Chapter 9.

Early Smart Textiles Projects: Electronic Fashions

Why Textiles?

My interest in smart textiles as a sculptural and active computing material was fueled by two very different fields of research: Wearables and Tod Machover's Hyperinstruments. After my early work in the *Brain Opera*, I desperately wanted a sensor skin that could be wrapped around a sculptural object to create a multi-channel, pressure-sensitive, musical instrument. At the same time, the Wearable Fashion Show (October, 1997) was happening at the Media Lab. While I was not particularly interested in the existing paradigm of strapping a PC to your body, I was fascinated by the idea of making clothes compute. Smart and electrically active textiles presented themselves as a solution to both problems. I was already interested in using textiles because of their

Figure 9.1 Early fashion projects in the Tree of Projects.

excellent design properties. Fabric is highly sculptable and immediate. It can be easily cut, shaped and sewn into many shapes. It can be dyed or printed on, and comes in many colors, textures and weights. Its woven structure makes it extremely flexible and strong when bent or stretched. Finally, textiles are the exact opposite of most computing materials: they are soft, flexible and intimate, and encourage people to touch them. As the material antithesis of most computers, textiles provided a direct way to radically change the meaning of computers through their tactile and materials properties. I also hoped that smart and electrically active textiles would provide a way to change and explore an active relationship between physical form and computation.

The smart textile projects presented in this thesis also represent a journey from the making of labor intensive, one of-a-kind items, to limited series, mass production. The first smart textile projects, like the *Firefly Dress*, were labor intensive, one of-a-kind items. Later projects, like the *Musical Jacket,* attempted to use manufacturing processes and designs that could be easily reproduced with a minimum of handwork, and that were easily implemented by textile labor untrained in electronics. Reproduction meant that these projects had to dummy proof, able to be made using the standard processes for manufacturing any stuffed item, like a teddy bear. Because textiles are an excellent material for creating a limited-series of multiple items, they made and enormous amount of sense for both demo-making and interactive projects. Replicating textile items does not require the cost of an expensive tool, as the injection molding of plastic does. And provided that the design of a textile object is done with the manufacturing process in mind, that object can be relatively easily replicated with a pattern. This is an ideal process for creating a limited number of multiple objects, in the 10-100 range. Mechanically, textiles are highly durable, perfect for the touching necessary for interactive installations, and the ability to easily reproduce textile objects also means that broken parts can be easily replaced.

Because the smart textile works presented in this thesis were motivated by different research agendas, they span a range of functions, from musical instruments, to electronic tablecloths, to purely visual fashions. And while they may seem to be functionally unrelated, artistically they are not. All the smart textile projects presented in this thesis are explorations of how sculptural and electrically active computing materials can truly change the aesthetic experience of computers and enable artists and designers to better communicate. They also all represent an investigation into *functional ornament*[1]. In all of these works, the smart fabrics are used both as functional circuit elements and as ornament. Early projects show a limited relationship between the design and sensing/electrical properties of the ornament. In later projects, that relationship becomes intimately intertwined. The design of the embroidered pressure sensors in the *Embroidered Musical Instruments* is both the result of aesthetic choices and their sensing and electrical needs.

[1] A further investigation of *functional ornament* can be seen in Chapter 2.

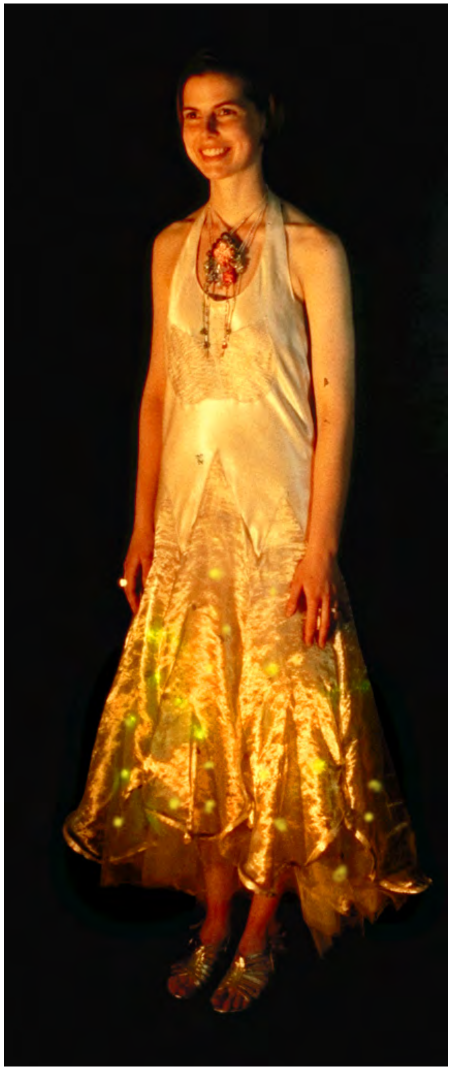

Figure 9.2 Emily Cooper, wearing the *Firefly Dress and Necklace*.

The Electronic Fashions

These electronic fashions[2] were created exclusively for the MIT Media Lab's 1997, Wearable Fashion Show, in collaboration with designers from different fashion academies around the world.

I began to think about using conductive fabric or computing fabric when Thad Starner presented me with Wearable Computers. They were so hard, and their cables so bulky and fragile, that I thought that there had to be better way to do it. My first demonstration of an electrically active textile was a sample of fabric from my wedding dress (metallic silk organza[3]), with a flashing LED magically suspended in it. I tested the conductivity of this fabric on a lark, and found that it was highly conductive. It was also anisotropically conductive (conductive in one direction). In metallic silk organza, conductive threads or yarns run only in one direction, on the weft of the fabric. They are also well spaced, so that each yarn can be individually addressed, like a single wire in a ribbon cable. This meant that it was possible to have both ground and power, or a circuit in a single piece of fabric. The idea of having a circuit in a single piece of fabric fueled much of the smart and electrically active textile works to follow.

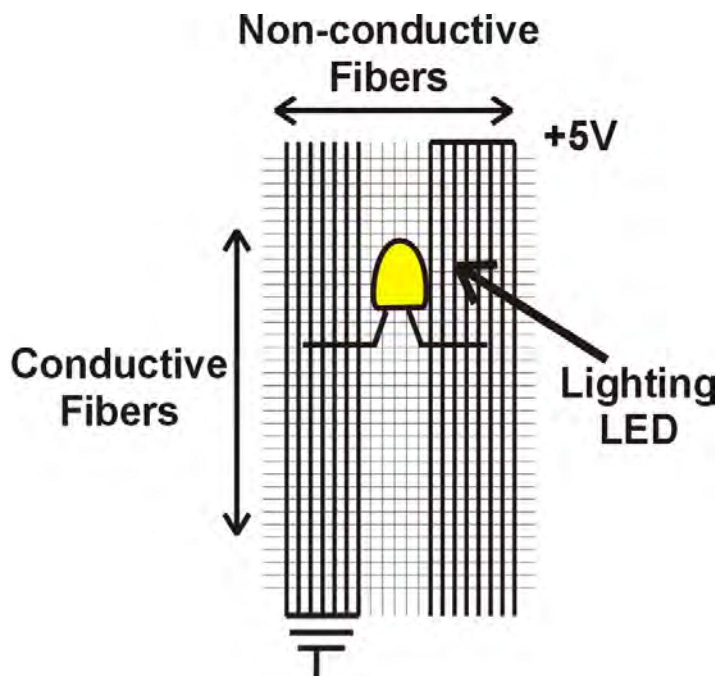

Figure 9.3 Diagram of my first demo of a fabric circuit, with a lighting LED suspended in anisotropically conducitng metallic silk organza, 1997.

[2] Descriptions of projects in this chapter refer to:
Orth, M., Post, R., and Cooper, E. B., *Fabric Computing Interfaces,* (short paper), Proceedings of Conference on Human Factors in Computing Systems, (CHI '98), Los Angeles, ACM Press, (1998).
[3] See the Chapter 15, the Materials Index.

The threads that make metallic silk organza conductive, are silk fibers wrapped with a metal foil, or what is called a gimped yarn. All of the fashions featured in this chapter use either the metallic silk organza, or the gimped yarn from which it is made, as electrically active elements. These metal wrapped yarns are centuries old and have been couched (tacked down), or woven into many decorative fabrics, like saris, in many cultures, for centuries. The fashions in this chapter turn these electrically active textiles into *smart* materials by using them for housing or design materials, (the fabric of the clothes), sensors, resistors, capacitors, antennae, and wires. These fashions also contain carefully disguised central circuitry or power supplies. Careful placement and design of these necessary "hard" parts, helped keep these fashions soft and flexible. Because all of these fashions display dynamic feedback visually, they must incorporate visual displays or lights, which are usually tactilely hard. Unfortunately, these hard and fragile display elements ultimately limited the flowing and soft quality of these fashions, as well as their practicality.

Firefly Dress and Necklace∗

The *Firefly Dress and Necklace* combines lights, simple on/off switch sensing, and sewn circuits into a dress with a level of detail and romance rarely associated with computing technology. While neither the necklace nor the dress *compute*, they still provide an exploration of the design advantages of making smart textiles function as a sensor, display substrate,

∗ In collaboration with Emily Cooper and Derek Lockwood.

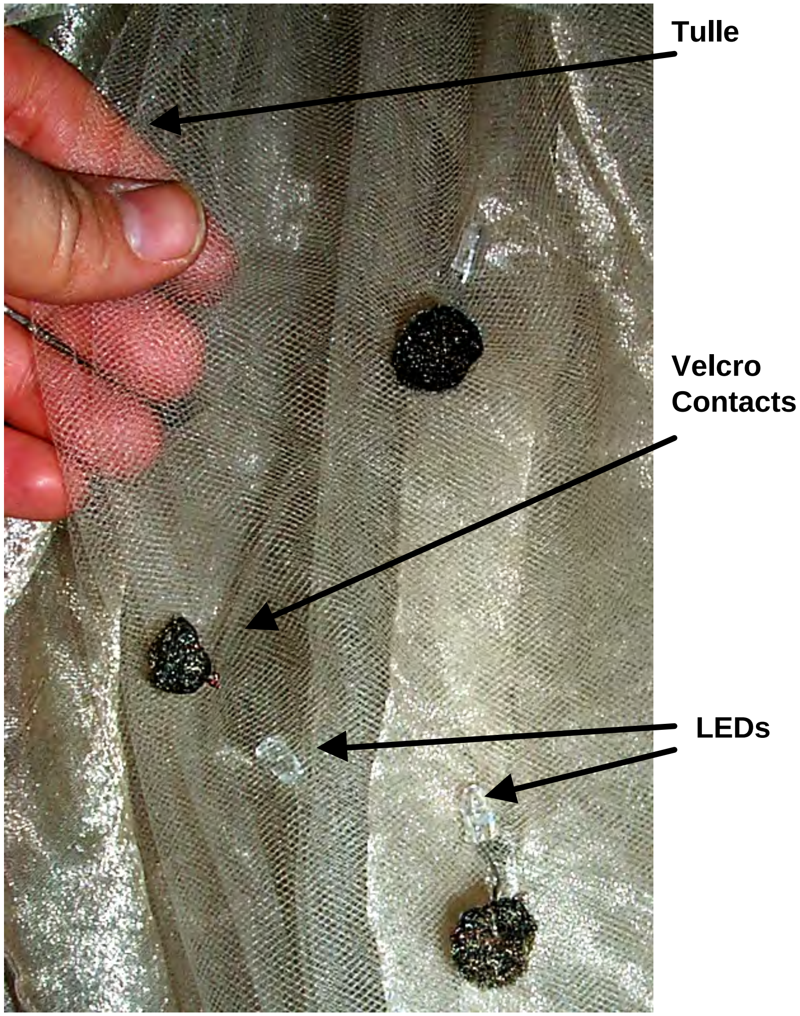

Figure 9.4 Detail of *Firefly Dress* skirt, with LED's suspended on tulle, and conductive, female Velcro brushes on their ends.

and design or housing material. The *Firefly Dress and Necklace* are also an exploration of how an electronic object can simply, visually, and expressively reflect the motion or state of its wearer. Both are a surprisingly beautiful reflection of its wearer's motion.

In the piecework *Firefly Dress*, the conductive metallic silk organza acts as a sensor, a display medium, a medium for electrical transport, and the physical material of the dress itself. Fabric traces sewn from the metallic silk organza distribute power and ground from a battery pack hidden under the dress to the outer skirt and bodice of the dress. The skirt is built from two layers of conductive fabric that form a power and ground plane, which are separated by a layer of insulating tulle. Suspended on the tulle between the fabric power and ground planes are LED's whose ends are attached to fuzzy brushes made from conductive, female Velcro. As the wearer moves, the fuzzy conductive ends of the LEDs brush against the fabric power and ground layers. This intermittent contact with the fabric power and ground plane completes the circuit, and causes the LEDs to light, simply reflecting the wearer's movement.

The *Firefly Necklace* uses multi-colored LED's to convey the motion of its wearer. The necklace has no power supply of its own. It is connected to the ground with a snap at the back of the neck, and connects to power when its conductive tassels brush against a fabric power panel sewn on the front of the dress. The flexible conductive tassels are made from metallic wrapped thread and conductive beads. As different tassels brush against the power plane, they feed

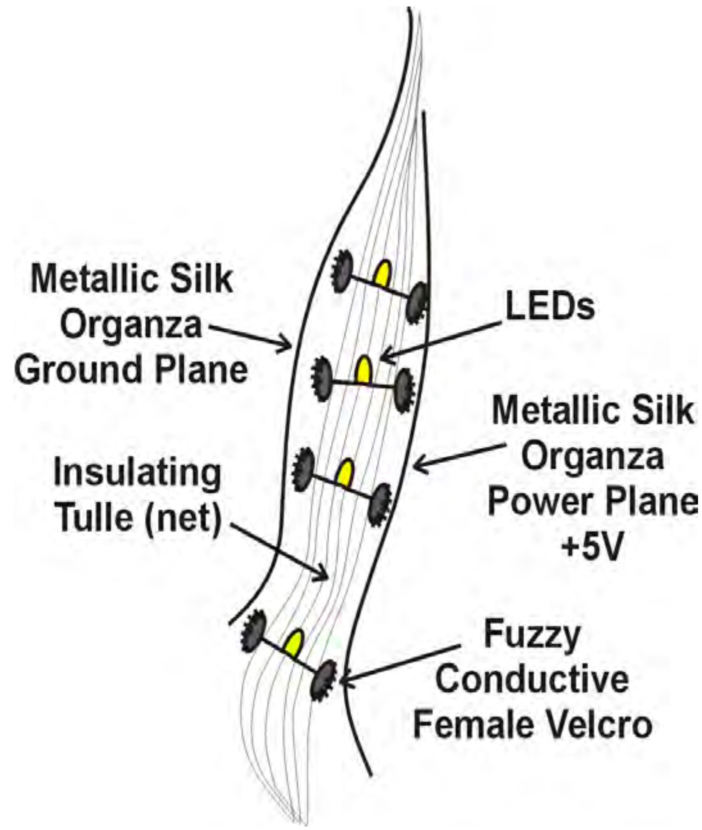

Figure 9.5 Electrical diagram of the skirt in the *Firefly Dress*.

current into different resistors and then into multicolored LED's. Because each tassel controls the current contribution necessary to create a specific color in the LED, the brushing of different tassels against the power plane causes the LEDs to rapidly change color.

This dress represents hours of labor on the part of many people. Creating durable fabric circuits, avoiding short circuits, and integrating fragile LED's into the dress was painstaking beyond belief. And while the resulting dress is very beautiful, it is not practical. You simply cannot sit down it, because the LEDs are hard and break. In this sense this dress is really a piece of haut couture, a one of a kind item that cannot be reproduced, and is not practical to wear.

material references*:* conductive Velcro, metallic silk organza and metallic wrapped thread.

Figure 9.6a, b *Firefly Necklace*, the blue tassel contributed the amount of current that made the LEDs flash blue. The red tassel did the same for red in the LED's and the green tassel did the same for green in the LEDs, creating color mixing in the multicolored LEDs.

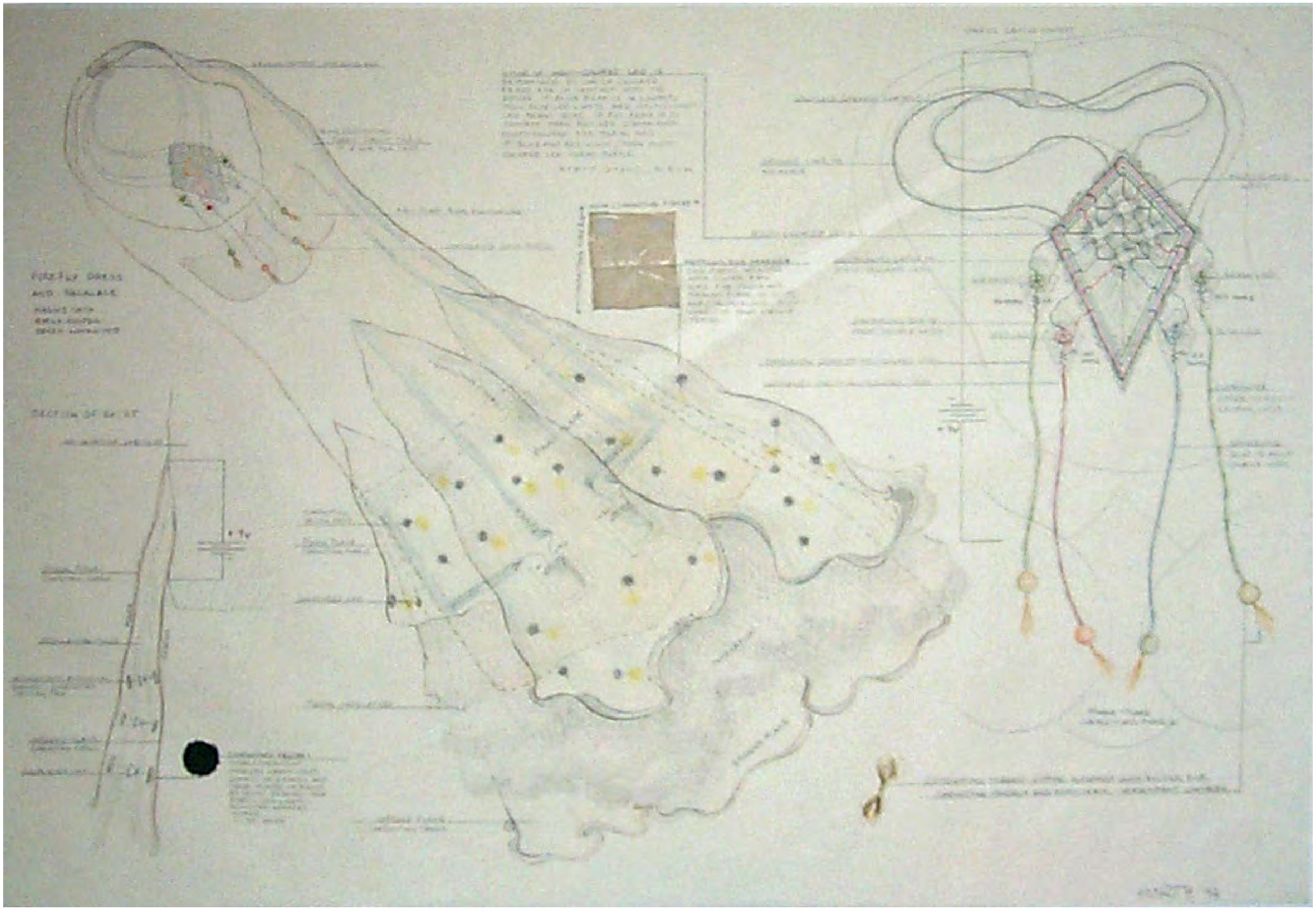

Figure 9.7 Fashion illustration/circuit diagram of *Firefly Dress and Necklace*, Maggie Orth, 1998.

Electronic New Year's Eve Ball Gown[*]

Patterned after a 17^{th} century French gown, the *Electronic New Year's Eve Ball Gown* is covered with floral hand embroidery made from the gold wrapped or gimped metallic thread. The floral embroidery acted as capacitive switches and wires to connect LEDs on the skirt to PIC microprocessors sewn into the hem of the dress. In this dress, the embroidery allowed the skirt of the dress to light up, but remain free from wires and other hard materials. By touching different metallic, embroidered, capacitive sensors sewn onto the dress, the wearer of the dress could trigger and control different light effects on the skirt. The PICs both capacitively sensed the embroidered electrodes, and controlled how the lights flashed. Each PIC circuit was individually powered with its own battery. Because the sensing was capacitive, the wearer was grounded to the circuit using an internal, fabric, power plane sewn into the waist of the dress. This demonstrated that placing a piece of metallic organza next to person skin was an excellent way to ground them for different capacitive sensing methods.

Like the *Firefly Dress* this dress was the result of the hand labor of many people. The gimped or wrapped thread used to create this dress stripped easily and had to be hand sewn with great care. Avoiding short circuits and creating electrical continuity in the dress was a painstaking process. Simply tying a not between the different threads did not create continuity. Folds in the skirt caused short circuits.

Figure 9.8 *Electronic New Year's Eve Ball Gown* with electronic embroidery, LEDs and PICs in the hem of the skirt.

[*] In collaboration with Emily Cooper and the students of Bunka Institute.

Like the *Firefly Dress and Necklace*, the *Ball Gown* is a relatively impractical, one of kind piece of haut couture. Unlike the *Firefly Dress and Necklace*, the *Ball Gown* uses *computation* to control and interpret the information from the sensors, making for an interesting comparison. While the *Ball Gown* allowed the user to actually turn off its lights, control the rate of flashing, and parts that flashed, it also required a lot more attention form the wearer. The *Firefly Dress* was ultimately far more visually compelling and easily “interactive” despite its lack of computation.

material references: metallic wrapped thread.
technical references: Complex Impedance Sensing.

The *Serial Suit*[*]

The *Serial Suit* allowed its wearer to use a simple touch to send enigmatic messages on an LCD display pinned to the lapel of the suit. The serial messages were sent from processors located in the pants to a serial pin located in the jacket, through circuitry sewn from metallic silk organza. Conductive fabric sewn into the waist of both the jacket and pants made the ground connection between the two when the wearer closed the jacket. The message was transmitted from the pants to the jacket when the wearer touched a conductive button on their sleeve, to a conductive fabric panel on the pants. This allowed the wearer to choose when to pass the message on to the display. However, the wearer could not choose which message

LED suspended in electronic hand embroidery,

Figure 9.9 An early example of the conductive, floral embroidery, used in the *Electronic New Year’s Eve Ball Gown.*

[*] In collaboration with Emily Cooper and Derek Lockwood.

was sent, as the processor randomly rotated through a series of messages.

This suit demonstrated the potential for distributing information around the body without hard wires and fixed electrical connections. The combination of the wearer choosing when to display a message and the computation choosing what message to display was humorous and encouraged conversation.

material references: metallic silk organza.

Figure 9.10 *Serial Suit* jacket.