Design Tool for Electronic Textile Clothing Systems

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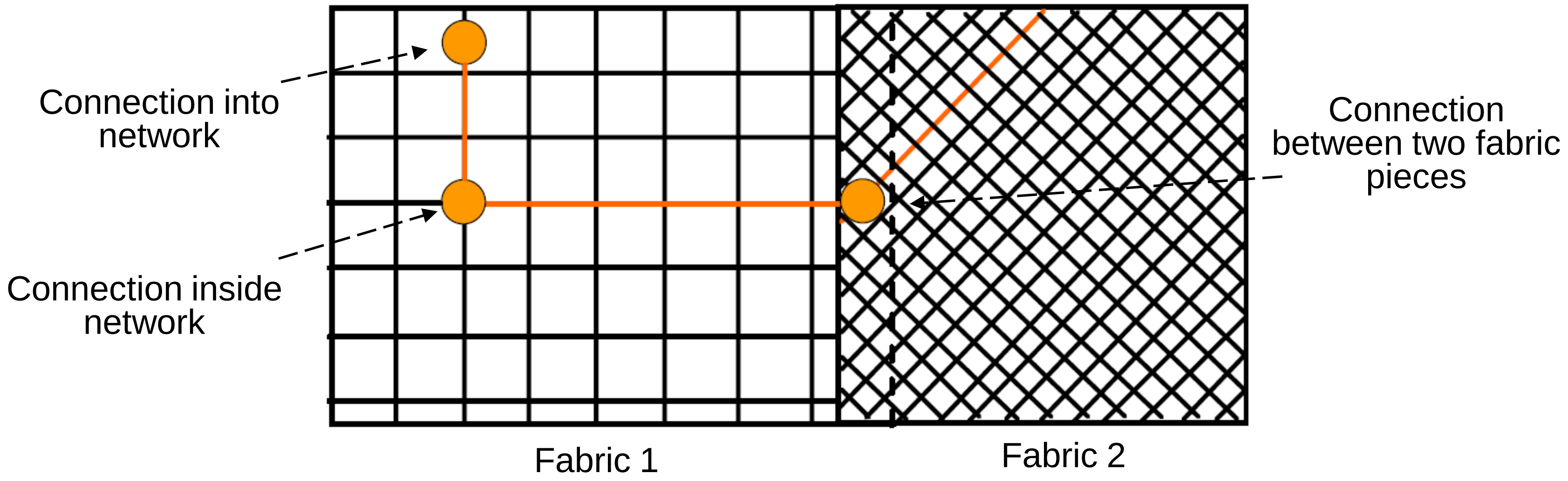
Background

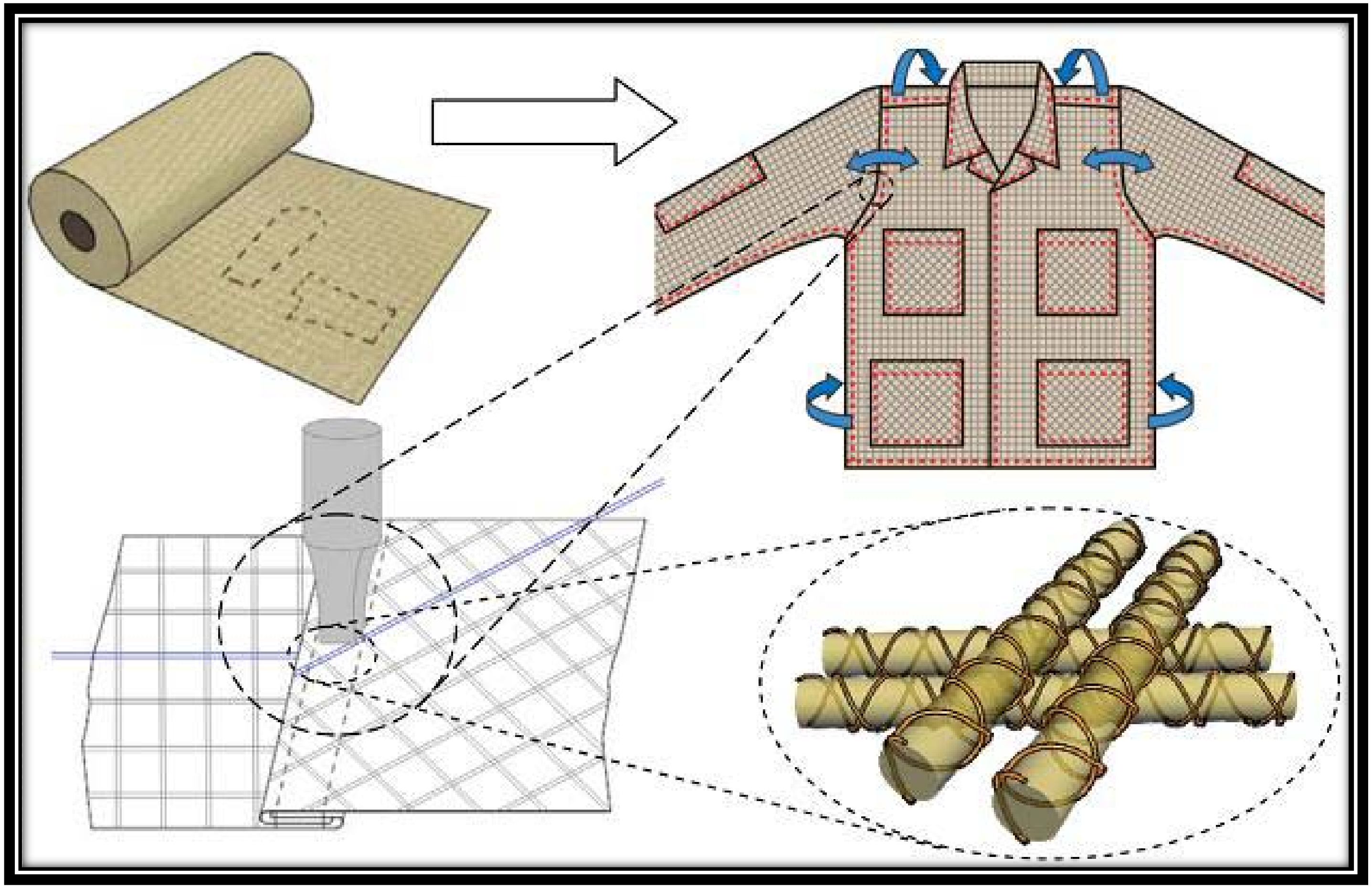
- The incorporation of electrically conductive threads into woven or knit fabrics is the subject of many research projects and product developments.
- The ability to cut and sew such fabrics into complicated structures with large scale electrical functionality has remained elusive.

Background

- Forming a functional network in textile articles such as garments and shelters requires three types of connections:
  - Between external electronic devices and the fabric
  - Between warp and fill e-yarns in a single piece of fabric
  - Between e-yarns in two separate pieces of cut fabric at a seam



Selectively Enabled Wiring in textiles (SEWit)



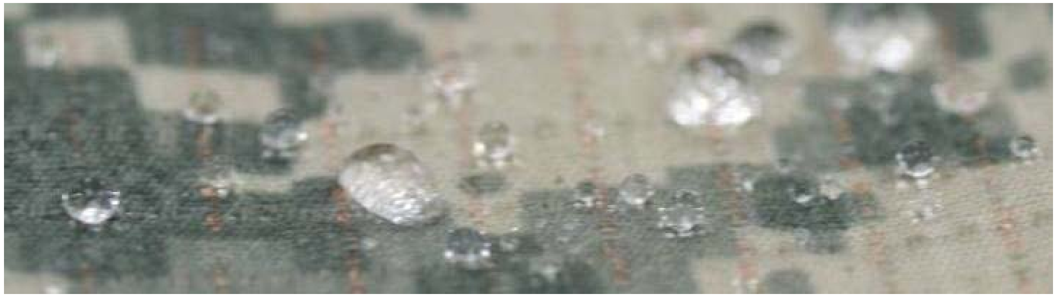
E-textile Fabric Development

- E-textile yarns, consisting of insulated copper wires wrapped around a cotton/nylon core yarn, were developed.

- The E-textile yarns were woven into the rip-stop portion of a Nylon/cotton fabric similar to that used in ACU garments.

Printing & Finishing

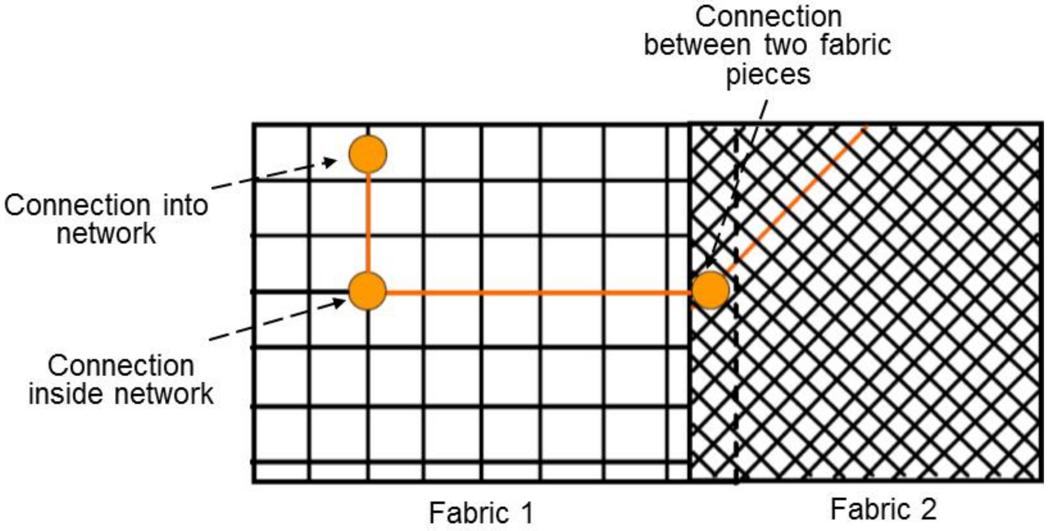
- Samples of e-textile fabric were sent to Bradford Printing and Finishing LLC for evaluation.
- These samples were inserted into a production run and subjected to normal printing and finishing processes including a Quarpel water repellent finish.
- Finished samples were evaluated for:
  - Electrical continuity: Passed
  - Enamel integrity: Passed
  - IR reflectance: Passed



Printed sample using desert sand wire with Quarpel water repellency finish

Connectorization and Integration

- 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



Networking Technologies

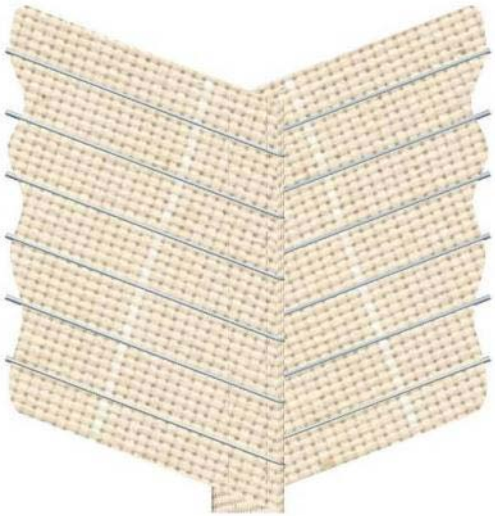
- Demonstrated the feasibility of transmitting power, analog audio-video signals, and 1000BaseT (Gigabit) Ethernet signals over SEWit e-textile networks.
  - Validated that transmission rates were identical to conventional Ethernet cables
  - Able to handle streaming video
  - Able to transmit across seams
- Investigated the feasibility of transmitting USB signals.
  - Requires shielding and impedance matching

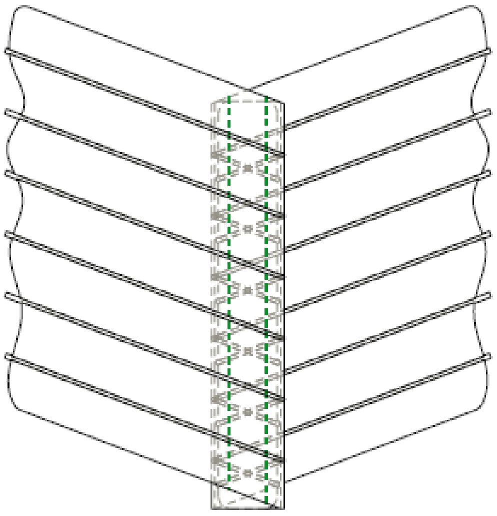
Prototype Garment Fabrication

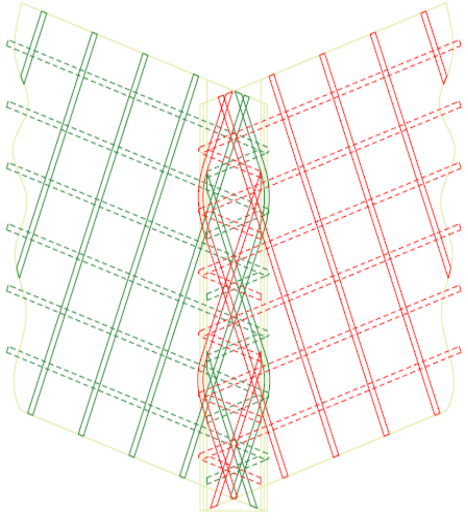
- Prototype ACU jackets were fabricated using printed/finished fabrics.
- Electrical networks were created that routed power between battery packs and:
  - Electroluminescent Insignia Patches
  - Heating Pads
- Prototype backpacks with integrated solar energy harvesting capabilities were fabricated

Importance of Seams in E-textiles

- 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.







E-textile Design Tool Motivation

- The design of e-textile networks remains a time consuming process that relies on specialized engineers and trial and error.
- Realizing practical development cycles will require a new design tool that can streamline the process of:
  - designing the E-textile fabric,
  - making the pattern,
  - assembling the textile article, and
  - establishing the desired electrical networks.

Development Strategy

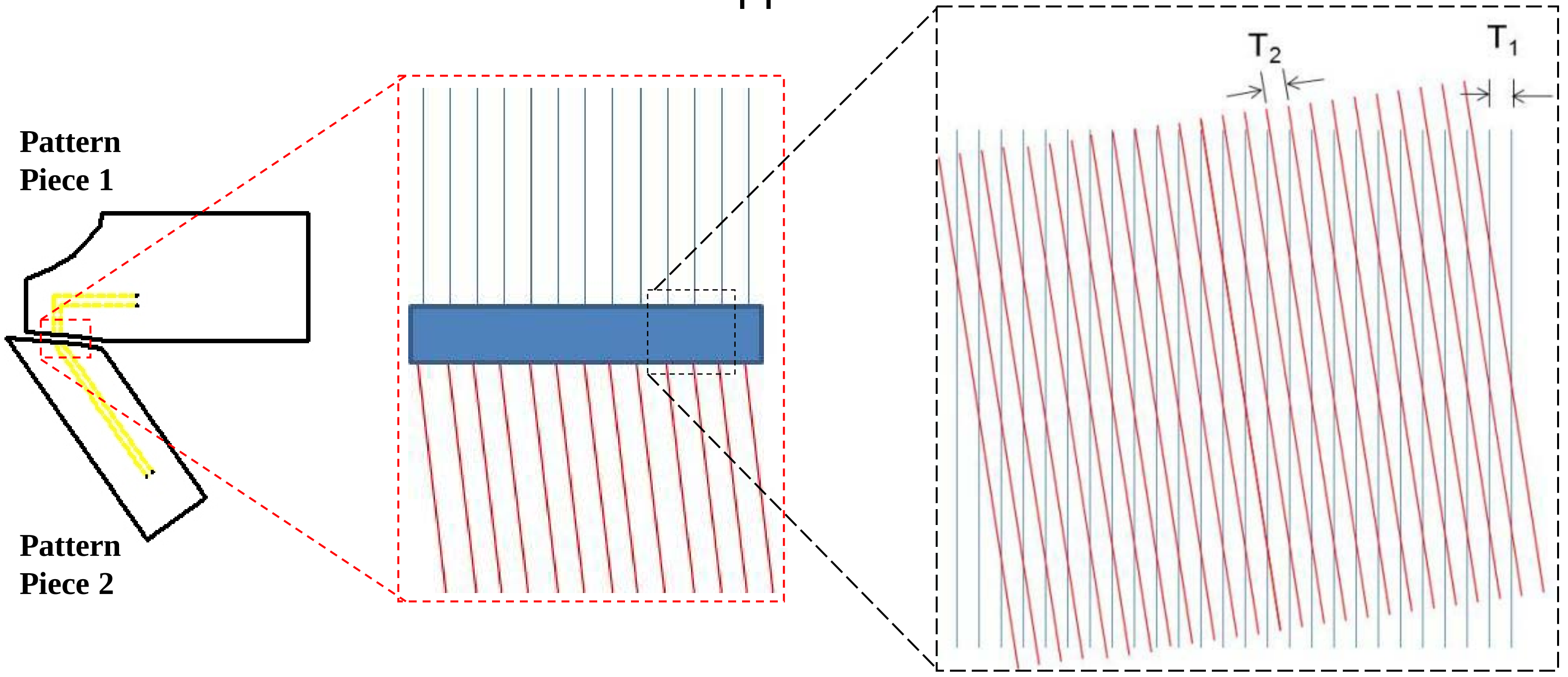
- It is not practical to predict in advance exactly where connections will occur so we are left with two options;
  - **Determine the location where e-yarn interconnects will occur between two pattern pieces once they have been sew together.**

  OR

  - **Make probabilistic predictions regarding the quantity and distribution of interconnects that will form between any two pattern pieces**.
- The first approach is valuable for certain prototyping scenarios but it does not provide any insight early in the design process.
- The second approach is more challenging to implement but results in a far more powerful tool that takes into account fabric, garment, and assembly parameters to arrive at an estimate of the number of interconnects that can be formed.

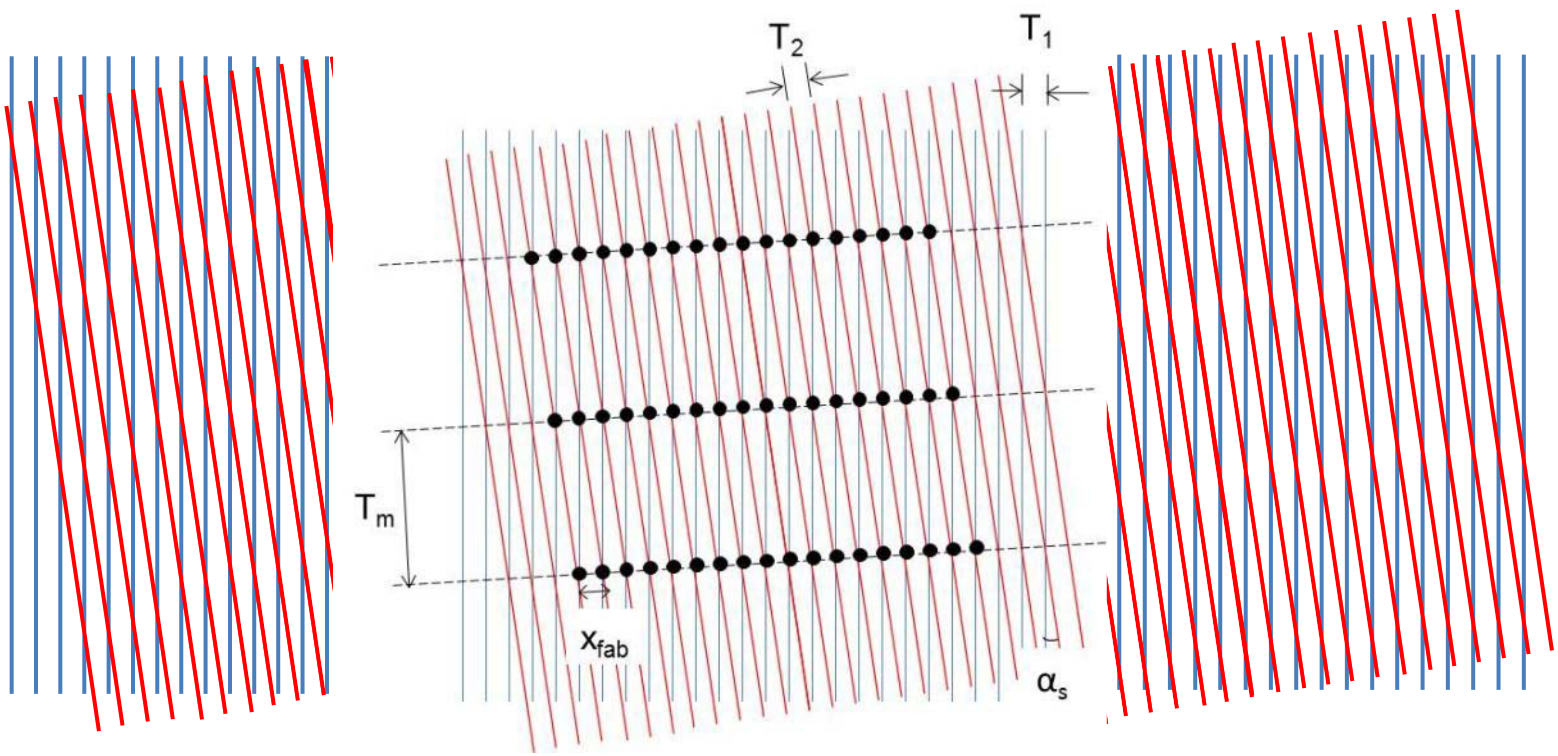
Phase I Objectives & Approach

- Develop a mathematical model that could predict the variations in interconnect density that can occur along a seam.
- Determine the probability of forming cross-seam networks based on input parameters for the e-textile, garment and ultrasonic horn,
- Permit adjustment of these parameters as needed order to achieve the desired results.
- The observation that the intersection of e-yarn grids in a seam creates moiré patterns formed the foundation of our approach.



Application of Moiré Pattern Models

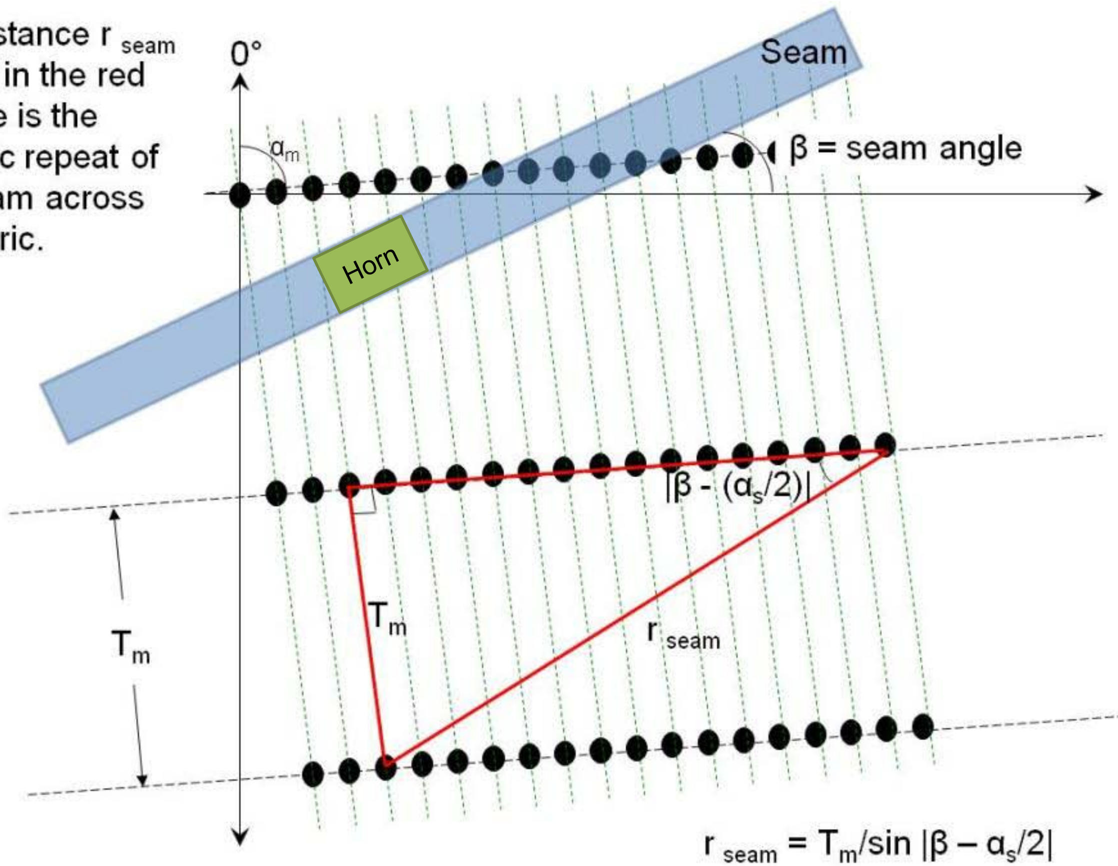
- Moiré patterns are interference pattern created when two grids are overlaid at an angle or when they have slightly different mesh sizes.
- The orientation and connection density of the lines that make up these patterns can be described using established equations.



Mathematical derivation of fringe parameters

Using these equations the relationship between the e-yarn interconnections forming the moiré fringes and the seam can be characterized.

The distance r_{seam} shown in the red triangle is the periodic repeat of the seam across the fabric.



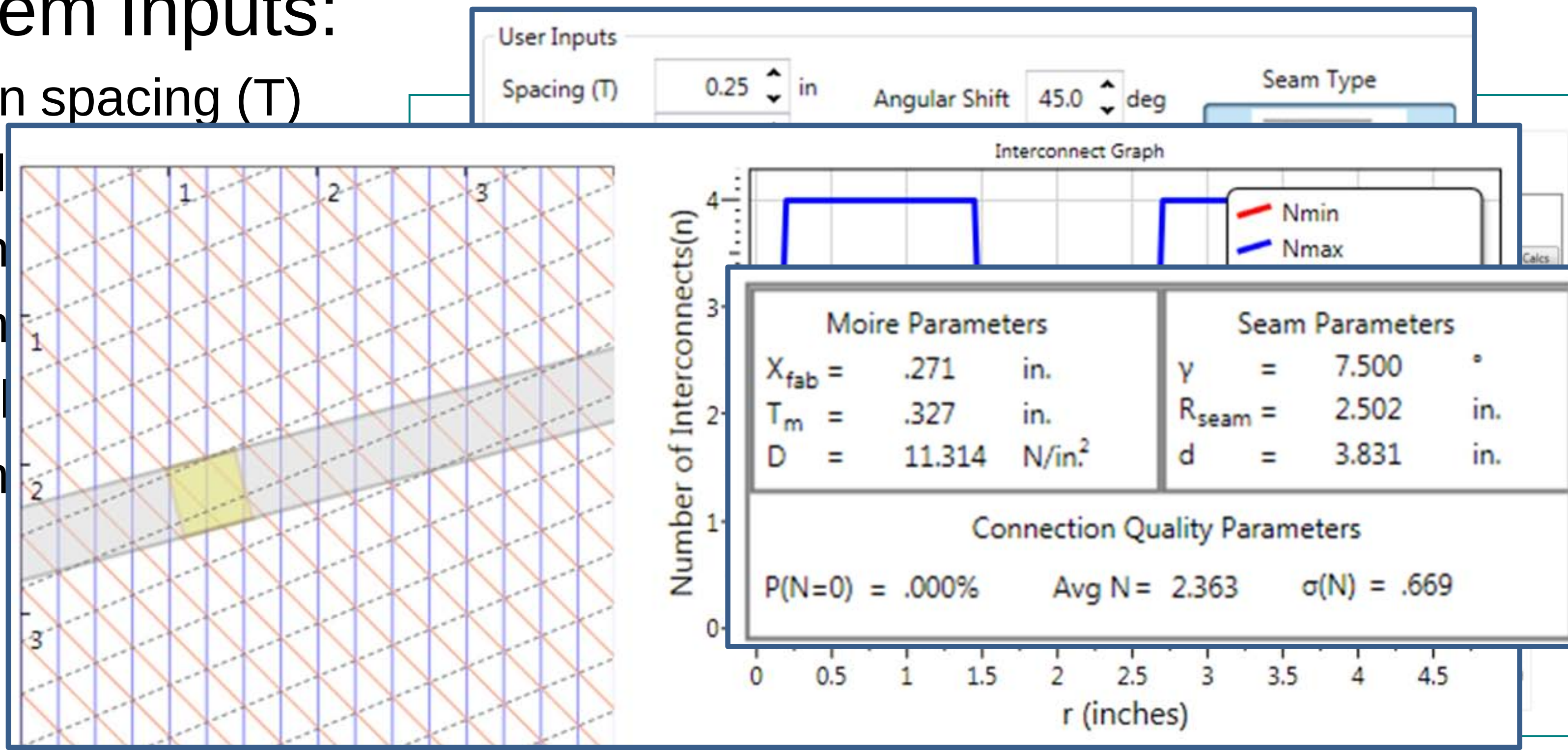
Software Development Strategy

- Investigated the iterative design and pattern making process used at the Natick Soldier Systems Center to transition from a design concept to the factory floor and how to best integrate our design tool into that process.
- Conducted a review of available pattern making software packages.
- Identified two basic design options;
  - Develop a plug-in module for an established closed-source package (i.e. Gerber's Accumark)
  - Develop a standalone tool that interfaces with established software packages.
- Near-term development has focused on a standalone tool to reduce risk and demonstrate feasibility

Initial Model development

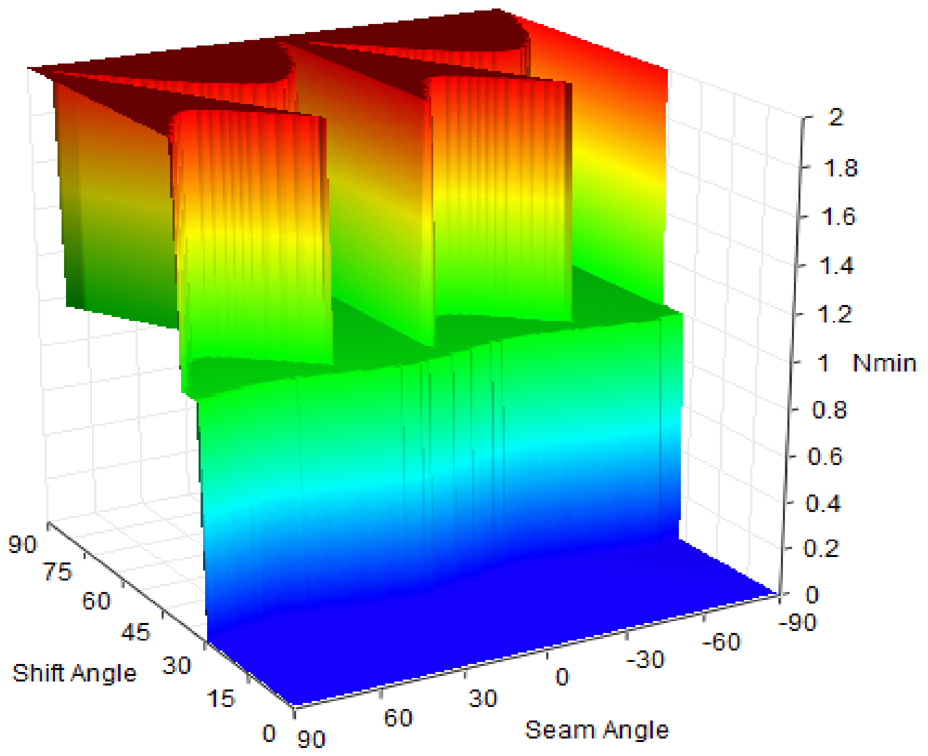
System Inputs:

- E-yarn spacing (T)
- Angul
- Seam
- Seam
- Horn l
- Seam



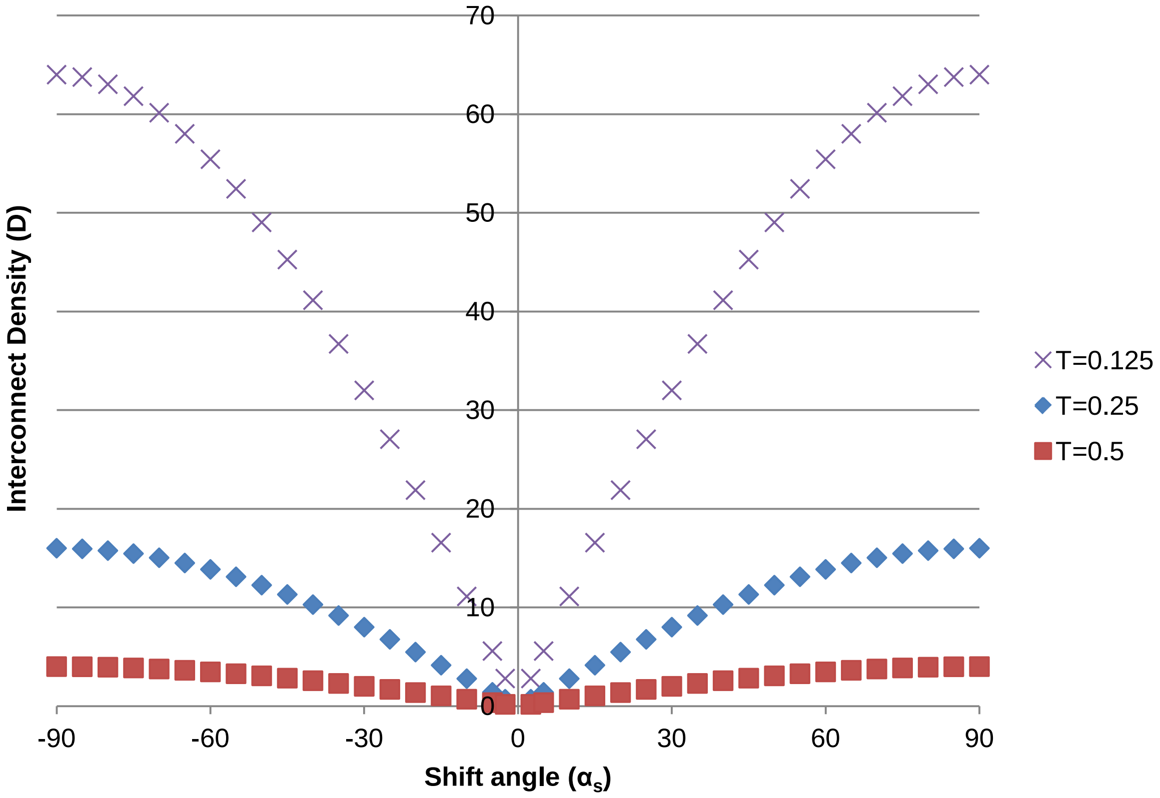
Data Export Function

- For a defined set of geometric parameters (Seam width, horn size, etc.) the following weld parameters can be exported for all values of α_s and β.
  - Nmin
  - Nmax
  - Navg
  - Std Dev
- Input Parameters:
  - T=0.25”
  - W=0.5”
  - Hd=0.5”



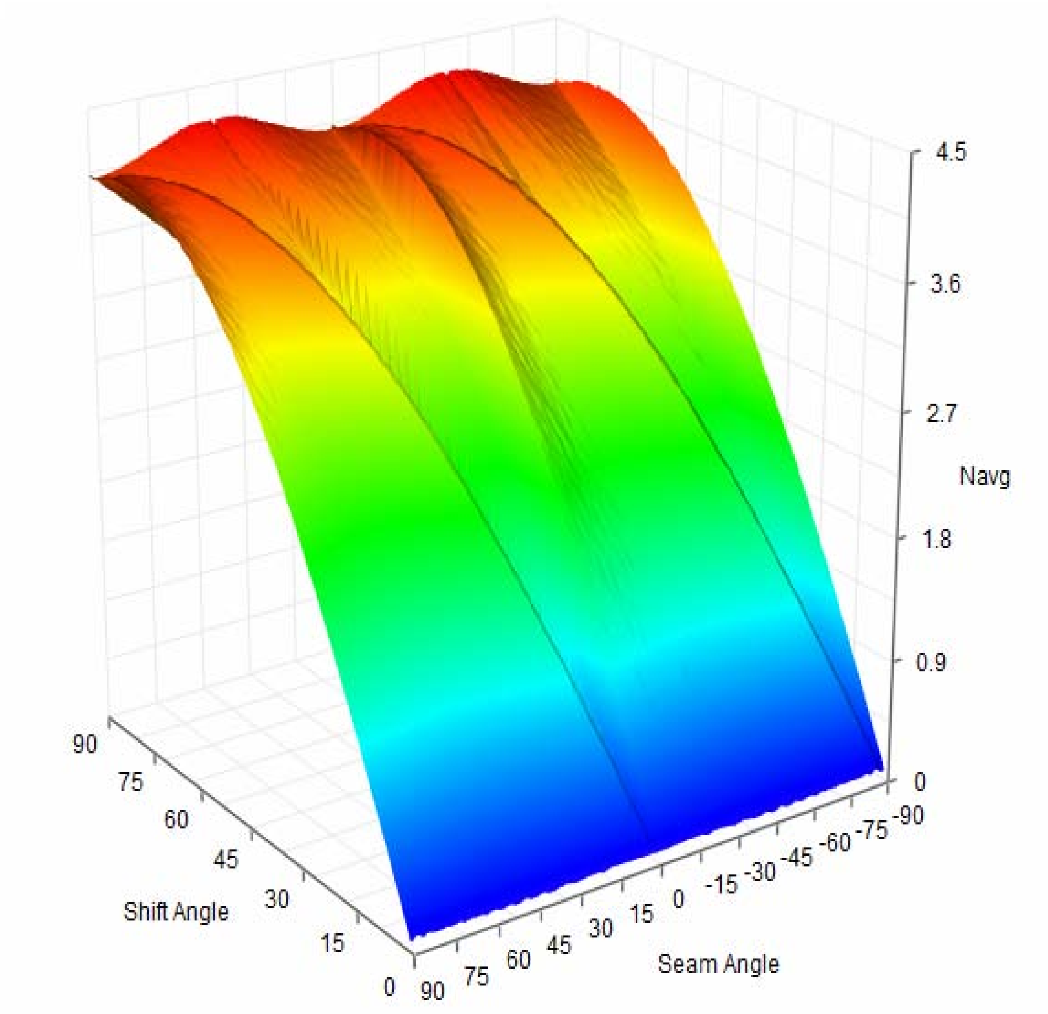
Moiré Parametric Study

The number of available interconnects per unit area (D) can be seen to be proportional to the square of T. This provides us with a powerful means for controlling the density of available interconnects in a specific region.



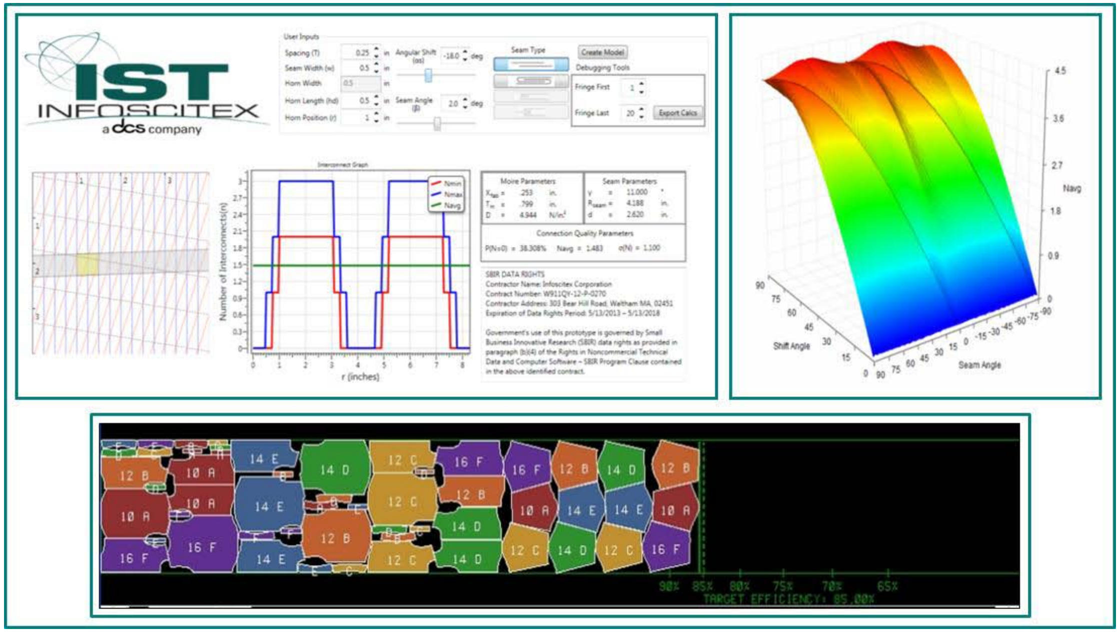
Shift Angle / Seam Angle

- E-yarn Spacing (T): 0.25-0.5”
- Seam Width (w): 0.5”
- Horn Width (hd): 0.5”



Next Steps

- Model extension
  - Additional seam types
  - 2-D yarns
  - Weave patterns having multiple length scales
  - Network Properties
- Software Extension
  - Real-time 3D plotting
- Software Interoperability
  - Patternmaking
  - Circuit layout



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Questions?

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