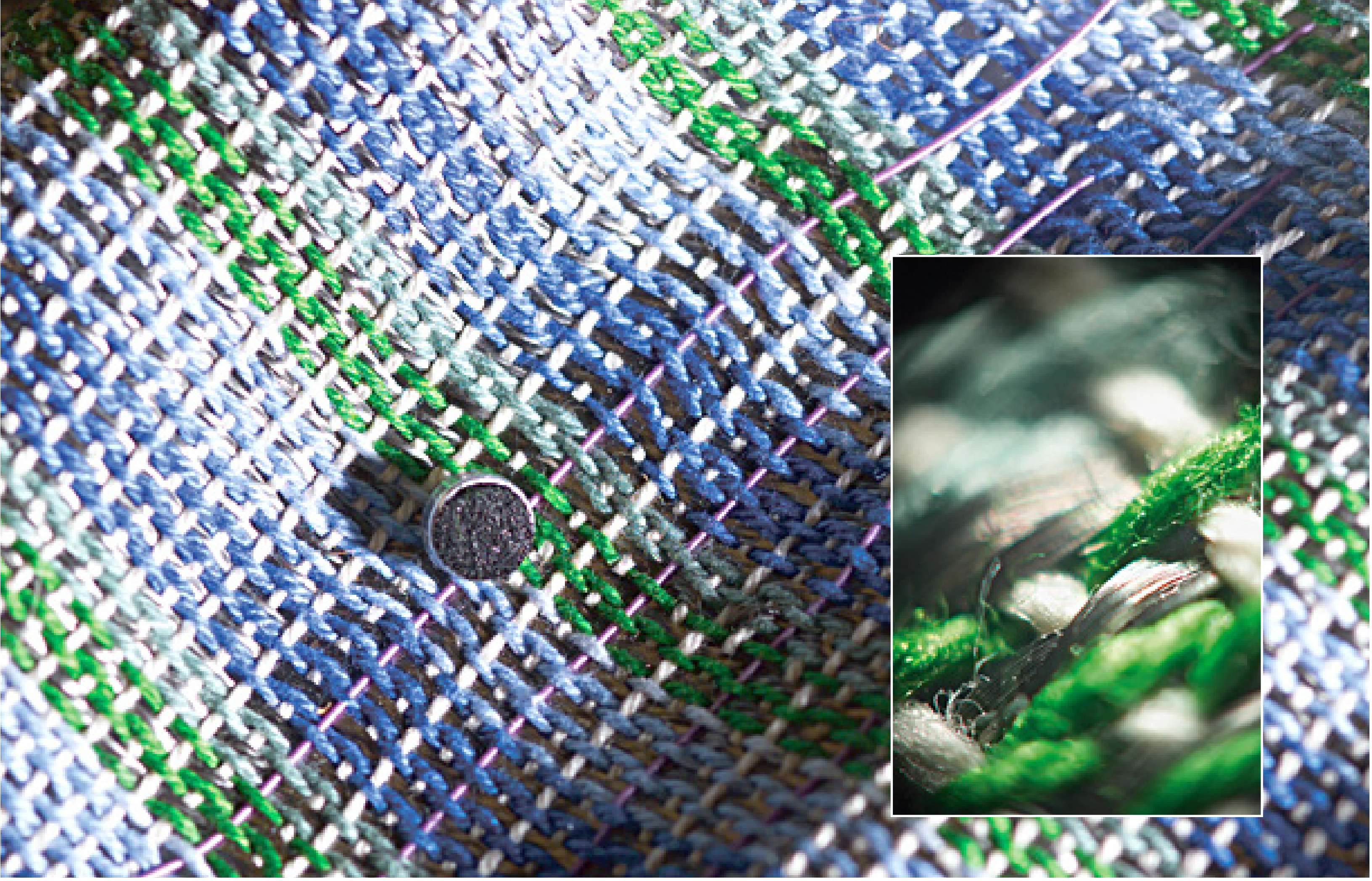

Virginia Tech Computer Engineers constructed a functioning 30-foot swath of acoustic array fabric with interwoven wiring and integrated microphone sensors and circuit boards. The original stainless steel thread (inset) was found to fray and create shorts, so it was replaced with the purple insulated thread pictured here.

E-textiles:

The Ultimate in Flexible Computing

Students taking this spring's ECE course on wearable and ubiquitous computing are directly involved in cutting edge e-textile work.

Computer engineers in Torgersen Hall may be weaving the future of specialized fabrics — e-textiles that can be used to sense tank movements, monitor homes for noxious chemicals, help firefighters maneuver in smoky buildings, and perhaps help stroke victims recover their function. Their biggest result to date is a 30-foot swath of fabric interwoven with stainless steel thread, and styled with microphones, sensors, connectors, and circuit boards.

The 30-foot fabric is a prototype acoustic array for use in military sensing. It is strong, lightweight, and flexible. It can potentially be fabricated as tents, parachutes, or camouflage nets. Developed specifically to detect and locate tank and military vehicle movements, it is the first functional e-textile that can perform all the operations involved.

Military Advantages Over Wireless Sensing Networks

The acoustic array fabric was developed in collaboration with researchers at the University of Southern California's Information Sciences Institute (ISI), which was funded by the Defense Advance Research Projects Agency (DARPA). "E-textiles are a big part of the U.S. Army's next generation soldier systems," explained Mark Jones, a lead investigator on the project. E-textiles for sensor network communications provide some field advantages over radio communications. RF communication can be detected and give away a unit's location. Also, e-textile systems have lower power requirements, since the signals from the sensors are carried along the wires interwoven in the fabric.

The technology has potential in many sensing and monitoring applications, such as monitoring homes for carbon monoxide, or other chemicals. "They can also be used in a smart home to detect the movement of people and adjust the lighting or sound systems," Jones suggested.

Recently the group began investigating the technology for carpets and wall hangings. "If we can put communications, sensors, and computation into things that already exist, that we already know about, we can more efficiently augment a home's capability," he said.

E-Clothing

With funding from the National Science Foundation (NSF), the group is also developing wearable e-textiles. Tom Martin, one of the e-textile group's lead investigators, believes the biggest applications for wearable e-textiles will be industrial, where the computers can display schematics for construction and maintenance workers, freeing their hands for their tasks. "The biggest advantage to e-textiles in that situation is wire management," he said. "Typically, when workers are in tight spaces, wires snag and connectors break. When we weave in the connections, the surroundings can't snag or catch on the shirt," he commented.

The first wearable prototype the group developed is referred to as "the ugly glove." It is a black fabric glove sporting electrical tape and wires going through the fingers. The glove was used to demonstrate typing without a keyboard. "We figured if we couldn't do the glove, our other plans also wouldn't work," said Martin.

Work, it did, and the group is now pursuing development of a mapper garment and a shape sensing garment. The mapper garment would be used as a shirt that maps a building as its wearer walks through it. "It is not simple; we need to account for the non-linear movement of the person, for turning, stopping, and for changes in the shirt itself as it gets worn," Martin explained. "We need to determine what sensors we need where. Placing them on the fabric is one thing, but when a shirt is worn, a sensor on a sleeve cuff can suddenly find itself in close proximity to a sensor near the belly button."

The team is using piezoelectric materials for the shape sensing garment, which they hope will be able to monitor precise movements of the body. "This could be used in physical therapy for stroke victims who must do their exercises in a certain way," Martin said. "The garment could indicate when they have moved correctly, or what they need to do to correct the movement. It could also be used for helping an athlete perfect a golf or tennis swing," he added.

A significant challenge in developing wearable e-textiles is modeling the movement of the human body. "We'd like to program these not as fabric, but as the actual shirt and pants," Martin said.

Modeling the Garments

The team is building a modeling environment so that precise simulations can be developed for e-textile projects and eliminate some iterations of prototypes. "We would like to use the same software for simulation and emulation," Martin said. "We need to simulate not just the fabric, but its user and its environment."

The e-textiles group is dedicated to introducing students to the technology and has introduced projects in this semester's course on Wearable and Ubiquitous Computing. The projects are directly related to the mapper garment, the shape sensing garment, and the physical aspects of e-textiles.

The researchers worked on a number of physical issues with the initial work—such as how to make connections between the woven wires and how to mount electronics components in the fabrics. "I would not like to be weaving forever," Jones commented, "but we have to understand what's going on at all levels in order to make reasonable choices. At this point, we need to manufacture the entire system here in order to have the level of control necessary."

The e-textile group is currently investigating special polymer fibers for different uses, such as those that can act as batteries or chemical sensors and some that change color for camouflage. They are discussing manufacturability with various textile firms. "In the end, we need something that is durable, washable, low-cost, and easy to manufacture," Jones said.

Computer engineering challenges abound. "We need to make e-textiles that are fault tolerant, and self configuring," Jones said. "We need to determine how to answer questions like how many processors and sensors do we need and where do we put them?"

Packaging is a big issue, he said. "Most chips are packaged with 100 or 1000 pins and we want only four or five pins. The pitch, or space between standard pins, is small. We need wider spacing for e-textiles. We need more things in a package, including the processor and memory," he added.

Regardless of the packaging, computing, and practical challenges, the group hopes to have at least one of the garments working by summer. "It's hard work," Martin acknowledged, "but it's fun."

Tom Martin (left) and Mark Jones (right) "model" the acoustic array fabric.