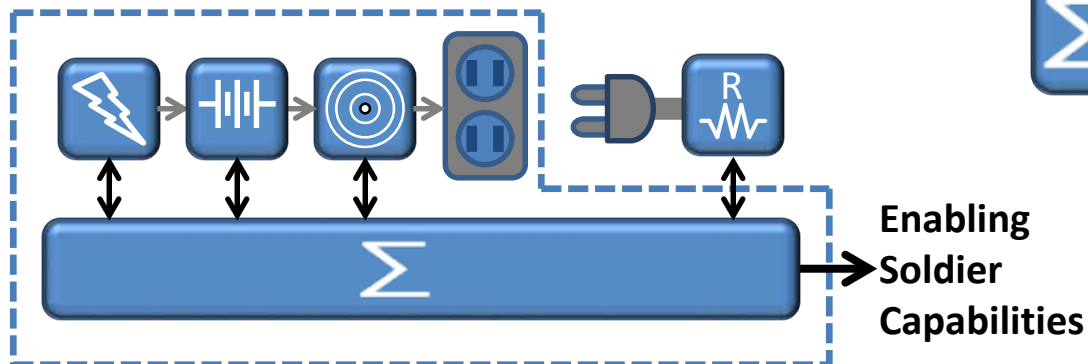




SOLDIER/SQUAD POWER & ENERGY FRAMEWORK



Power & Energy Framework





POWER GENERATION KINETIC ENERGY HARVESTING



- **Pro**

- Lightweight
- Power availability

Backpack Frame Kinetic Harvester

- Energy generator based on frequency and mass
- Material: plastic
- Can be used as a static power generator
- Ruggedized frame able to handle up to 100 lbs.



- **Con**

- Low to medium noise
- Effort required
- Acceptability

Kinetic Knee Harvester

- Energy Generator based on knee movement
- Materials: Kevlar and carbon fiber





ELECTRONIC TEXTILES DEMONSTRATION



Etetextiles replace cabling that transfers power between legs and up torso of Bionic Power's kinetic energy harvesters.

Etetextiles also replace some cabling in the eIOTV compatible network reducing weight and snag Hazards.

Reduces cabling weight and snag hazards.

TRL – 6 (fabric); TRL – 4 (welding)



Technology Demo: 10 – 12 Oct 2017, CCDC-SC Fightability Course, Hudson, MA.

Objective: evaluate electrical harvesting potential of knee harvesters when networked with etextile trousers and E-IOTV and impact on mobility, agility and comfort.

Who: Two EXFOR size large Soldiers

Results: No difference in electrical performance between cables and etextiles; soldiers preferred etextiles.

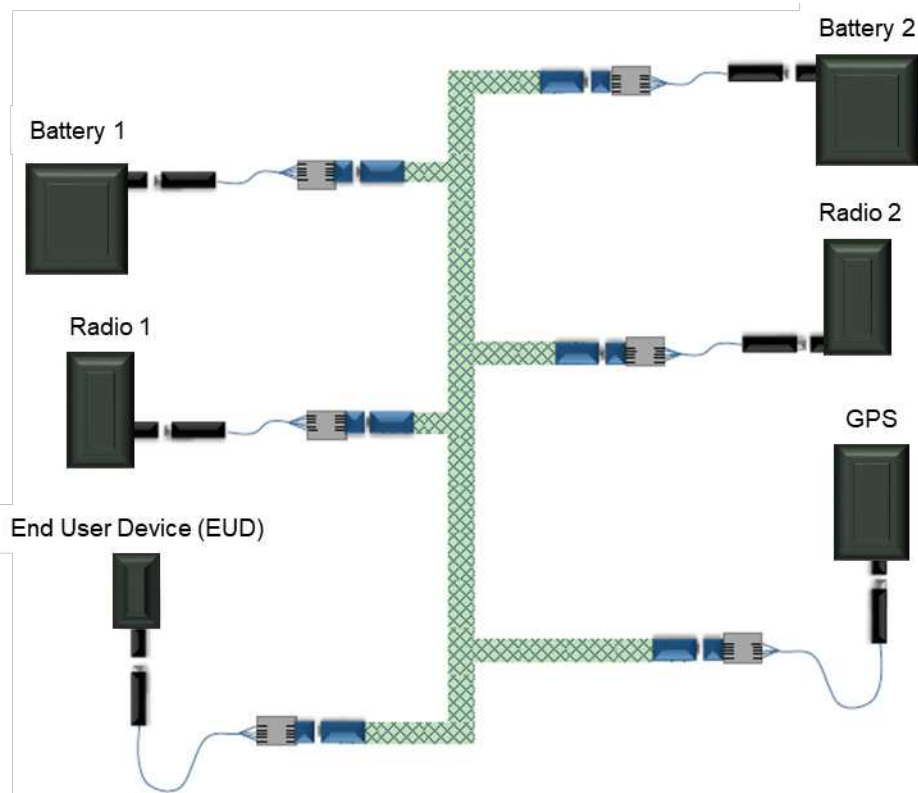




DEVELOPMENTAL ETEXTILE NETWORK



Etextile Network



Purpose: Develop a custom connectorized etextile network for eventual and full integration with IOTV or similar Soldier tactical vest at same or reduced cost and meeting MIL-STD performance requirements.

Results/Products: Prototype network that passes power and data between etextiles and wearable devices that is durable, insulated, and EMI-shielded.

Payoff: Wearable low-profile electronic network with distributed versus centralized power manager creating smaller components facilitating better integration into the Soldier system resulting in improved mobility, agility and comfort, as well as weight and snag hazard reductions.



Selectively Enabled Wiring in Textiles (SEWit)

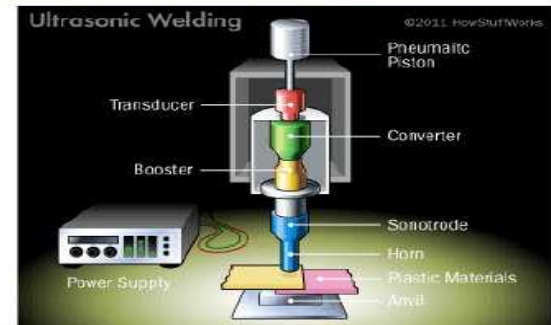
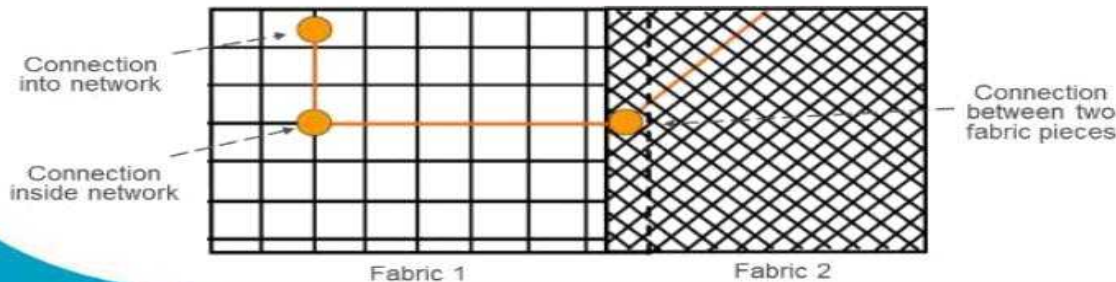


Enabling Technology

Elements of IST's E-textile Technology



- E-Yarn Construction
- Weaving
- Printing/Finishing
- Network Assembly





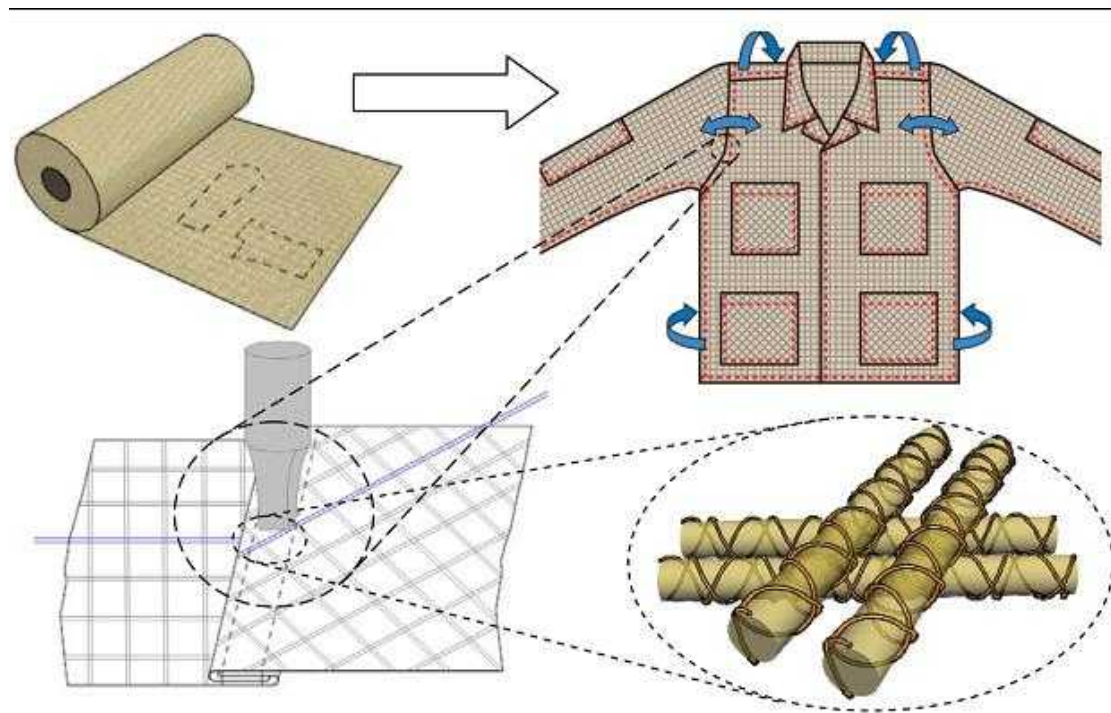
ELECTRONIC TEXTILES - SEWiT



Novel Seaming Technology for Electronic Textiles

Modification of ultrasonic welding technology to form electrical pathways across seams

Enabling Technology



“Method of Making Electrically Active Textile Article,” US Patent No. 9,009,955, Patent License Agreement with DCS.



Electronic Textiles SEWiT Data Sheet



SEWiT Data Sheet (US Patent: US9009955)

- **Durable:** Abrasion resistance similar to that of comparable textiles
- **Launderable:** 20 – 100 cycles
- **Print/Coating Compatible:** Proven compatibility with conventional role-to-role processes include scouring, screen printing, and sanforizing.
- **EM Signature:** Compatible with E-textile shielding materials. Demonstrated shielding effectiveness of up to 90 dB.
- **Power Capabilities:** Networks can be tailored to system requirements. Examples demonstrated to date include:
 - 6A @ 16V (96 W)
 - 2.6A @ 384VDC (998 W)
- **Data Networks:**
 - Able to form e-textile networks that are compatible with virtually any standard.
 - Examples demonstrated include Ethernet (Gigabit), SMBus, serial ATA, analog audio/video, USB 2.0 (high-speed).

- **Field Modifiable:** Networks can be modified or repaired using easily portable equipment (fits in a carry-on case)
- **Weight Savings:** Application specific - Typically 20%- 80%:

Cable Construction Comparison	g/m
COTS (Cable and Fabric)	67.3
SEWiT Integrated	40.97

- **Temperature Stability:** Good mechanical properties demonstrated -40°F to 150°F
- **Fluid Resistance:** Demonstrated resistant to prolonged (30 day) exposure in JP8, Hexane and salt water.
- **Graceful Degradation:** Grid architecture can be used to provide redundant pathways and ad-hoc configurability.
- **Manufacturing Readiness:** Demonstrated 80 ft. runs of fabric on commercial looms and functionalized after garment assembly using standard ultrasonic weld equipment.

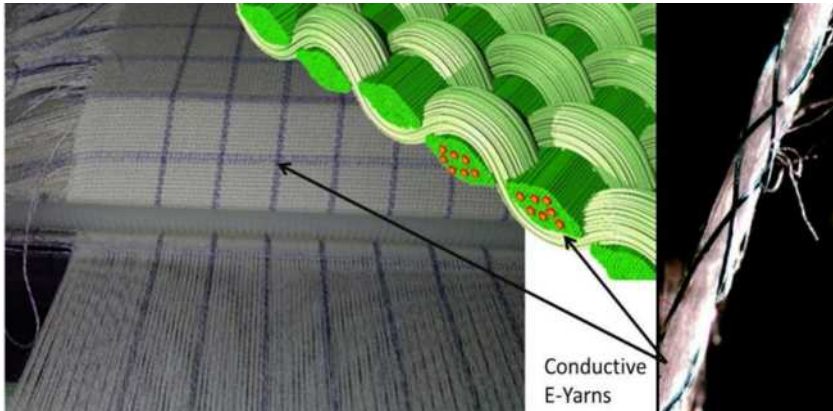


Electronic Textiles - SEWiT Sensor



Background

DCS has been developing etextile solutions since 2005 RDT&E has led to the generation of patented technology and a library of methods and means for its application



Capabilities

DCS's SEWiT technology provides low-profile electronic networks, designed for use in soldier system, that reduce snag hazards and system weight, resulting in improved mobility, agility and comfort.

DCS has used this technology to produce a variety of garment based power and data networks, sensor networks, antennas, and antenna feedlines.

Defense Health Agency (DHA) Research

Through a series of DHA funded SBIR programs, DCS and Mantel Technologies are working to develop complementary E-textile technologies that support the aims of providing increased readiness, better health, better care, and lower cost.

E-textiles for External Threat Sensing (DHA17-001): Use E-textiles to detect, identify and estimate the severity of battlefield injuries (blast, burns, ballistic impact, etc.).

Human Signatures Collection with E-textiles (DHA17A-001):

Identify unique human EM signatures indicative of performance decline or health issues and develop strategies for collecting these human signatures on-body using an E-textile system.

Digital Signature Management for On-body Data Security

(DHA172-002): Develop E-textile network designs and a digital signature manager capable of handling the encryption and authentication process for on-body sensor data.

Payoff and Relevance to DoD

E-textile networking and connectorization technologies can be used to support the development and fielding of:

Textile-based power generation and storage networks.

Wearable networks of miniaturized sensors (environmental, CB, TICs/TIMs, etc.)

Physiological monitoring garments (plethysmo, temperature, moisture, ECG, EMG) that serve as an early warning system to protect against physical/thermal stress and identify performance issues.



Laundryable Enhanced Electro-textile Snap-connector Arrangement (LEESA)

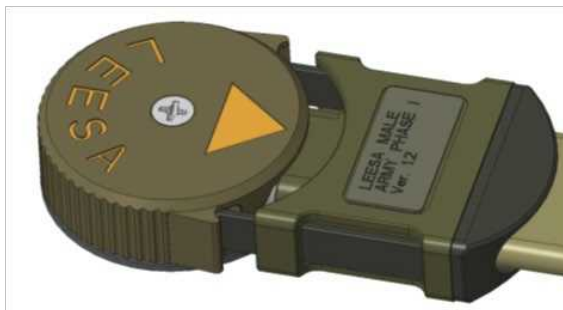


Enabling Technology

Electro-textile



Connector – Male



Connector Pair Assembled

Purpose: Replace round, stiff COTS electrical cables and connectors with flat, lightweight wearable and washable electronic textiles and connectors fully capable of integration into Soldier tactical vest at same or reduced cost and meeting MIL-STD performance requirements.

Results/Products: Set of prototype electronic network systems fully designed for battlefield wear that are durable, insulated, and EMI-shielded and support power-data managers, radios, end-user devices, and conformal batteries.

Payoff: Wearable low-profile electronic network designed for integration into the soldier system reducing snag hazards and system weight, resulting in improved mobility, agility and comfort.



LEESA and SEWiT



Improved Outer Tactical Vest (IOTV)





ELECTRONIC TEXTILES



Wearable Electronic Cables – power and data bus

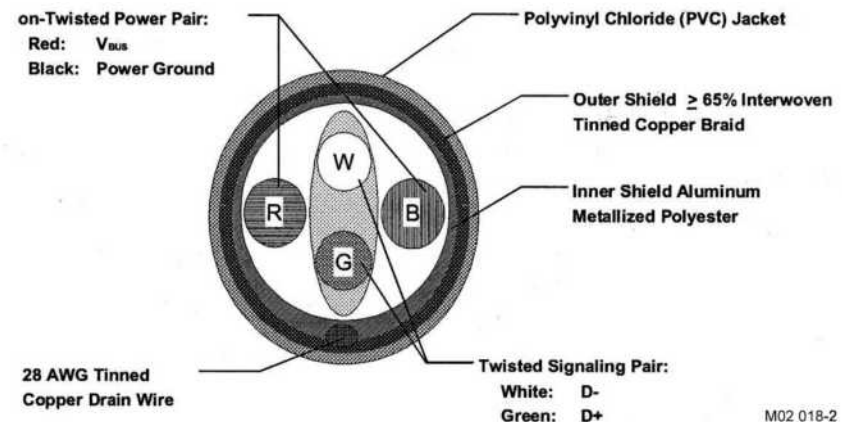
Manufactured in accordance with USB 2.0 specifications except:

- Data Transmission Medium – 28 AWG twisted copper pair, PVC insulated, wrapped with aluminum Mylar foil
- Power Wires - 20 AWG stranded, tinned copper, PVC insulation
- Drain – 28 AWG copper wire in contact with data medium
- Warp and Filing Yarn – Filament Nylon
- From concentric to flat assembly
- “**Wearable Transmission Device,” US patent No. 6,727,197 Patent License Agreement, QinetiQ NA**



From top:
White power wire
Drain wire
Shielded twisted data pair
Black power wire

Enabling Technology



M02 018-2



ELECTRONIC TEXTILES



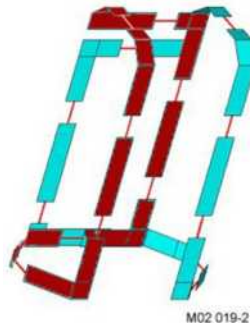
Radiating Conductor:

- Double plain weave narrow fabric technology
- Parallel conductive strips made from tinsel wire
- Nylon filament warp, filling and binder yarns
- Optical fiber stuffer components



Etextile version - Single Channel Ground and Airborne Radio System (SINCGARS)

- Double Loop Merenda Antenna, 30 – 88 Mh range
- Electronic switching modules (CERDEC)
- Body conformal, visually covert
- Transitioned to CERDEC





ELECTRONIC TEXTILES



Heated Handwear:

- Powerstretch Gloves
- Harness
- Battery Pack:
 - 8 watts of heat each glove
- Splashproof
- Heat Level:
 - 1 hour duration
- Weight:
 - Entire system: 1 lb
 - w/o gloves: 0.6 lbs
 - w/o battery & gloves: 0.3 lbs





ETEXTILES – NEW STARTS, OPPORTUNITIES



New Starts:

- Manufacturing Production of Electronic Textiles for Wearable Heating Devices
- Electronic Textile Enabled Personal Area Networks (EPAN) For Ground and Air Soldiers

Small Business Innovative Research Program

CCDC-SC Broad Agency Announcement



Smart Textiles Standardization Efforts



ASTM D13.5 Terminology for Smart Textiles

Approved

Scope. This terminology standard covers terms related to smart textiles, technical textiles, electronic textiles, and wearable electronics including fibers, yarns, fabrics, and end products.

Smart textile, n – a fiber, yarn, fabric or end product with one or more properties that change by design in response to stimuli, such as those from mechanical, thermal, chemical, electrical, magnetic or other sources. (Synonyms: intelligent textile, intelligent textile system, smart textile system.) (See technical textile.) Discussion: smart fabrics differ from technical fabrics in that fabric properties change in response to a stimulus. A thermo-chromic fabric changes color in response to the application of heat and is a smart textile.

Technical textile, n – a broad term for fiber, yarn, fabric or end product used for applications where functional performance is of primary importance; wherein a textile provides functionality due to inherent material properties and/or an applied treatment. (See smart textile.) Discussion: water repellent, flame resistant, and antimicrobial fabrics all provide functional performance against stimuli such as rain, flames, and microbes but the fabric properties do not change in response to those challenges.



Smart Textiles Standardization Efforts



ASTM D13.5 Terminology for Smart Textiles

Approved

Wearable electronic, n – an electronic device that is worn on the body either as an accessory or integrated into clothing. Discussion: the device, which is usually standalone, can be permanently or temporarily integrated into clothing, e.g. such as a sensor.

Metallic fiber, n – a manufactured fiber composed of metal, polymer-coated metal, metal-coated polymer, or a core covered by metal which can be transformed into a yarn or made into fabric by interlacing the strands in a variety of methods including weaving, knitting, braiding, felting, and twisting



Smart Textiles Standardization Efforts



ASTM D13.5 Terminology for Smart Textiles

Under Review

Electronic textile, n – a fiber, yarn, fabric or end product comprising elements that result in an electrical circuit or the components thereof.

(Synonyms: electromagnetic textile, electro-textile, e-textile, etextile.)

Discussion: any combination of textiles and other components engineered to provide properties necessary for the creation of a circuit.

Potential new terms to define:

Electronic textile connection

Electronic textile connector

Conductive trace

Passive textile

Active textile

Optical fiber

Composite fiber

BUT WHAT WILL THIS COST?

PRICING OUT E-TEXTILE FUNCTIONALITY FOR SAFETY WEAR



Ezgi Ucar



AGENDA

- ABOUT LOOMIA
- INTRO TO E-TEXTILES IN PPE: FUNCTIONALITIES AND USE CASES
- INDUSTRY CHALLENGES
- PRICING OUT E-TEXTILES: STEP BY STEP COST CONTRIBUTORS TO E-TEXTILES IN PPE

THE FUTURE OF SMART FABRIC IS BRIGHT

The smart fabric industry will be a

\$130B global market

by 2025 and that future will be screenless.*

Meet LOOMIA



Maddy Maxey
Founder

Ezgi Ucar
CPO

PAST CLIENTS



JULIANNA BASS



TAILORED BRAND

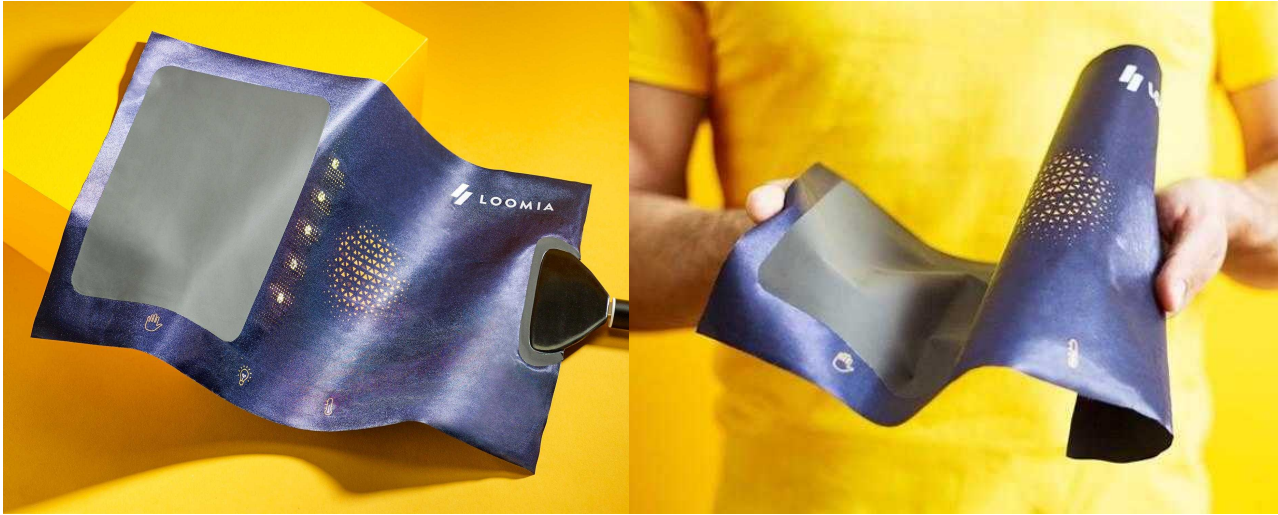
AWARDS



LVMH
30 FINALISTS



LOOMIA's DNA



LOOMIA designs and manufactures technologies that bring **functionality to soft goods**. We create a **soft circuit system** called the **LOOMIA Electronic Layer (LEL)** that can be designed to heat, light and sense. We **customize** the design of the LEL for our customers to ensure it fits their needs.

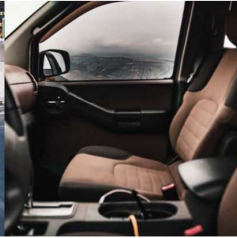
Industries Serviced



Consumer Apparel



PPE



Automotive



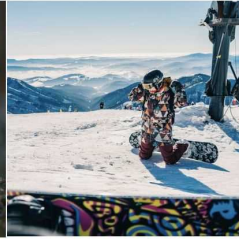
Outdoor Gear



Sports Apparel



Soft Goods



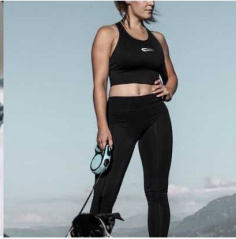
Snow Gear



Interiors



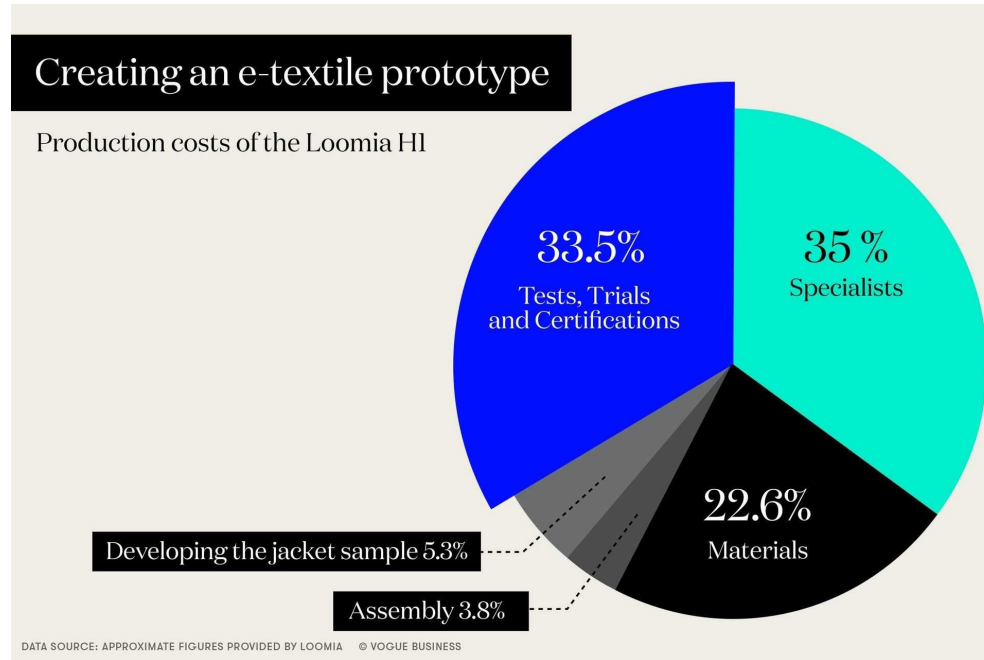
Footwear



Health focused Wearables

We work with a range of companies who produce soft good products including **snow apparel**, **automotive**, **personal protective equipment (PPE)**, **outdoor apparel**, **functional footwear**, **wearables** and **interiors**.

LEL Development



Loomia spent three years and \$750,000 developing the LEL.

E-TEXTILES IN PPE

FUNCTIONALITIES AND USE CASES

FUNCTIONALITIES FOR PPE



HEATING FOR COMFORT



HIGH VISIBILITY

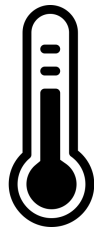


INTEGRATED SENSORS
AND ALERT SYSTEMS



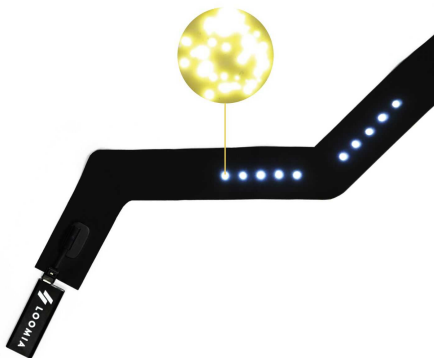
CAP TOUCH
CONTROLS

USE CASES FOR PPE

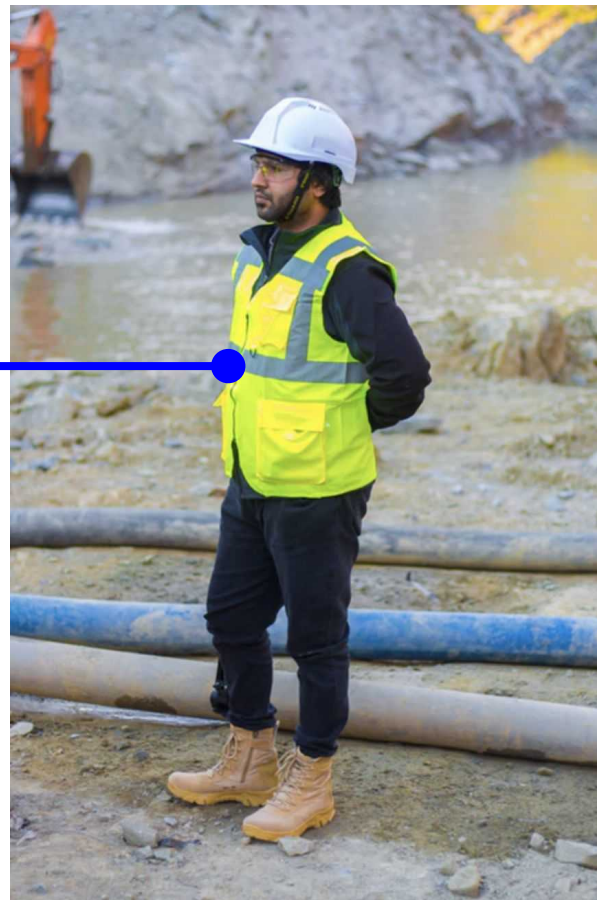
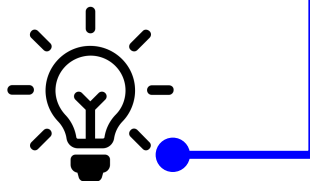


HEATING FOR COMFORT

USE CASES FOR PPE



HIGH VISIBILITY



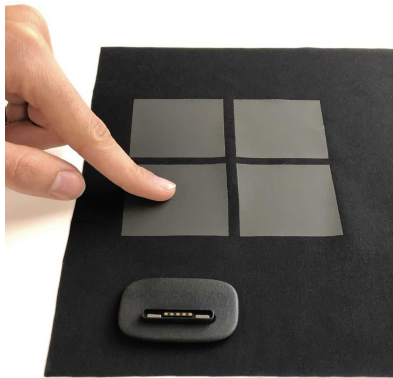
USE CASES FOR PPE



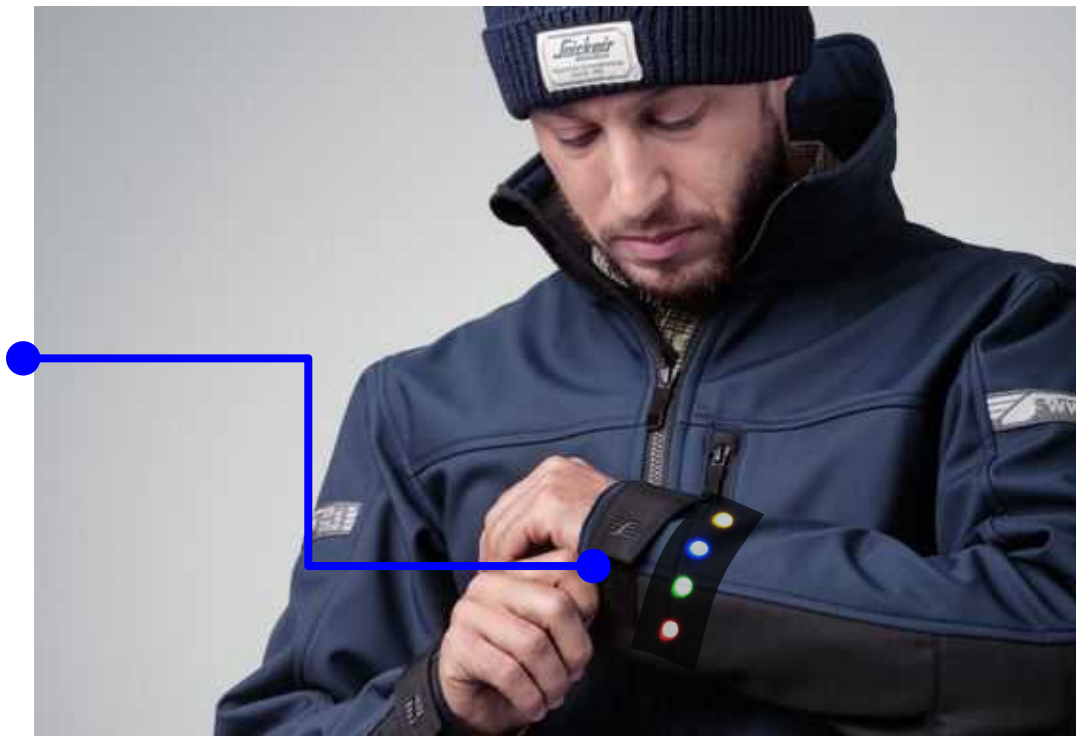
INTEGRATED SENSORS
AND ALERT SYSTEMS



USE CASES FOR PPE



CAP TOUCH
CONTROLS



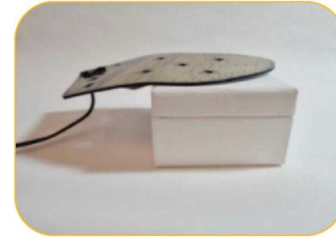
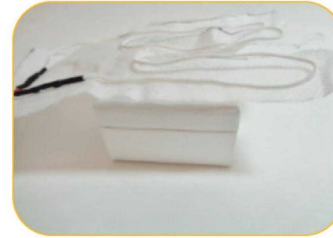
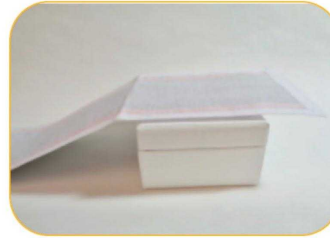
INDUSTRY CHALLENGES AROUND E-TEXTILES

Industry challenges: **Form Factor**

Integration of e-textiles into PPE requires an element of **comfort and ease** for the user.

Having a **stiff, hard components** or a **heavy power supply** will interfere with the usability of the equipment in the intended setting.

This challenge requires a certain amount of NRE in the e-textile portion to get a **drapable, flexible and light form factor**.

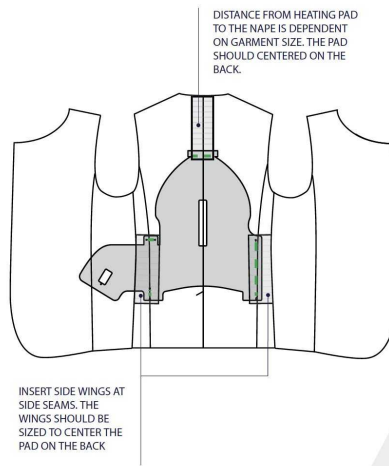


Industry challenges: **Manufacturing /Integration**

Wired systems can be hard to integrate into a cut and sew production facility. Many smart textile components require **special machinery or skilled labor** to integrate into a garment.

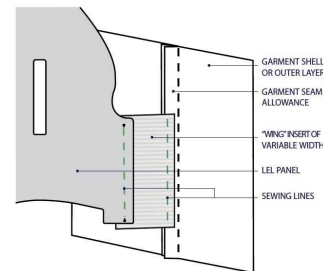
LOOMIA creates an entirely **wire-free system** to allow easier electronic integration into soft good products. We create **machine sewable and bondable** panels that eliminates the complexity in production.

Other e-textile manufacturers have their own methods of getting around this issue, which again requires some NRE.



SEW TABS & WING SYSTEM USES :

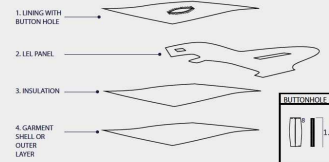
Functional Apparel
Furniture
Automotive/ Transportation
Outdoors Accessories
Consumer Apparel
Personal Protective Equipment
Industrial



BUTTON INTERCONNECT



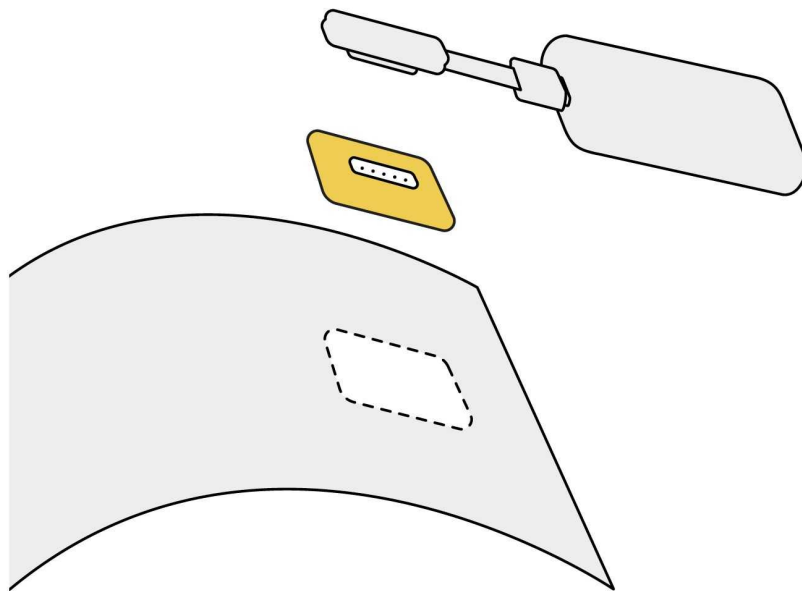
MATERIAL LAYERS IN ORDER OF APPLICATION



Industry challenges: **Hard/Soft Connection**

The **hard-soft interface** is a challenge for our industry. When integrating a component into an e-textile, the hard-soft interface must be **overcome to ensure that zone does not break when stressed, nor have a higher resistance than the rest of the assembly.**

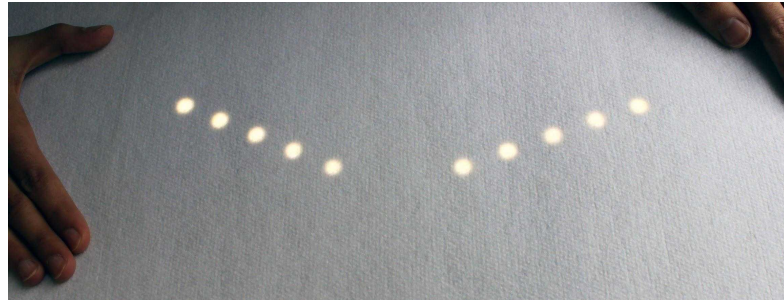
This challenge is especially important to overcome in heavy mechanical stress applications of PPE.



Industry challenges: **Customization**

Customization is a requirement in certain applications of e-textiles in PPE, especially in functionalities requiring high accuracy sensor readings, personalized alert systems or environmental robustness.

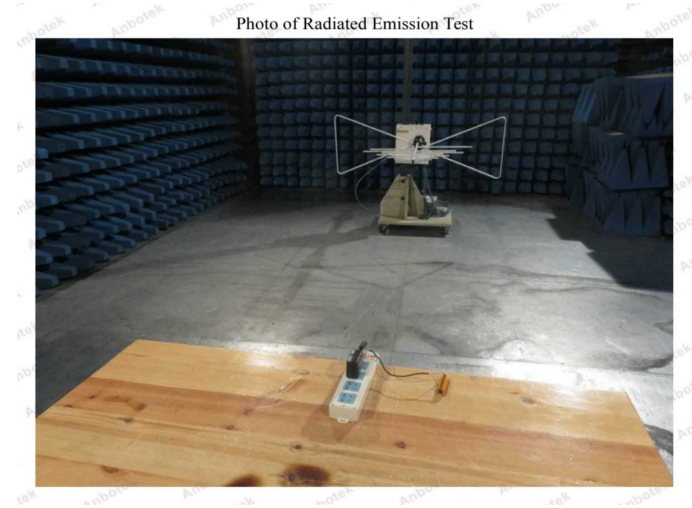
Off-the -shelf solutions cannot provide the customization necessary for such applications.



Industry challenges: **Lack of Standards**

E-textiles industry is still missing the necessary **certification standards** for the product category. Efforts are being made to set the standards by groups like IPC at the moment.

Due to this lack of standards, e-textile providers are getting certifications created for **electronics and/or textiles** with slight modifications, which adds to the development time and cost of a product.



PRICING OUT E-TEXTILES:

1) PROTOTYPE TO PRODUCT (NRE)

Why is NRE necessary?

- Functionality Customization
- Environmental Robustness requirements
- E-textile integration into PPE
- Certification modifications
- Form factor customization
- User testing and iterations on design and engineering
- Design for Manufacturing

LOOMIA's NRE to Production

Phase	Deliverables	Timeline
Phase 1 Design & Strategy	<ul style="list-style-type: none">Concept refinement, use case discovery and market research to pin down functionality specifications.	6 Weeks +
Phase 2 Customization	<ul style="list-style-type: none">Design & engineering Iterations to build you a functional prototype that can be used for marketing, proof of concept, or internal buy-in.	6 - 24 Weeks +
Phase 3 DFM Development	<ul style="list-style-type: none">Iterations of DFM files to ensure your product is perfectly ready for production	4 Weeks +
Phase 4 Pilot Production	<ul style="list-style-type: none">Pilot production with our manufacturing partner	10-24 Weeks
Phase 5 Scale Production	<ul style="list-style-type: none">Pilot production with our manufacturing partner	TBD

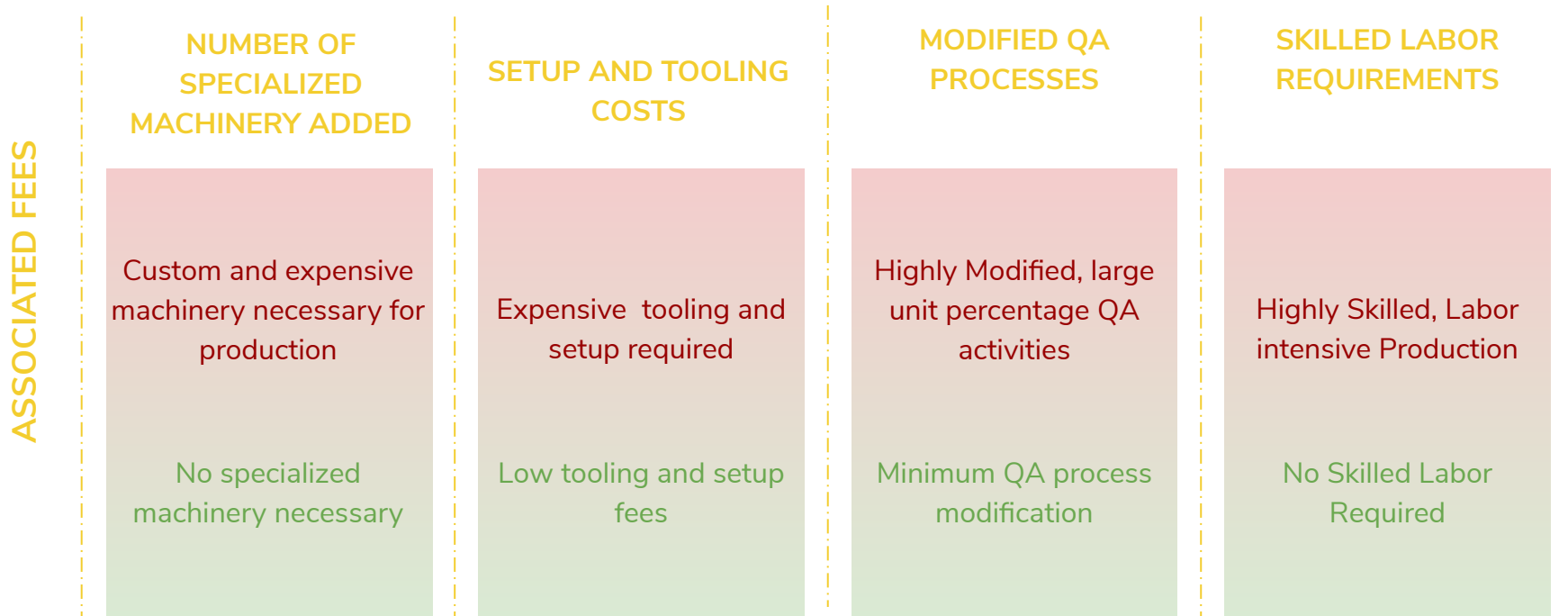


PRICING OUT E-TEXTILES:

2) MANUFACTURING

Manufacturing Costs Associated

E-textile manufacturing costs depends on contributors as detailed below:



LEL Pricing

The LEL unit price depends on contributors as detailed below:

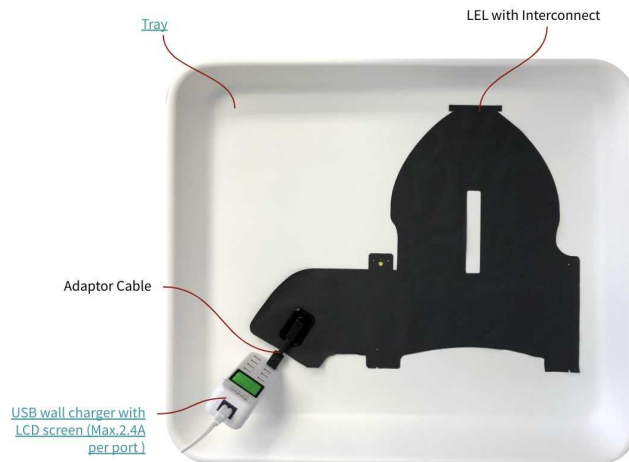
UNIT PRICE	SCALE	SURFACE AREA	ENVIRONMENTAL ROBUSTNESS	MOUNTED COMPONENTS
	Low scale production (2,000 unit MOQ)	Large surface area (36" x 48")	High chemical exposure and mechanical robustness needs	Large number of expensive mounted components (gold plated, magnetic, etc.)
	High scale production (above 10,000 units)	Small surface area	Minimal robustness and reinforcement needs for insulation	Minimal and lower price point mounted components (standard usb connectors, cheaper controller options, etc.)

PRICING OUT E-TEXTILES:

3) TESTING AND CERTIFICATION

INTERNAL TESTS (part of NRE)

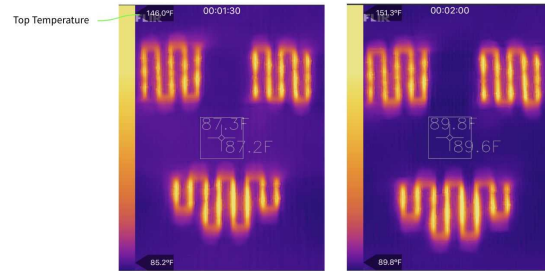
- Step by step process resistance variability
- Crease Testing
- Stretch/strain Profile
- Electronic Cycling
- Humidity, water penetration and PH testing for insulation methods offered
- Temperature profile
- Patterning method geometric profile variability
- Temperature and pressure durability
- In-house to scale production translation



Power source connection:



Temperature readings with Thermal camera:

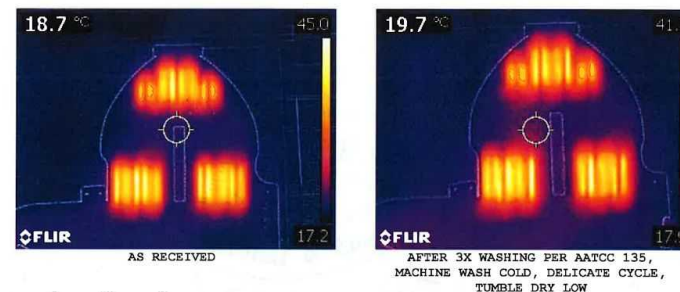




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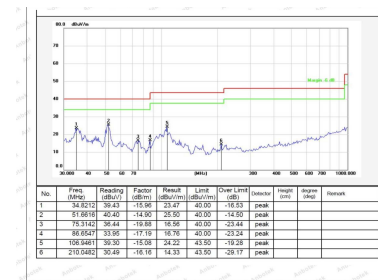
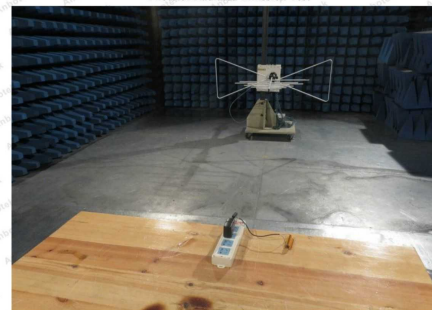
FILE: LOOMIA.A031319A
SAMPLE IDENTIFIED BY CLIENT AS:
 Fabric Submitted
 Ref: LEL Panel
 Color Dark Grey

IR-INFRARED (FLIR) ANALYSIS,
MAX HEAT BY FLIR:



- AATCC 135 Wash Testing
- AATCC 158 Dry cleaning (modified)
- AATCC Bleach colorfastness
- AATCC Crocking
- SEM Imaging after chemical exposure
- FCC Certification
- EDX chemical analysis
- CE Certification

Photo of Radiated Emission Test



Thank You

please contact us at maddy@loomia.com or ezgi@loomia.com
with any questions or feedback.