Sensors Converge

E-Textile Based Systems Using Different Modalities for Damage Detection and Status Monitoring for Military and Other Applications

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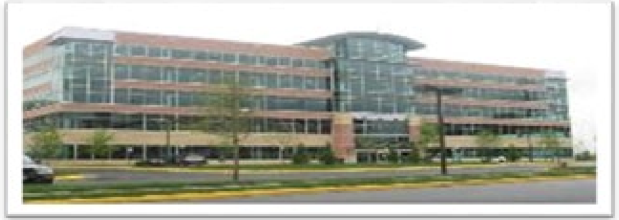
About…

DCS Corporation

DCS is a premier professional services firm providing advanced research and development, engineering, prototyping, technical, and programmatic support services to the DoD and other national security-focused customers.



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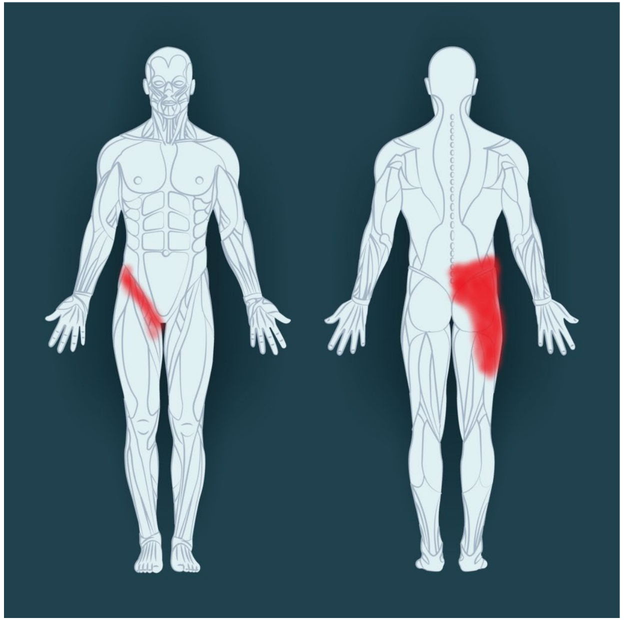
Alexandria, VA 22310

What Was the Problem?

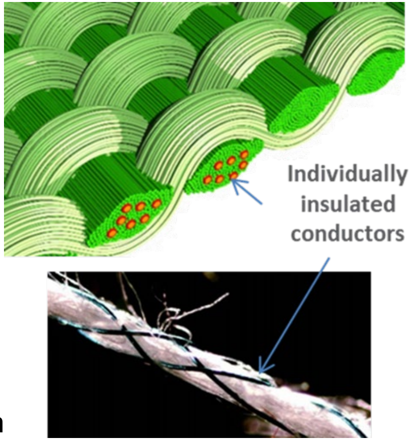
- The Defense Health Agency (DHA) was seeking a medical simulation to model the impacts to E-textiles that coincide with bodily injury. Once established, the expectation is to use the e-textile impact to infer bodily damage.
- The objective of this program was to develop a set of E-textile materials and measurement systems to meet the needs for a damage detection testbed system.



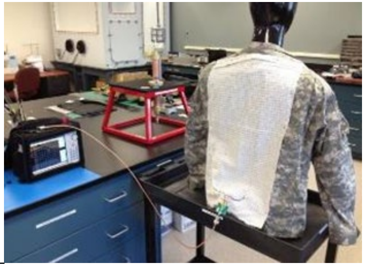
Why Were We the Right Partner?

DCS has the capability to design, fabricate, and evaluate textile articles, including those that feature embedded electrical functionality.

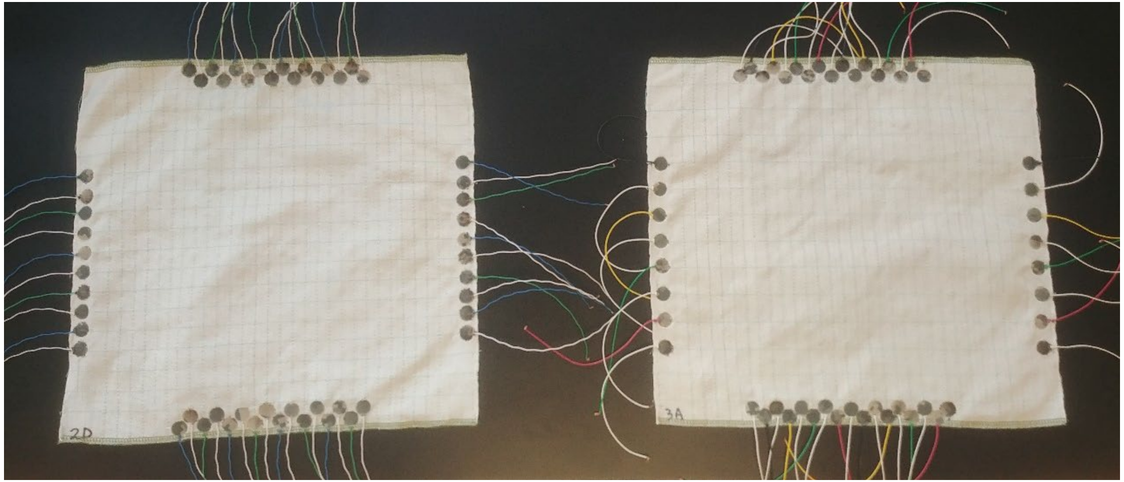
- Fiber/Yarn characterization
  - Mechanical
  - Electrical
  - Melt Properties
- Fabric Characterization
  - Electrical
  - EMI Shielding
  - Environmental
- Network Formation
  - Ultrasonic welding station
  - Portable ultrasonic welding system
  - Soldering stations
- Network Characterization
  - Impedance (LCR) Meter
  - Time-domain reflectometer
  - Oscilloscopes

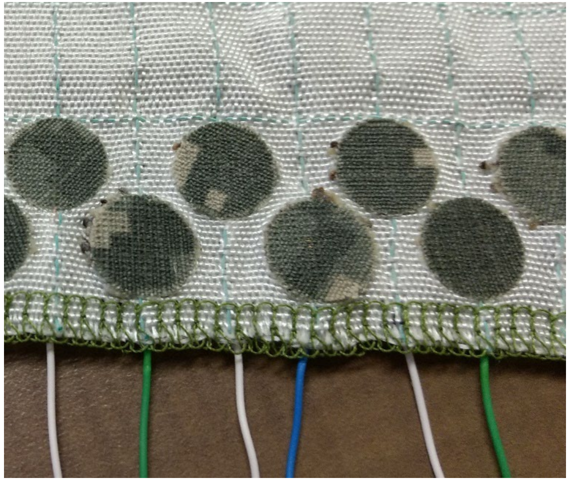


- Prototype Fabrication
  - Cut and sew stations
  - Sewing machines
  - Sergers
  - Rivet and fastener presses
- System testing and qualification
  - Current capacity
  - Environmental
  - Launderability
  - Signal Integrity



Phases of Textile Development



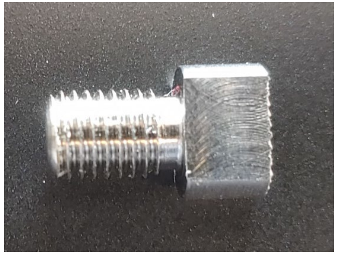


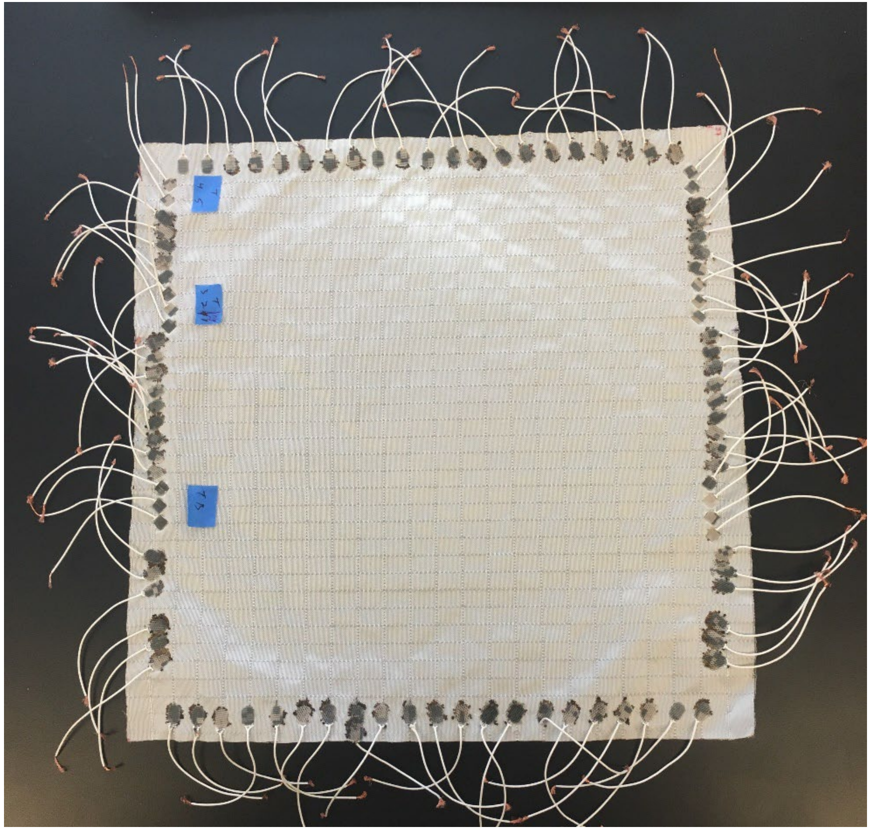
- Functionalized E-textile samples using DCS optimized ultrasonic welding techniques
- This staggered approach caused undesired variability in the trace capacitance, so a new technique was explored

Phases of Textile Development

- Replacing the rounded horn with an oblong horn allowed more trace connections, facilitating a denser grid pattern.

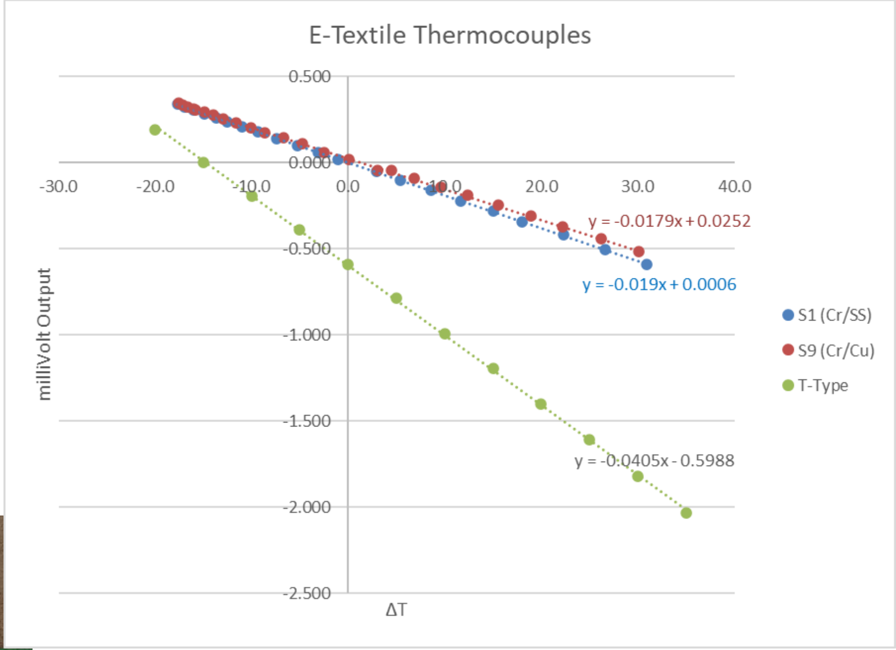
- 13.5” x 13.5” swatch allowed for a 20 x 20 sensor grid

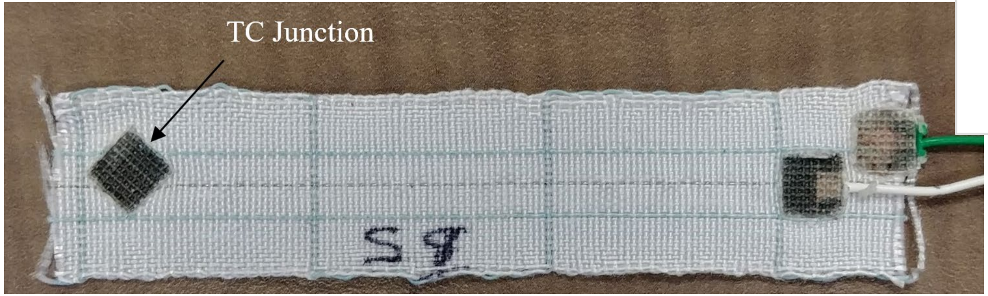




Thermal Sensor Integration

- Using conductive fibers made from dissimilar metals to produce an embedded thermocouple
- The most consistent performer was Chromel and Stainless-Steel pairing
- The performance was still several times less sensitive than a standard T-type thermocouple, but as both metals are typically used for negative terminals that is expected.





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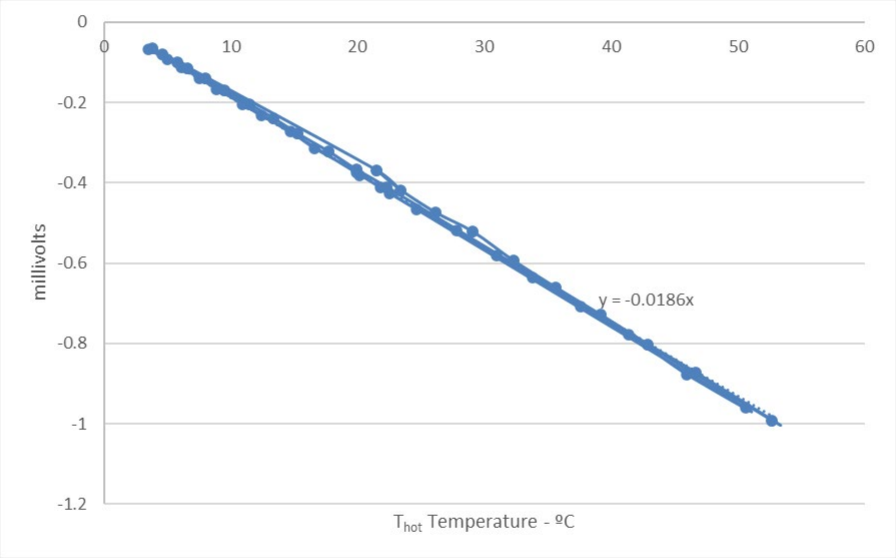
Thermal Sensor Integration

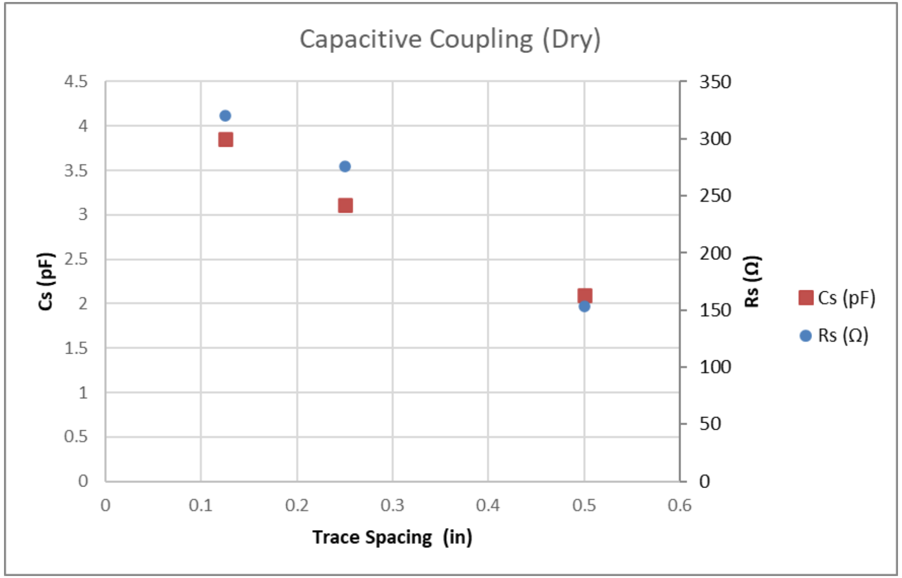
- An improvement can be made by replacing the chromel with constantan wire, but due to project limitations that was outside scope
- A linear fit of the data shows an 18.6 μV/ºC sensitivity at Tcold = 0ºC.

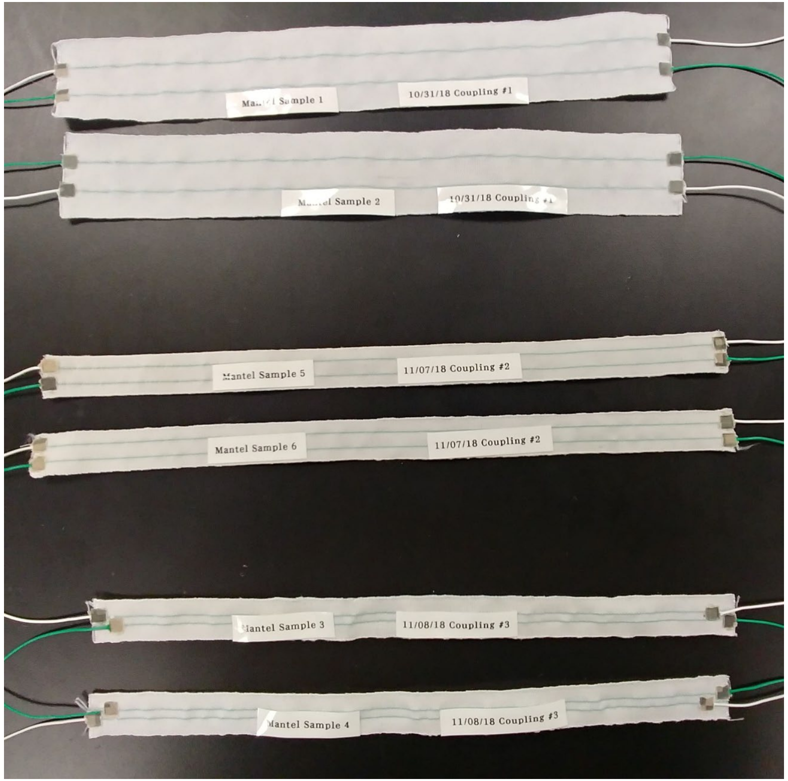


Thermocouple Type	Sensitivity (μV/ºC)
S1 E-Textile (Chromel/Stainless Steel & Copper)	18.6
K (Chromel/Alumel)	41.276
E (Constantan/Chromel)	76.373
S (Platinum/Pt+Rhodium)	9.587

Moisture Detection

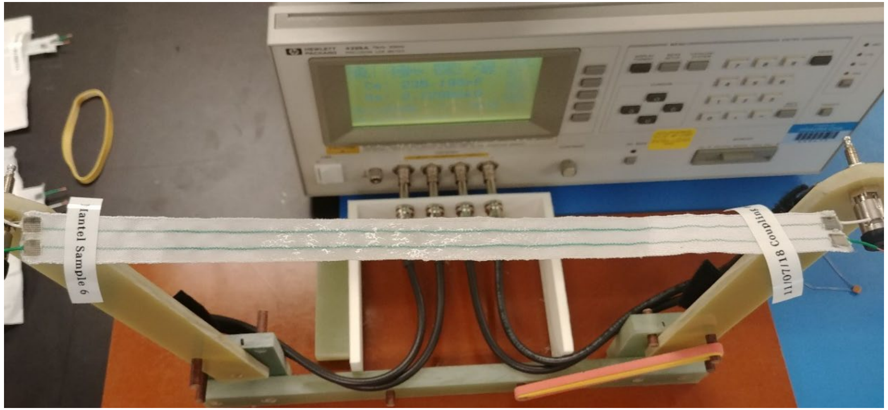
- Created samples of varying spacing
- .5“ (Top), 0.25“ (Middle), and 0.125” (Bottom)
- Relationship between the spacing and the capacitive coupling was found to be linear

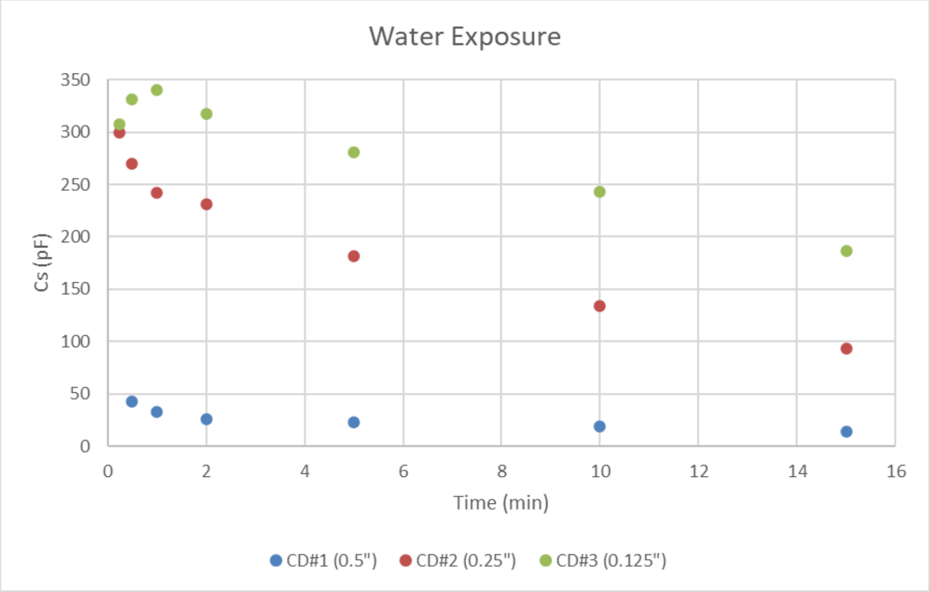




Moisture Detection

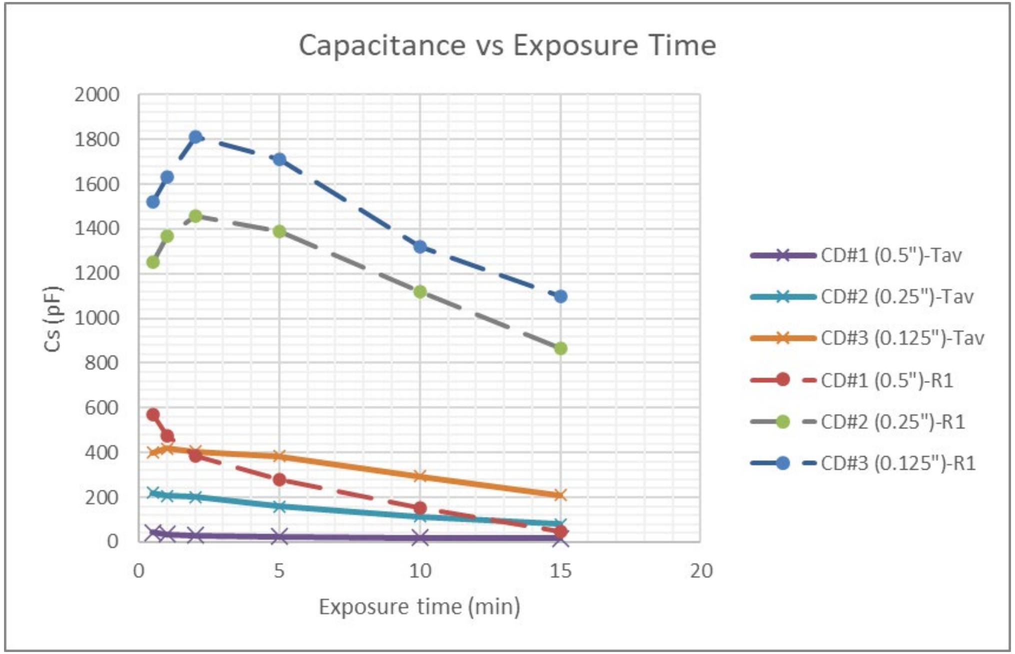
- Introducing water greatly increased capacitive coupling
- Using the known dielectric constants materials, the type of saturation could be deciphered.





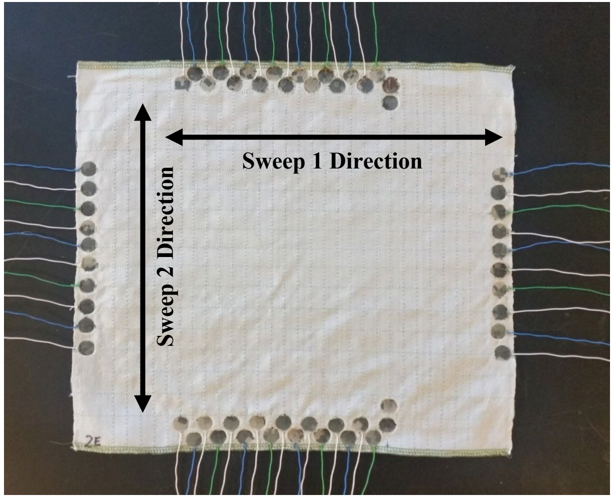
Moisture Detection

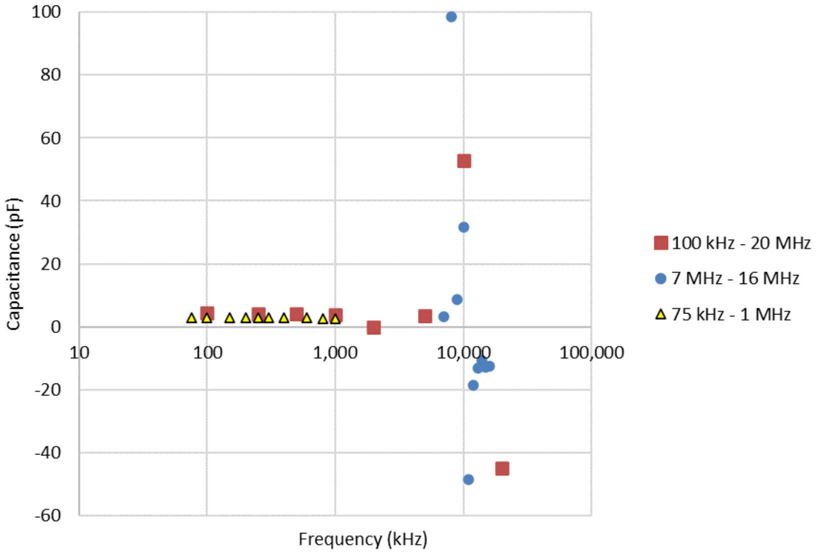
- The blood simulant selected was ¼ strength Ringer's solution (R1)
- Clean tap water (Tav) was used as comparison
- The presence of salts in the R1 solution increased coupling, allowing for a clear difference in the results
- The 4x-6x increase in capacitance readings is easily noted and can be used to status monitoring and fluid differentiation.



Frequency Sweep Evaluation

- Using low, medium, and high frequency sweep patterns to evaluate rectangular sample response
- Even though the low frequency band produced relatively lower capacitance values its consistency and reliability made it the preferred operating band.





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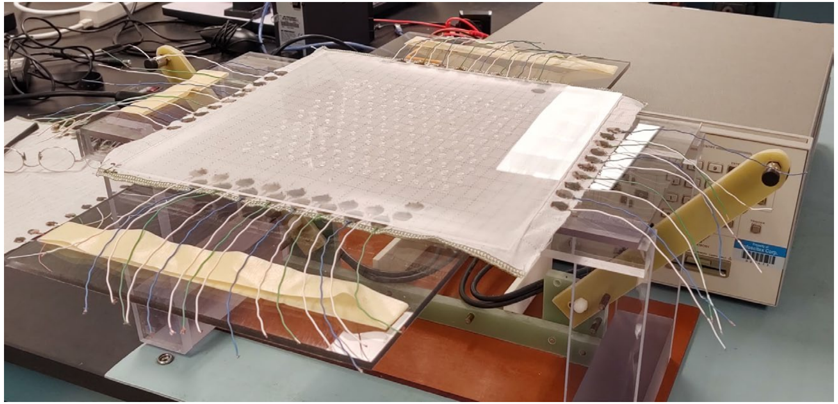
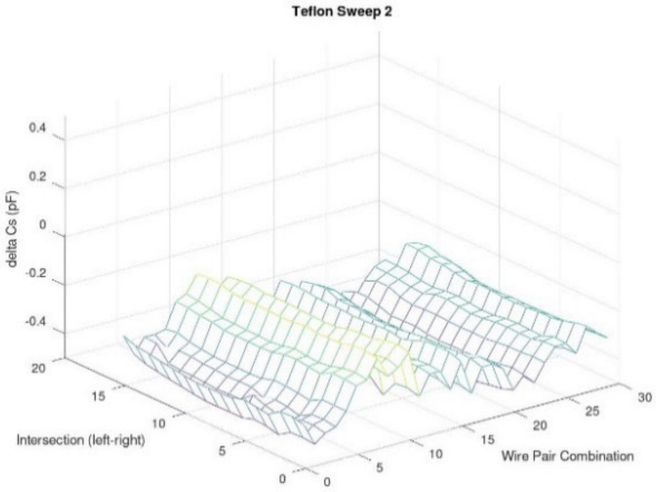
2D – Perturbation

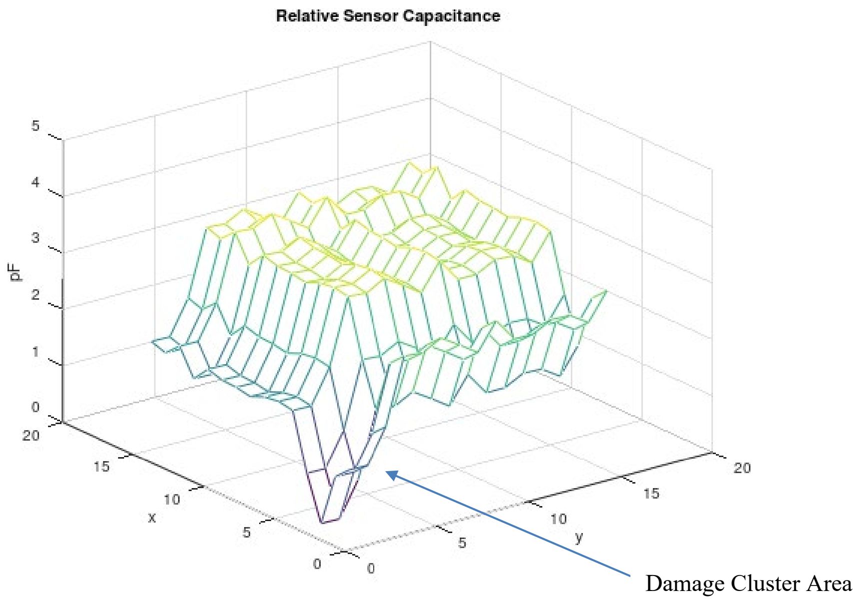
- A Teflon block was placed on the intersection points
- By subtracting out the base measurements from the Teflon measurements, a model could be made.
- Comparing this model to other bare measurements changes can be observed

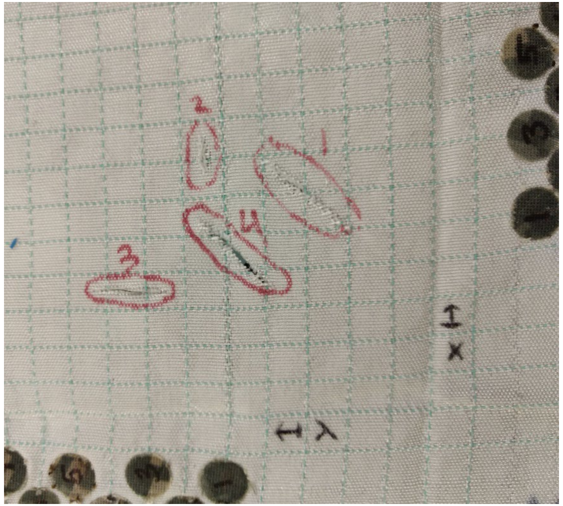




Cut Detection

- Adding puncture wounds to the material
- The cut traces show up in the 3D plot of the material with much lower capacitance
- a ‘shadowing’ effect can be seen emanating from the area of damage over the runs of the pairs broken.





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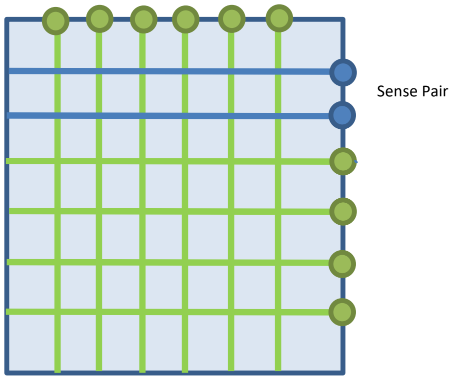
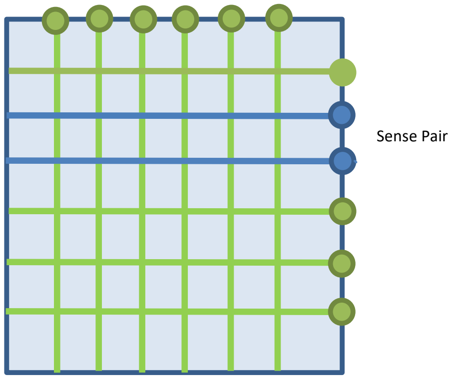
Measurement Complications. Solution: Auto-shielding

- Measurement of a small capacitance in a physically large structure is difficult without a fixture and method for control for external influences.
- Without a way to mask or shield the sensor, error compensation and filtering would need to be applied in software
- Auto shielding is a means of implementing a grounded shield to protect a measurement from external influences
- All of the sense lines not used for a pairwise measurement are grounded to the shield connection



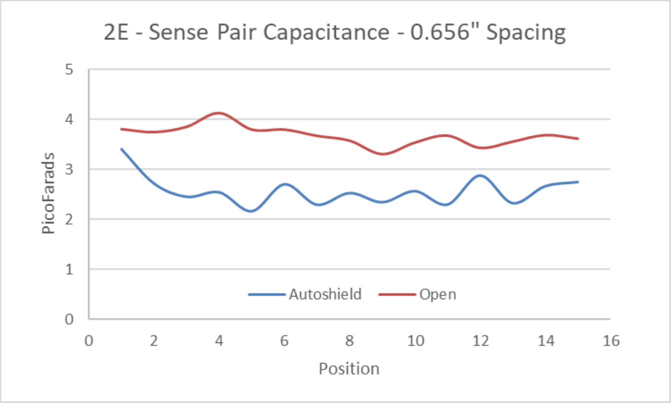
Grid E-Textile Sensor – MEASUREMENT 1

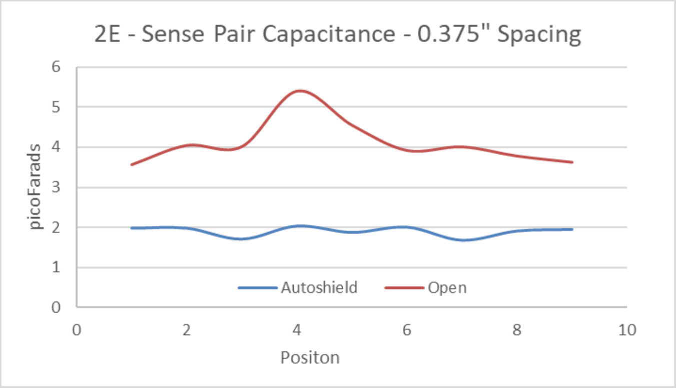


Grid E-Textile Sensor – MEASUREMENT 2

Measurement Complications. Solution: Auto-shielding

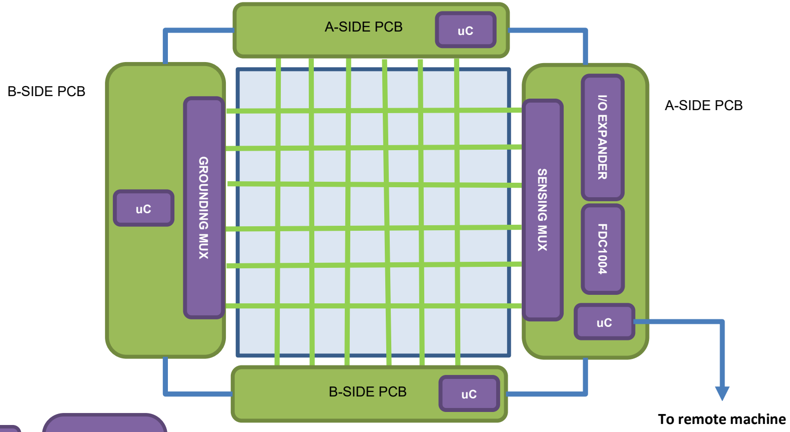
- By selectively connecting to a grounded shield circuit, several sources of error are eliminated, including:
  - Distributed proximity effect
    - Local changes are picked up by non-sampled pairs, which couple back into the sense pair during measurement
  - EMI influence
    - Large areas of ungrounded conductor act as antenna for local EMI, coupling back into the sense pair measurement
  - Position variance
- Measurement stability was noticeably improved



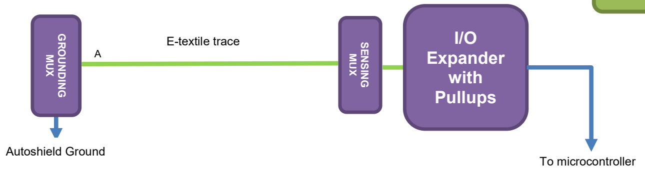


Functionalizing Samples

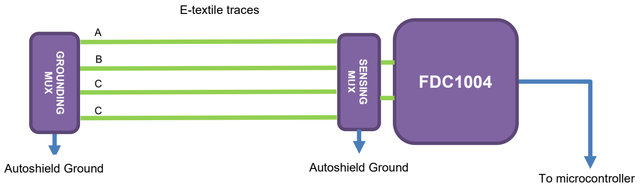
- All of this work has been through manual sampling and modeling from a static test bench
- To allow for closer to real time testing a jig assembly with software monitoring was designed
- Coupled with automated auto-shielding, the sense pairs can be polled rapidly allowing for continual model updates.



Trace Resistance Mode

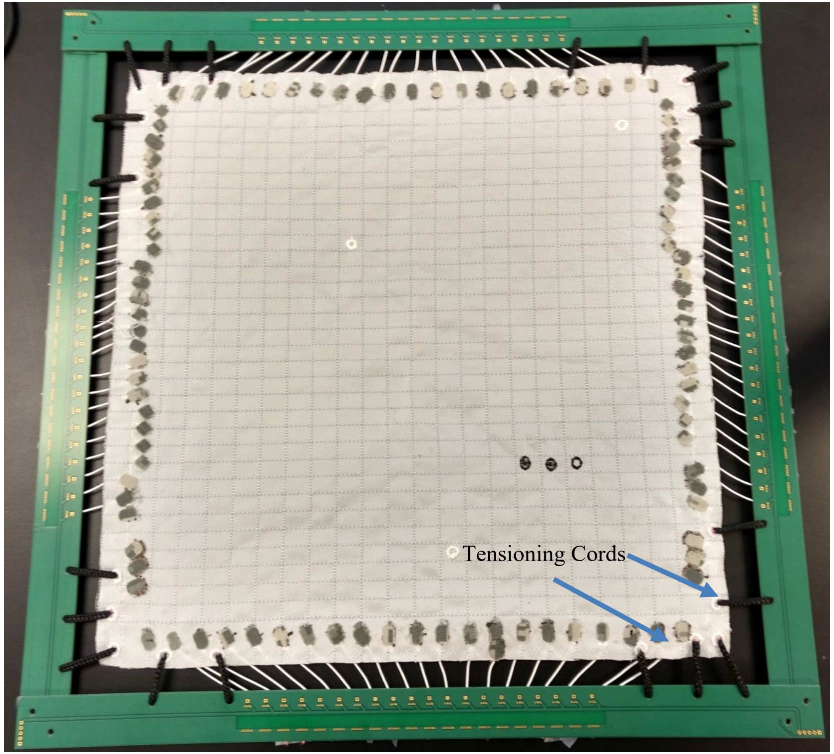


Trace Capacitance Mode



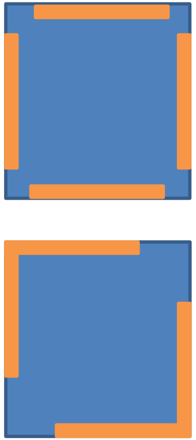
Functionalizing Samples

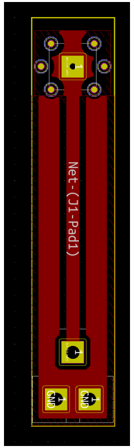
- Rigid printed circuit boards were used to tension the structure and route out the sensing pairs
- Sequencing of the MUXes through this scheme to meet the needs of the resistance and capacitance measurements was controlled by a microcontroller module offboard

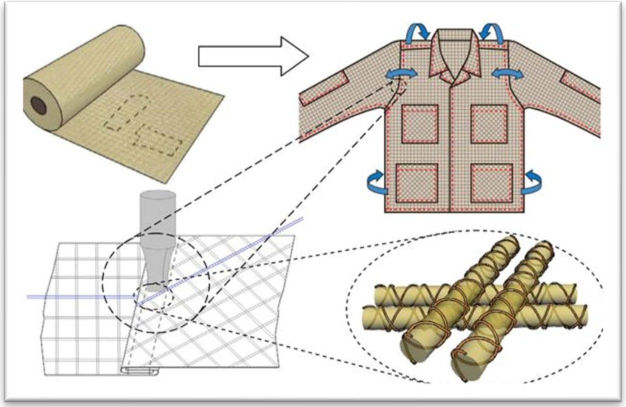


Future Development of Sense Network

- Rigid PCBs do not facilitate use in garments or blankets
- Flex PCBs can be used along edges, sonically welded to replace wires
- Data processing and control can be offloaded to a larger unit integrated into a handled or unit mounted device
- For garments, seems can be used as panel connection points
- Patchwork blankets can be produces by combining smaller sections of sensing E-textile
- Adding stretch using new conductive fibers will bring additional sensing modalities to expand the sensing capability







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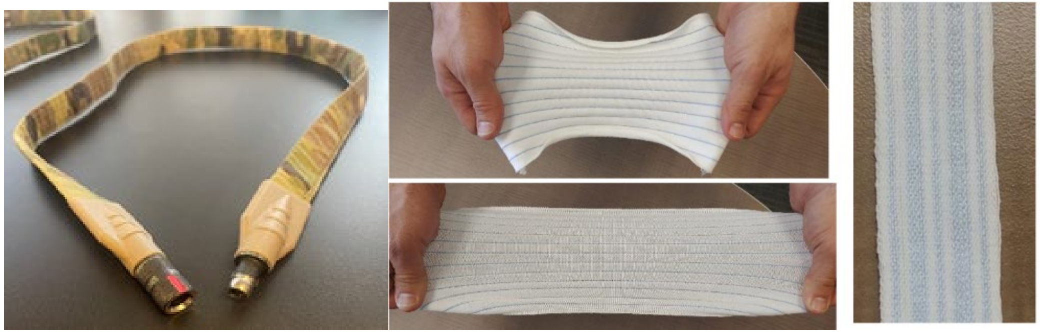
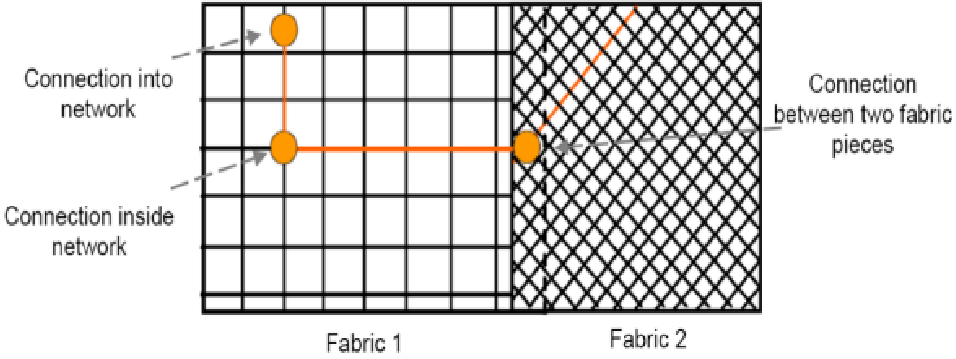
DCS Ongoing/Future Development

- Creating E-textiles capable of USB 3.0 gen 2 data speeds and reliability
- Integrating electrical networks for communication and power delivery into stretch fabrics, allowing for deformation.
- Development of new E-textile connectors to facilitate more natural connections and less hard points
  - Using additive manufacturing to have contacts embedded into a non-conductive housings
  - Utilize rigidized flex-circuits to have direct interface between E-textile and connector
- Electrifying nylon webbing by embroidering E-yarns into belts, straps, and slings





Thank You for Your Attention

- Please contact me with any questions or with interest in what DCS can provide for you