

City Centered Cycling

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Name: Lyle Reilly

Signed.....

Date.....

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Name: Lyle Reilly

Signed.....

Date.....

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City Centered Cycling by Lyle Reilly

ABSTRACT

This project explores design considerations and processes involved in the development of sports performance clothing specifically aimed at city cycling commuters.

Research with a focus on smart clothing and electronic integration was used to form a technical framework in which the requirements of the end user were addressed.

The result being the creation of a wearable electronic jacket containing a lighting system aimed at improving safety and comfort aspects affecting cycle commuters.

The project methodology was essentially practice based with a strong experimental approach linked to the physical testing and refinement of electronic and clothing integration.

Design aesthetics were equally important and are presented as a visual record linked to the use of computer related technologies which have influenced the design planning and processes of the project.



Fig 1. Completed white jacket

Introduction to exegesis.

This exegesis presents research about design processes and considerations used in the development of the Master of Art and Design project named City Centred Cycling. The documented work highlights some theoretical discussion about the cross disciplinary nature of the project which incorporates elements of sportswear; product design and electronics. The practice based work is presented in a case study format which shows stages of experimentation leading to development then refinement of a wearable electronic cycling jacket carried out between May 2007 and Sept 2009.

The Exegesis consists of the following sections:

A project introduction that highlights the following :

- The initial rationale for the research.
- The significance of the research.
- The overarching research questions that frame the study.
- The overall and personal context of the study.
- The overall approach to the study.

A review of research material that informed the project:

This section highlights some existing research in the field of wearable electronics that has proven to be relevant and valuable in the approach of the project.

Methodology Outline:

This section highlights the approach to practice based research in relation to key references, before going on to indicate how research relationships and specialist feedback were included to extend understandings of the study area. The methodological approaches identified were adapted to suit the experimental nature of the project and are combined to form a human centred framework that targets the intended end user of the project; the cycle commuter.

Practical investigation:

Practical investigation is documented in 3 progressive phases of studies that demonstrate the practical nature of the work. The phases highlight experimental processes and relevant reflection that went on to influence and inform the subsequent stages of the project. Three distinct research phases are documented in the form of case studies. The case study format has been used as a way of distinguishing these phases of the project to define research focus and working process that were being used at the time. The research phases are named Red, Green and White, specifically named after the colour of the garments produced.

- The **Red** phase shows early experimental pieces of work that explore function and fit leading to a collaborative attempt at electronic integration.
- The **Green** phase concentrates on design and practical considerations while implementing a wearable electronics system.
- The final **White** phase, documents how research understandings have been combined with expert advice and the use of technology processes to refine the final project piece.

Conclusion:

The closing section of the exegesis

- evaluates the success of the investigation;
- A response to project research questions.
- Indicates how this research has added to the body of knowledge in the field.
- indicates future research direction and possibilities as a result of this study

The visual documentation contained in the exegesis is closely linked to the text and is printed double sided for continuity reasons .

Introduction to project

I came to this project because my personal experience as a cyclist lead me to believe that research in the area of sportswear design and wearable electronics could be targeted to meet the needs of cycle commuters. I wanted to combine my cycling experience and fashion related skills with the challenge of introducing smart technology to create a piece of cycling clothing that was aesthetically pleasing and safer for the wearer.

The aim of the City Centred Cycling project has been to develop a wearable electronic jacket specifically aimed at city cycling commuters. The key factors that were considered were that the jacket should be comfortable to wear, offer protection from wind/rain and be highly visible to traffic. While the aim of the work was to produce a functional cycling jacket, the research focus explored the design processes and considerations associated with the introduction of wearable electronics, in particular the integration an LED electronic lighting system to increase visibility to motorists.

By undertaking this research I have been able to gain a deeper knowledge of how electronics and my own field of fashion can be combined to produce what is known as “wearable technology”. Professor David Smith, co-organiser of the “Wearable Futures” Conference held in Newport, South Wales in 2005, defines wearable technology as “.....an emerging trans-disciplinary field bringing together concepts and expertise from a variety of disciplines, ranging from materials science, through computer engineering to textile design” (Smith, 2007). This point highlights a main challenge facing the project and the importance to include expertise from disciplines outside my own experience and abilities. This required the development of an interdisciplinary framework that has been central in

allowing the work to progress in a professional manner. The introduction of specialist feedback and expertise has had a significant impact on the approaches to electronic integration of the project.

There was an experimental and trialling approach used throughout the project, in fact all the jackets made have been worn for testing to obtain feedback to assess progress of design applications. So the intention of the presented work has not been to create beautifully crafted items of finished clothing but more a review of prototype progress made in the context of the development of wearable electronic clothing aimed at cycle commuting.



Fig 2. Lyle Reilly cyclist



Fig 3. Wearable electronics

Research significance

The research significance of the project is based around the inter-disciplinary concerns that embrace the field of wearable electronics. In recent years there has been an increase of commercial product available, yet there remains lack of accessible research material that is devoted specifically to the implementation of the discipline. Aspects limiting a lack of accessible knowledge include commercial confidentiality and intellectual property issues which prevent access to existing product details and design process. More importantly the bodies of knowledge required for wearable electronic integration currently exist in separate domains, mainly fashion design and manufacture or electronic engineering. The field of wearable electronics is a growing discipline that draws expertise from a mix of related areas, but at this stage a common location to house this new field of expertise does not fully exist. So the significance of this particular research is to contribute to the growing body of knowledge that is being built around wearable electronics. The contribution shares understandings and insights that have surfaced as a result of the practice based design approaches used in the study. While the project presents work specifically targeted at cycle commuter use, the electronic integration information presented is transferable for fellow researchers exploring the inter-disciplinary nature of wearable electronics

The main questions posed by the research are:

- What are the main design considerations for wearable electronic integration?
- What practical advice can be offered to fellow researchers embarking on a wearable electronics project?
- To what extent does effective design planning influence a wearable electronic project?

Cycling/ Social Context.

The project is informed by social issues related to transport in Auckland, New Zealand, but indirectly could apply to many cities around the world. Issues such as increasing fuel costs, parking difficulties, traffic congestion, transport delays and pollution are concerns facing city residents. A possible solution to these issues could be an increased use of cycling which is generally seen as an environmentally friendly, healthy, inexpensive and flexible alternative to private car usage. Stephen McKernon, Director of New Zealand design research company Supplejack supports Auckland cycle commuting based on the following projections:

The Auckland Regional Land transport strategy (2005) estimates 340,000 people will move into the Auckland region by 2016. If car ownership remains as high as now, there will be 195,000 more cars. Traffic could increase by nearly 25%, congestion, pollution and other motor- related problems would then also increase (McKernon, 2007, p.8).

There is growing support overseas, J. Mathew Roney researcher at Earth Policy Institute highlights this point " With more than half the world's population now living in cities, there is tremendous potential for municipal governments and urban planners to increase bicycle use by following classic European examples like Copenhagen and Amsterdam" (Roney,2008). Within these cities cycling commuting has flourished due to cycle focussed transport planning, public education and an overall acceptance of a cycling culture.



Fig 4. petrol consumption



Fig 5. Cycling health benefits



Fig 6. Danger of cycling



Fig 7. Cycle commuters

Safety aspects

Cycle commuters no matter where the location are presented with certain issues, including: lack of visibility to motorists; lack of protection from the elements; hygiene when arriving at workplace. The context of the project sits around the challenge of attempting to find solutions to these issues. Safety is of particular concern to the project, evidence points to the vulnerability of cyclists, essentially safety is the reason why a wearable lighting system is included as an effort to increase rider visibility to traffic.

The goal of the project has been to create well designed sports performance clothing that enhances the commuting experience and safety for the user. Realistically, it is fair to say that sports clothing alone may not be the sole catalyst for an increase in cycling commuting or a reduction in accidents, but could perhaps contribute to social change that compliments cycle focused infrastructure developments such as cycle lanes and road user education.

A New Zealand Ministry of Transport report outlining crash statistics tells that during 2007 12 cyclists were killed, 181 were seriously injured and 699 suffered minor injuries in police reported cycle crashes on NZ roads. It is reported that the estimated social cost of crashes involving cyclists was \$172 million. The report also highlights that more than 50% of accidents occurred on busy urban roads during peak traffic times of between 8-10 am and 4-6 pm. Two suggested reasons for this are heavy traffic conditions and the onset of darkness (*Cyclist Crash Facts, 2008*).

Personal context

On a personal level I have a huge connection with this project. I have been an active cyclist for over 25 years and continue to commute by bicycle on a daily basis. My career path has allowed me to specialise in the technical aspects of fashion design process. So consequently I have taken the logical step to connect my understanding of fit, construction and fabrication directly to my cycling experience to formulate a working process for the targeted project. My initial focus was towards high end performance clothing with an emphasis on aerodynamics, fit and fabrication for cycle racing. However the challenging question, “What is your point of difference?” resonated strongly with me when posed at an early critique session. The question was valid, there was little evidence to suggest that I could push my existing skill set to the point of significant improvements to the work already being done by top Sportswear companies.

A subtle but important shift of direction occurred as I questioned the fact that the majority of cycle clothing is targeted specifically at road racing, BMX or mountain biking, yet despite a worldwide increase in cycle commuting there is very little clothing targeted for this use. Also, I had been intrigued by the field of wearable technologies and thought that the idea of a cycle commuting jacket with an inbuilt lighting system could create a research challenge with a “point of difference”. The fact that I was out of my comfort zone having very limited prior knowledge of wearable electronics meant that there was an element of discovery that could drive the project.

A review of research material that informed the project

Interaction of technology and clothing

"No longer can we look at a piece of cloth and think of it as technology as old as time. We must start to realize that it holds infinite possibilities when put into the hands of a creative team who strive to answer the question, "What if?" (Wilson, 2005 p209)

A number of authors share Dr Patricia Wilson's optimistic view surrounding the potential of smart textiles wearable electronics, however, specific research material discussing practical work and integration of wearable technology that could relate to my work is limited. There are a range of possible factors for this; the relative newness of this field of research; the range of possible technology applications; the interdisciplinary nature of the field and the location of where such research should be placed. It is hoped that this current situation is addressed in order that new developments including my own work can significantly add to the body of research available. Despite the lack of specific practical application research available, I have found value in a number of projects and examples of practical work done by fellow researchers that have connection to the overall approach taken to this project.

The New Nomads project sponsored by Phillips Electronics is an example of how creative minds from different discipline background can be pulled together to create innovation to *"weave electronic functionality into clothing with the aim of empowering the wearer on his or her journey to tomorrow's world"*. (Marzano, 2000 p4) The project originally set up in the Phillips Redhill laboratory United Kingdom in 1997, comprised a team of fashion designers, industrial design engineers and electronic engineers who were given a fairly wide brief to explore the possibilities of incorporating small electronic devices within clothing. The resultant work of the team anticipates and responds to the future of professional work-wear, sportswear, interactive clothing for children and youth as well as brief examination at ecological and health related clothing. It is unclear if in fact any of the wearable electronic clothing shown in the finalised book of the project published in 2000 was fully functional, but in some respects the conceptual ideas and look of the work has helped to galvanise my thoughts for the project.



Fig 9. Staying Alive Mountaineer's Suit from New Nomads project
Koninklijke Phillips electronics 2000

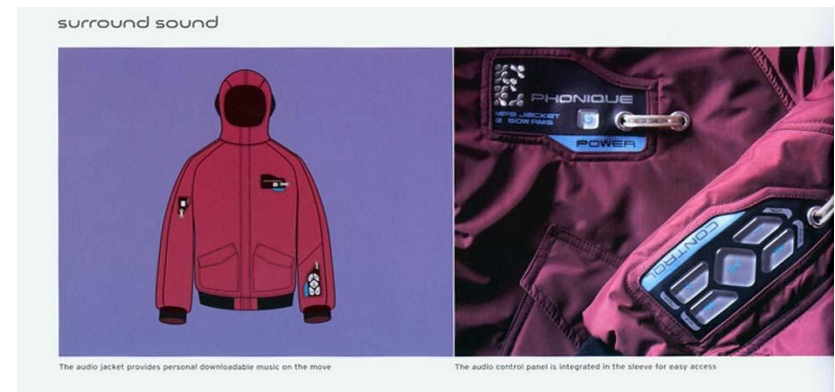


Fig 10. Surround Sound Audio jacket from New Nomads project
Koninklijke Phillips electronics 2000

Engineering versus fashion

To date the use of wearable technologies has predominantly featured within the specialist areas of healthcare, military and high performance sportswear. However a number of respected commentators of the subject, namely Jane McCann (2005), Ariyatun and Holland (2005) share Professor David Smith's belief that the emergence of the discipline within the commercial sector is still some way away. Smith makes the following quote in *"Smart clothes and wearable technology"*, *"One is struck by the obvious fact that very little of what is shown appears to be actually "wearable". Many excellent ideas do not seem to make the transition from laboratory "bread-board" prototype to marketable day-to-day application"* (Smith, 2007 p4).

Smith proposes a theory for this lack of cohesion from concept to final product suggesting that there may be a lack of understanding by industrial designers and engineers about the technical aspects of fabrication, clothing manufacture and ergonomic body fit. I tend to support this belief having had some recent involvement with a New Zealand based electronics company specialising in Smart technologies. I was surprised to discover that the company do not employ any staff from a clothing or textiles background despite showing commitment to the wearable electronic business.

Another factor highlighted by David Smith is the perceived lack of understanding of the process of design to potential wearer, he notes that *"the technocentric R&D models which are currently dominant in the industry and academia often pay little attention to real humans"* (Smith, 2007, p4). Such comments imply that more consideration of human centred factors is required to create an environment enabling wearable technologies to flourish.

Design for people... wearable electronics in snowboarding

Companies who have produced successful commercial wearable electronic products appear to have a strong affinity with their intended user group. This point is particularly evident in the sport of snowboarding where the use of wearable technologies is linked directly to the sports youthful identity and the understanding of emerging technologies. A clear illustration of this can be drawn from the comments made by Bryan Johnston, Vice President of Burton's Global Marketing *"Music and technology are a huge part of the snowboard culture"*. <http://www.motorola.com/mediacenter/news/detail.jsp> Burton and other leading brands have been able to make the connection that the new sport of snowboarding has its own identity and that young participants are in tune with new developments and show a responsiveness to adapt to new wearable technologies. While my cycle wear project is not commercially driven, as an active cyclist I am in tune with the New Zealand cycling culture and the "real human" considerations surrounding the project.

The Burton Audex iPod Snow jacket which introduced *Soft switch technology was released in 2003 and is heralded as a commercial benchmark. (Fig 11) Since then companies such as Levi's, Reusch, H4 and indeed Burton have expanded on the MP3 theme progressing towards mobile phone integration. Most recently O'Neil in 2008 released the NavJacket which includes a GPS navigation system to assist snowboarders. (Fig 12)

*Soft switch technology was originally developed by Canesis Network in Christchurch, New Zealand 2004



Fig 11. The Burton Audex jacket is a joint venture between mobile communications company Motorola and Burton snowboard apparel. The jacket offers wearable communication and entertainment via integrated Bluetooth wireless technology to download music via your Bluetooth-enabled phone or portable music device.



Fig 12. NavJacket by O'Neill snowboard division incorporates a GPS navigational system that can be used in the mountains. The navigational system is connected to a with a digital flexible display placed on the sleeve and the audio instructions in the hood

High tech versus low tech.

An interesting phenomenon associated with wearable technology has emerged in recent years as more and more people are experimenting with wearable technologies instead of waiting for commercial companies to come up with the ideas. Leah Bueachly from MIT Media Lab USA describes this as the “democratization of technology”. On a recent visit to New Zealand she said *"I believe the democratisation that we've seen in the software universe that enables people to become journalists and photographers is coming into the physical world"* (Bueachly,2009). This point would appear to be her rationale behind the development of the Aurdino LilyPad, a DIY wearable electronics system which essentially simplifies a lot of the complex computer programming and connectivity normally associated with electronics expertise. As a result of this practical innovation there are many amateur enthusiasts involved in a growing social network linked to wearable technologies. Websites such as *talk2myshirt* and *Fashioning Technology* are just two examples that attract a worldwide following.

The 2 examples shown on this page are from the talk2myshirt website. Firstly a commissioned piece called ‘Human Synthesizer’, Fig 13 made by Jasmin Jodry from th1ng explores wearable communication possibilities.

While designer Jeffrey S. Engelhardt Fig 14, shares a similar line of enquiry to myself in his efforts to produce illuminated clothing especially for the safety needs of runners during low light conditions. His research includes the use of Electro Luminescent (EL) wires for a flexible integration to ensure great wearing comfort. The images show the EL wire position on the upper back connecting to a rechargeable battery source. Future research possibilities for the NR4 illuminated running apparel include a soft GPS location module and performance monitoring .



Fig 13. human synthesizer

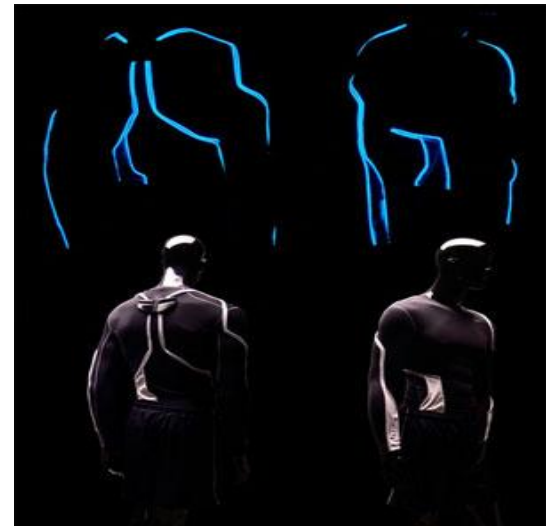


Fig 14. NR4 illuminated running apparel

Worldwide sharing of ideas

The Talk2myshirt website is testament to the power of the sharing of ideas through the internet, during August 2009 alone there were over 40 posts published covering a wide range of Wearable related innovations. This includes highly technical applications such as a wearable electronic health monitoring system and a renewable power supply bag aimed at assisting third world countries.

There is an even broader eclectic list of artistic endeavours that includes such items as an electronic umbrella, illuminated flip flops, a sound generating Tuxedo, a human synthesizer, interactive performance wear and even sensor boots. Just how well received these developments are preserved is perhaps cause for debate, just because a products includes high tech integration does not guarantee any success beyond the designers creativity. Robert Wright, author of Nonzero: The logic of Human Destiny points out *“Your brain may have given birth to any technology, but other brains will decide whether the technology thrives. The number of possible technologies is infinite, and only a few pass this test of affinity with human nature”* (Wright, 2000,p42).

Just where the future of Wearable electronics goes is uncertain, but there is a sense that the direction can be shaped by people for people and perhaps the democratization of technology that Leah Beauchly talks about is underway. Indeed Sabine Seymour, author of Fashionable Technology 2008 highlights a noticeable shift from the embedded technologies such as iPod and LED integration towards new possibilities.

“Many artists and designers prophesize more provocative scenarios for the future of such technology. These artists foresee that this trend will eventually have an unprecedented social impact, due to the wide-ranging possibilities for self-expression, connectivity, and public communication of innovative technologies” (Seymour,2008,p23).

Fig 15. The Accouphine Tuxedo created by Vincent Lederc, Joanna Berzowska and the XS lab in 2006 explores artistic and futuristic possibilities by attempting to *create a 3D sonic environment around the human body that can be activated and modulated through movement and the hands and cloth.*

Fig 16. LED lights on the umbrella perhaps have both practical and psychological to brighten up a rainy day? (Sockmaster 2008)

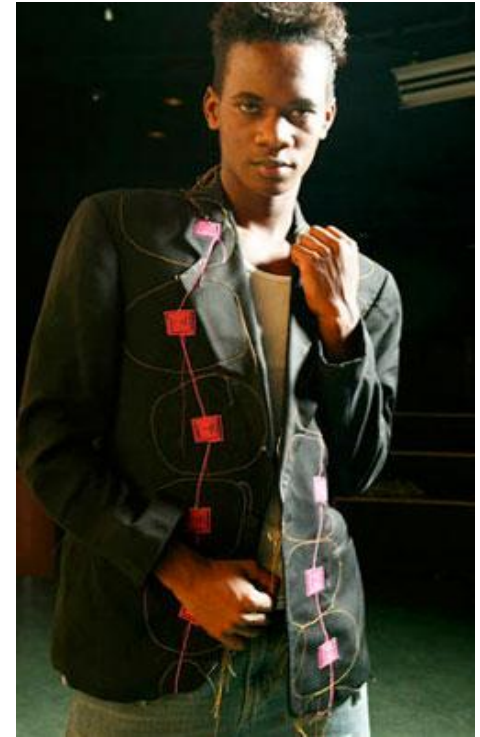


Fig 15. The Accouphine Tuxedo



Fig 16. Umbrella with LEDs

City Centered Cycling Methodology

Methodology outline

The City Centred Cycling project was developed using methodological approaches that suited both the needs of the research study and my personal style of working. The fact that the jackets were to be made for cycling commuters indicated that an “end user” was in mind and this identification helped to keep the project focused despite the cross-disciplinary boundaries encounter. My approach to work practice has previously been based on tacit knowledge and personal experience with the focus on technical and design aspects of the fashion industry. I am an experienced pattern maker with a particular emphasis on computer aided design. My career has progressed towards the specialized roles of technical manager and design room manager for prominent companies in New Zealand and the United Kingdom. The skills developed over 25 years have ensured that I have a good knowledge of fit, fabrication and function that has been directly applied to this research. The intention of the project however, has been to extend my skills and knowledge in a new direction towards wearable technologies and within this section some fresher methodological approaches applied to the project are discussed.

New Product Design, Action-Research, Research Relationships

Jane McCann, Director of Smart Clothes and wearable Technology (SCWT) group, Newport School of Art and Design, United Kingdom) makes an interesting point in her belief that *“performance sportswear design, concerned with end user requirements is closer in philosophy to industrial or product design than to fashion design”* (McCann,2005,p46). This comment was pivotal to the approach used for the City Centred Cycling project. Looking at the project in a problem solving context more akin to product design than fashion design helped to target the “end user cyclist”. This lead to the introduction of a methodological approach called **New Product Design** (NPD) which was adopted after studying Ariyatam and Holland’s paper “ A strategic approach to new product design in Smart Clothing” (2005)

The NPD approach was valuable to establish initial research understandings around the nature of cycle commuting and wearable electronics relative to the end users of the study. The fact that I am also a cycle commuter is significant and I include myself very much as an “end user”. This point proved particularly valuable during the project testing stages. The project included experimentation and trialing phases similar to that used within fashion industry work practice that I am familiar with, so I regard my natural style of working to comfortably sit within an **Action-Research** framework which draws from Donald Schön’s notion of the “The Reflective Practitioner”. Schön indicates that when someone reflects-in-action *“he does not separate thinking from doing, rationating his way to a decision which must later convert to an action”*. (Schön 1983, p68) Finally, it was important to include advice and feedback from specialists from outside my normal field of expertise. The input given from these **research relationships** has ultimately proved vital to the execution of the project

Methodology approach 1. (New Product Design)

McCann suggests that *“to practice successfully, those involved in product research and development must identify, understand and respond to a broad range of both technical and creative issues”* (McCann 2005, p54). This particular point was an important consideration to find a balance of technical, function, comfort and aesthetics aspects for the project. In response to the question, how to find a balance for the project? I found Ariyatam and Holland’s position useful in the context of integrating the different design philosophies of electronics and fashion. Through the New Product design (NPD) model the authors present a methodological framework that can link multiple paradigmatic or design approaches in a beneficial, balanced way. The key to this process is the focus on the end user and the value of feedback at various stages of the design process. I have included the New Product Design (NPD) methodology within the City Centered Cycling project by adopting the following 3 stages:

NPD Stage 1 The key issues:

The key issues are the considerations and multiple viewpoints posed within the NPD model, encouraging different thinking towards the end users needs. Essentially this requires being open-minded to applications from other areas, such as the identification of alternative use of technology, fabrications and techniques. The benefit of this can be illustrated in a cycling context, modern clipless pedals developed in the early 80's by the French company Look were an adaptation of the technology used for Ski bindings. The point being that research has to extend wide enough to draw in possible solutions from other fields of study. My practical investigation in the following sections show some examples of an openness for adaptation such as:

- The inclusion of fit testing and fabric print techniques in **Red** phase of the project.
- The introduction and experimentation with the Aurdino LilyPad wearable electronic system in the **Green** phase of the project.
- The adaption of technical processes to create lighting power source in the white phase of the project.

NPD Stage 2 Hypothesis and research methods:

User centred requirements are at the heart of the design thinking and work methods used for the project. The process included the gathering of research material within the field of wearable electronics to see how others are using technology for similar projects. While I have drawn a lot from my personal experience, the research has been inspired by feedback and advice from others. In particular the **Red** phase case study uses targeted questions (pages 26 & 27) to establish a clearer picture of how a commuter actually responds to using the jacket, project decisions were then made as a result of the feedback.

NPD Stage 3 How to handle complexity:

The complexity of drawing together elements from a variety of disciplines was approached through a transformational process where the full integration of technology from technical / functional and fashion design aesthetics were given optimum balance. The result emphasises the shift from a purely technical or alternatively a purely aesthetic approach to a user centred one. The progression of technical and aesthetic considerations raised during the project have eventually shaped the outcome of the final White jacket. (Fig 17)

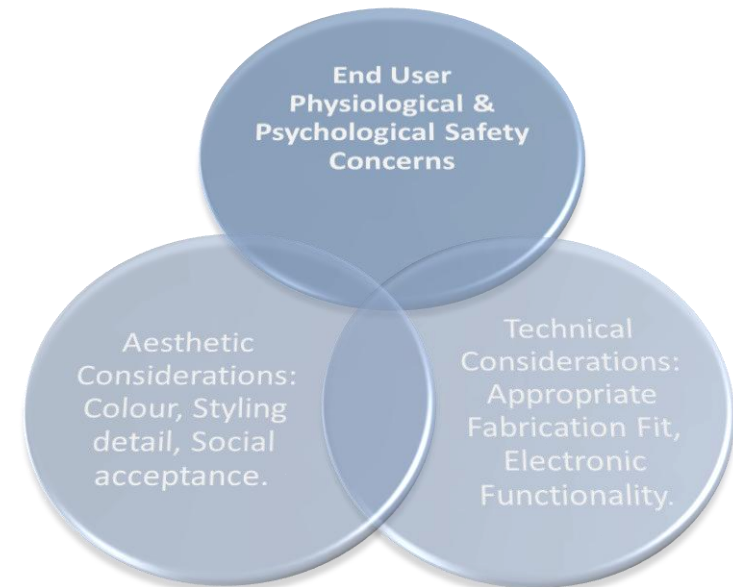


Fig 17. The diagram above illustrates the framework of how aesthetics and technical concerns are considered in the context of the end user being central to the project.

Methodology approach 2. (Action research)

Donald, A. Schön's book *"The Reflective Practitioner"* (1983) was relevant as it places value on the judgments, understandings, reflections and consequent actions that an experienced practitioner undertakes. He refers to this process as "reflection-in-action"; the diagram below (Fig 18) illustrates the action research spiral showing 4 stages: (Planning, Action, Observation and Reflection). In many respects this way of working reflects much of the process that I have used throughout my career without actually knowing there was a name for it. Within the fashion design rooms I have worked, the decision making process of style development has had a cyclic nature that requires sampling, testing, assessing, reflection, refinement....before repeating the process till an optimum outcome is achieved. I have been able to apply this process to the City Centered Cycling project.



Fig 18. "The Action Research Spiral" adapted from Schön 1983.

Schön describes the process of reflection-in-action within a problem solving context, *"As he tries to make sense of it, he reflects on the understandings which have been implicit in his action, understandings which he surfaces, criticizes, restructures, and embodies in further action"*. (Schön, 1983, P50). It is interesting to note that the testing and experimentation applied to this project often produced results that were quite different from how the original concept was envisaged. An example of this can be seen in the Green Phase case study where a number of approaches were trialed before a solution was found for the best implementation for the use of conductive thread to transmit an electrical signal was realized.

Being open minded to experimentation is important and has pushed the boundaries of the project. While the original goal of the Cycling clothing range remained, the research questioning as a result of reflection-in-action cycles was regularly reframed as an ongoing development process. Stephen Scrivener takes Schön's, "reflection-in-action" notion by applying it to problem solving research, and indicates that *"new discoveries call for new reflection-in-action"* and that *"the reframed problem becomes the basis for experimentation to discover what consequences and implications follow from it"* (Scrivener, 2000). I have been able to relate to this process and work with a research framework that is underpinned by my professional and cycling experiences. My reflective comments within the case studies are directly linked to archival material and project evolution that responds to questioning posed by both problem setting and solving.

Research relationships

In order for the project to expand beyond my own limitations it was crucial to seek specialist knowledge in areas that I was not experienced in, in particular, electronics, methods of electronic integration and fabric printing. The term research relationships loosely describes the interaction I had with a number of experts whom I consulted with in order to develop my skills and understandings in such technologies. In each of these interactions specific development aspects of the City Centered Cycling project were dealt with in a questioning manner to which the experts responded by either offering advice or actual practical solutions that were included in the finished pieces.

- **Electronic expertise** Manukau Institute of Technology (MIT).

The original question posed for Red 3 was; can a small circuit board with appropriate lightweight power supply capable of powering 9 LED lights be developed? The results of this collaboration lead to a the completion of an early functional piece which formed the basis of later research.

- **Electronic implementation and consultation** (Purtech Ltd).

Professional electronic consultation was included to take the final piece to completion. The consultation centered around the question – “How to design and create a purpose built wearable electronic?”

- **Screen and digital printing expertise** (AUT University) was introduced to create the aesthetic look of the Red and white phase. Primarily the questioning centered around the most appropriate methods of translating digital design ideas directly to hi tech sportswear fabric. The expertise provided ensured that print detailing could be applied to the work.

- **Garment construction consultation.** (AUT University) After producing the majority of the jackets myself I chose to introduce professional help to construct the final pieces for a more professional finish. In doing so it became apparent to me that the construction methods for electronic integrated clothing are quite complex and are critical to this study.

An important aspect of this research was having the ability to realise my own strengths and knowing when to seek outside expertise. On a practical level some of these processes could have been simply contracted out to experts. But in the context of this study, that approach would serve no purpose as it was the inclusion of all the facets of expertise that were needed to achieve the original aim of the study to “explore design processes involved in developing sports performance clothing specifically aimed at city cycling commuters with a focus on smart clothing” (CCCP Abstract)

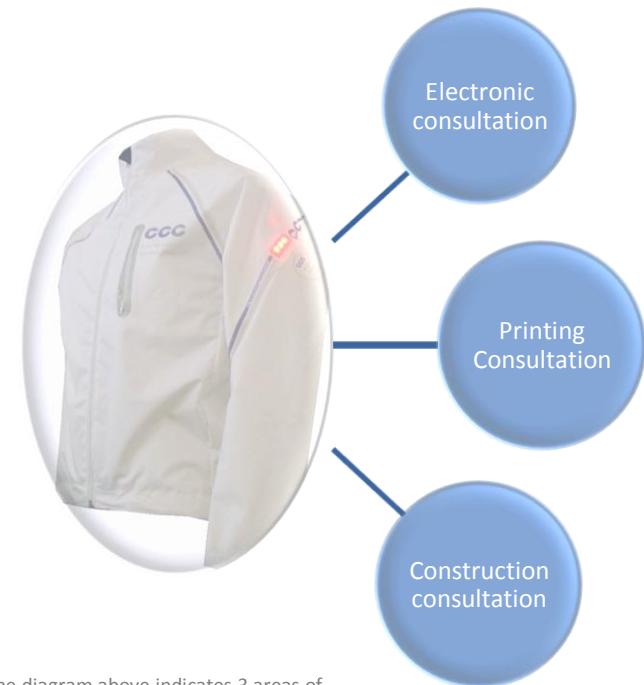


Fig 19. The diagram above indicates 3 areas of consultation that were used to feed directly into the project.

Red phase case study

The Red phase shows early experimental pieces of work that explore function and fit leading to a collaborative attempt at electronic integration.

Red phase case study

The following pages show processes and reflection of the he work carried out during the 2007 Red phase of study. This phase was very important in formulating the direction that future work in the project would take, in particular the inclusion of electronic integration, printing techniques and a consolidation of fit.

This case study includes 3 jackets entitled Red 1, 2, and 3 that were developed one after the other in a largely experimental manner linked to the “Reflection & Action” methodology. To demonstrate the use of this methodology I have included some cycle user feedback of actual jacket testing which was reflected upon before decisions for further action were made. The progressive nature of the work shows movement from purely sportswear considerations of fit and aesthetics towards the initial exploration of a wearable technology for cycle commuter wear.

It is important to note that during this phase I was able to integrate the wearable electronic component of the project for the first time. I have been fortunate to work collaboratively with researchers with an electronic engineering background, this significantly reshaped the project and has resulted in the LED lighting system incorporated in the final piece Red 3.



Fig R1. shows Front views of Red 3,2&1 Jacket.

Electronic integration

Having spent some time experimenting with existing reflective tapes to make the jackets appear more visible, I felt that I was making little headway in increasing visibility safety as reflective tape is already widely used by cyclists, road workers and for emergency services officers. Integrating lighting within the jackets seemed an exciting and possibly effective way of addressing the issue. However, with no prior electronic experience this prospect seemed challenging. In New Zealand, the only evidence that I had seen of how this could be done was the Torpedo 7 lighting vest (FigR2). Aesthetically, the overall look of the vest was somewhat crude, but in regards to a functional piece with visual safety in mind, the flashing lights performed extremely well to alert traffic of a cyclist. I was able to draw inspiration from that fact that it could be done and also the prospect of taking the concept to a more aesthetically designed item.

I have been fortunate to have a shared interest in cycling with Glen Nicholson and John Leak electrical engineering Lecturers from Manakau Institute of Technology, Auckland (MIT). Through this connection I was able to seek advice and direction on the electrical integration of a LED lighting system. Firstly by connecting a 12 volt battery to 3 LED lights placed in the pocket of a cycling jacket. Although this phase used fairly rudimentary electronics, it was a significant step forward in the quest to successfully integrate a functional lighting source to the project.



Fig R2. shows Torpedo 7 visibility vest



FigR3 Shows a 12 volt battery linked to 3 flexible LED lights

Testing of Red 1 winter jacket

Leading up to the creation of this jacket I had done some preparatory research in the following areas:

- Garment fit appropriate for cyclists in the riding position
- Investigation of fabrics with wind proof and moisture wicking properties.
- Consideration of how these fabrics could be strategically placed on a jacket.
- Investigation of the effective use of reflective piping and LED lighting.
- Aesthetic considerations when using reflective piping.

At this stage, basing my understandings on the analysis of existing cycling products and personal technical clothing experience. The Red 1 jacket marked the first serious attempt to test much of the initial research assumptions and review progress. On completion of the jacket an end user wearer trial and research questionnaire was initiated to obtain feed back of how the jacket actually performed. The trial was carried out by an independent source, in this case research colleague Glenn Nicholson who would later contribute to the electronic integration of Red 3.

The research questions were designed to gain specific feedback on particular aspects of Fit, Comfort, Safety performance during the testing stage, as well as a general appraisal of aesthetic considerations. The following summary of this questionnaire results outline some key aspects that that were picked up as a result of having end user feedback for consideration.

Safety Aspects: The jacket was primarily used during winter and in poor lighting conditions of early morning and early evening. The wearer indicated that the jacket colour, reflective piping, LED back light were contributing factors for an increased sense of safety in traffic.

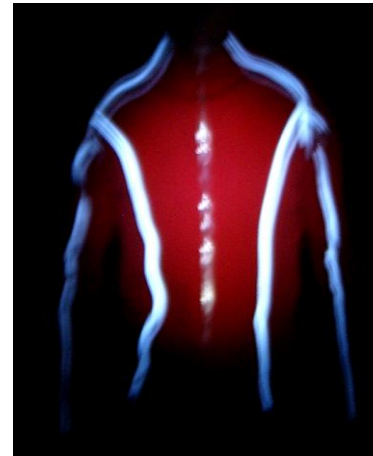


Fig R4. Red 1 Front view under limited lighting conditions

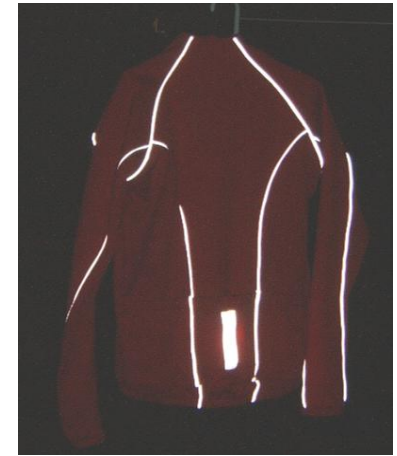


Fig R5. Red 1 Back view showing vertical LED lighting strip

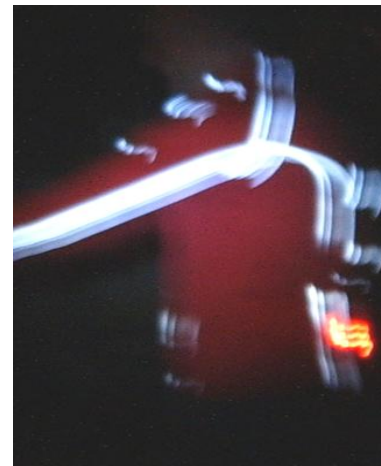


Fig R6. Red 1 Detail showing movement under torch light

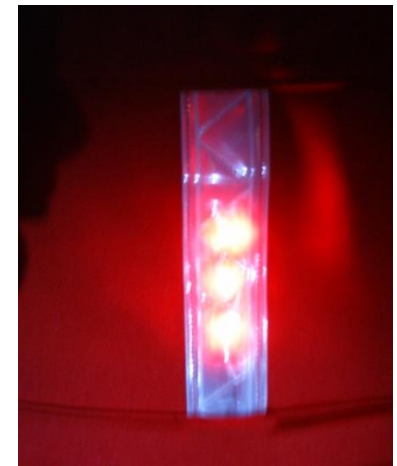


Fig R7. Red 1 Close up of back pocket with vertical LED lighting strip

Testing of Red 1 winter jacket

Fit:

The general fit of the jacket was regarded as too small with the emphasis being too much on a high-end sports performance fit, rather than a more relaxed fit that would perhaps be more appropriate or favoured by cycle commuters.

Comfort:

Red1 uses a mix of fabrication intended for comfort, the wind proof “Hydrotec” is used in the exposed areas of chest and arms, while the lighter breathable fabric is placed on side panels and back. In reality, testing would suggest that this choice of fabrication is appropriate for temperature under 15 Celsius. So consideration must be given for the comfort of the wearer in warmer temperatures.

Aesthetic considerations:

Comments were favourable in regards to the overall look of the jacket, but that improvements could be made to the construction, in particular the zip and pocket functionality was not seen as substantial enough. Finally the rather primitive use of LED lighting system powered by a 12 volt battery should be reviewed.



Fig R8. Red 1 Detail shows forward cut shoulder and sleeve to replicate riding position



Fig R9. Red 1 Close up of back pocket with vertical LED lighting strip



Fig R10. Red 1 Close up of high grown –on neck



Fig R11. Red 1 Front detail showing reflective piping and grown-on neck

Reflection on Red 1 jacket.

An important aspect taken from the process around the Red 1 jacket was the realisation that the identified research methodologies were appropriate for the study and felt natural to work with. The action research elements of the work were linked to the new product design process of obtaining secondary feedback in the form of a user survey ensuring some balance to perceptions of how successful this stage of the project was.

Key strategies and tasks undertaken in light of the Red 1 jacket reflection:

Fit Considerations

Fitting of jacket is too geared towards aerodynamics; as a result more relaxed comfortable fit options were explored.

Specific areas for pattern reconsideration were the shoulder area to increase movement when worn, sleeve area was too tight and the neck detailing proved to be uncomfortable due to reflective piping detail.

Construction considerations.

Use of reflective to used more sparingly. Reduce piping bulk.

Pay closer attention to quality of trims used. IE zipper, hem gripper.

Strategic placement of LED lighting

Longer term Action plan

Active search for more appropriate fabrication

Initiate a more formalised lighting integration project with MIT



Fig R12. Red 1 testing stage



Fig R13. Red 1 testing stage

Red 2 jacket: a transitional stage.

By working within an "Action Research" mode I was able to break down the immediate achievable goals of improving the fit and construction of the jacket delaying the longer term objective of sourcing lighter weight fabric and introducing an LED lighting system. As a result of this identification Red 2 jacket should be seen as a tightly defined mini project with the focus firstly on securing a relaxed fit. To achieve this, computer pattern development work was used after comparing dimensions from a mixture of casual-wear and sports-wear tops to determine a more appropriate fit. The more generous fit appears to give a more comfortable feel over the shoulders and extra freedom in the sleeves, the new simplified collar also shows improvement. It is notable that this stage marks the departure from earlier aerodynamic influenced work to the application cycle commuter feedback .



Fig R14. Fitting stage of Red 2 testing of riding position



Fig R15. Fitting stage of Red 2 testing for freedom of movement.



Fig R16. Testing stage of Red 2 in Spring conditions



Fig R17. Testing stage of Red 2 Checking shoulder movement

Red 2 construction and componentry details:

An improved attention to the components was significant, especially; the zip, elastics, more appropriate use of reflective piping to ensure a more comfortable and durable jacket. Trialing for inside electrical cable casings was introduced on the inside of Red 2 in anticipation of future integration of the lighting system that was planned and developed at MIT for Red 3.



Fig R18. shows inside grip tape apply to hem and are introduced to prevent the jacket riding up at the back when cycling.



Fig R19. shows 6cm x 2cm reflective tape applied to outside of cuff. This addition is extremely effective as an indicator for following traffic just when turning.



Fig R20. Shows inside hydro-tech breathable membrane lining to act as a wind-stopper to front panels shoulder and fore-arms. High quality 60cm plastic zip.



Fig R21. Twin lower back pockets constructed using water-proof fabric to reduce the effect of spray from the back wheel of the bicycle. Center panel stitched in through reflective tape for increased visibility.

Red 3 electronics

The experimentation and reflection process took a further step forward with the planning of a third Red jacket. As this part of the project depended on the success of the collaboration with MIT it was important that both parties were clear about roles and expectations. The brief for Red 3 was initially to have 3 LED lights that could be applied to the jacket and could be clearly visible from 100mts at night, in reality the team actually added some additional features. Clearly I was in charge of the clothing side, ensuring that fit, aesthetics and method of electrical integration could be achieved. While the MIT specification was specifically to create a small circuit board that would include the following :

Specification of the Smart vest circuit

Runs on two 3volt button cell (CR2450)

Can power on at low voltage.

Control Board Size 75mmX60mm.

Brightness control keys.

Power ON/OFF key.

Light Pattern control key.

100 Hours of battery Life

Full documentation of planning and technical implementation phase prepared by MIT is available in appendices



Fig R22. Test for lights at 50mts at night



Fig R23. shows computerised conceptual design work for Red 3 Jacket

Red 3 aesthetic Inspiration

For the final Red jacket I had sourced an appropriate sportswear fabric that would be suitable for a winter cyclist. The fabric was, lightweight with moisture wicking properties, fleece backed for warmth, lycra based structure for comfort, but with limited colour options. Rather than seeing the colour limitation as an obstacle, I viewed this as an opportunity to introduce design aesthetics through transfer printing directly to the fabric, in particular the use of bright colours to can make a cyclist appear more visible in traffic,

At this point a number of coincidences and underlying inspirations were pulled together to create the artwork ready to produce Red 3 jacket. In June 2007 I attended the AUTEX World Textile Conference in Tampere, Finland. I found that the area had a rich history of industrialization, in particular with a strong Socialist tradition that was evident in local exhibitions and in the Lenin Museum dedicated to the first Soviet Leader. I was attracted by the boldness of the local artwork and immediately saw connections to my own project. CCCP stands for the Union of Soviet Socialist Republics that existed between 1922 and 1991, my project title City Centered Cycling has been given a little creative licence to use the same initials by adding the word "Product". The use of the colour red has over the past 100 years has tended to have political connotations, my choice to use the colour has more to do with strong visibility and presence



Fig R25.The Lenin Museum, Tampere, Finland.



Fig R26. Werstas Finnish Labour Museum, Tampere, Finland.



Fig R24. Project Artwork for CCCP using Corel Draw, used for creation of film for screen printing process



Fig R27. Project Artwork for Red 3 using Corel Draw, used for creation of film for screen printing process

Red 3 printing process

The aesthetic inspirations were brought to life by the introduction of fabric screen printing. The printed look of Red 3 was satisfying and rewarding as it was an entirely new learning process for me. The initial setup of screen printing can be a time consuming process but offer good results and is cost effective for production volumes. However, the experimental nature of this project lends itself towards digital fabric printing technology (explored in White phase p 50) as it offers more design flexibility through.

Sublimation Screen Printing

Screen printing can be directly applied onto fabric but in this case, as synthetic fabric was used, a sublimation process was more appropriate for bold colour., The sublimation process involves screen printing ink of an image onto paper before transferring the image to fabric under extremely high temperature. A temperature of 200 degrees Celsius was applied to the fabric panels for 90 seconds producing the release of a gas allowing the transfer of ink from paper to fabric. The sublimation process is used extensively in sportswear because of the ability to replicate rich colour and for durability to ultra violet light for outdoor use.

I have included a list of points for future consideration while using this process:

- Extremely high temperatures are required to achieve a good colour depth of print.
- Fabric fleece backing was flattened under such high temperatures.
- Large panels had to be heat transferred by adapting a fabric fusing press.
- Special attention needs to be paid to reverse printing process.
- Process can be labour and time intensive.
- Screen printed principles can be applied to electronic circuit boards printing .



Fig R28. Artwork using Corel draw software



Fig R29. Image film exposure for colour separation

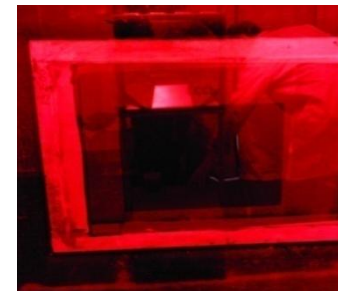


Fig R30. Film exposure to pre treated silk screen using ultra violet light



Fig R31. The unexposed sections rinsed off

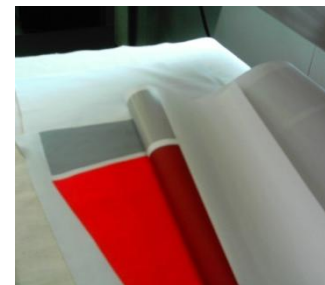


Fig R32. The heat sublimation process



Fig R33. Printed work cut out

Red 3 electrical integration

Basing elements of my work around the methodology framework of Ariyaturn and Holland's; *A strategic approach to new product development in smart clothing*. (2005), I felt it was important to stay design focussed and simply not to add lights to an existing jacket. An important factor in this was the communication with electrical engineers at MIT. Regular meetings brought out a lot of questioning and mutual problem solving occurred particularly around the actual integration and functionality of the lighting system. See (Fig R34 & R35) showing cable placement meeting, wiring was planned using Red 2 jacket.

The strategic placement of the LED lights on Red 3 was based on discussion with fellow cyclists, determining that lighting the upper sleeve and lower back areas would present greater visibility of the rider to motorists. The consideration that a commuter often carries a back pack was a factor in the decision making. Combining the 3 lights on the jacket with a standard front bicycle light ensures that at least 2 LED lighting devices are exposed to road users at any one time. Supplementary reflective piping placed on shoulder, lower side seam, mid back and cuff also increase visibility potential.



Fig R34. Cable and circuit board placement



Fig R35. Cable and circuit board placement

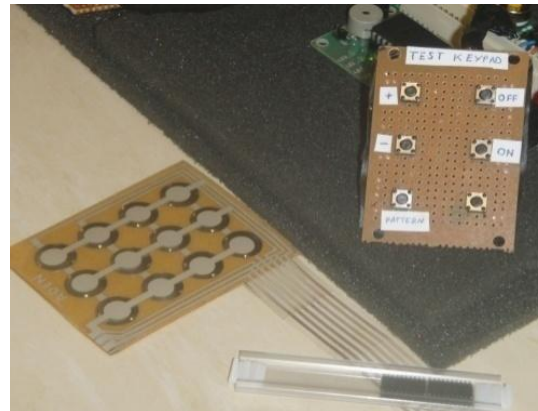


Fig R36. Test circuit board controller

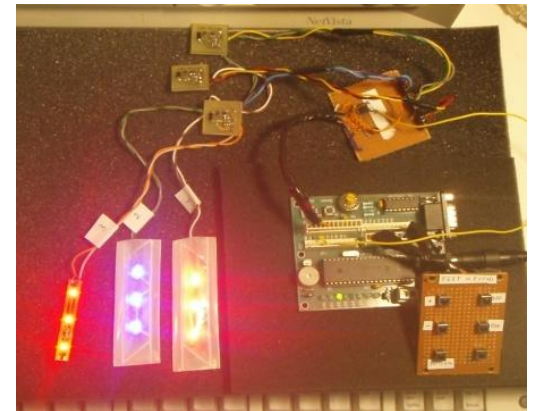


Fig R37. Test of circuit board & LEDs

Red 3 electrical integration method

Having established an appropriate fit and look to Red 3 the real challenge was to establish a way to conceal and integrate electronics and wiring. The sample process shows how a plastic covered window was used to display elements of the a 12 button phone keypad. The keypad was adapted to create an on/off switch, control of LED brightness and flash sequence. The actual LED's are sandwiched within a pliable reflective strip which can be easily mounted directly onto the outer fabric.

The wiring is placed within a waterproof casing which was sewn onto the inside seam allowances that acted as a channel between the circuit board and the LEDs. In the case of the right sleeve the wiring channel was taken around the back neck-line, while the lower back LED was connected via the vertical mid-back seam. Careful consideration was given to the fact that the wiring would need to be able to move with the wearer, so an extra 7cm allowance was added to the length of cabling to prevent breakage should the jacket be stretched in any way.

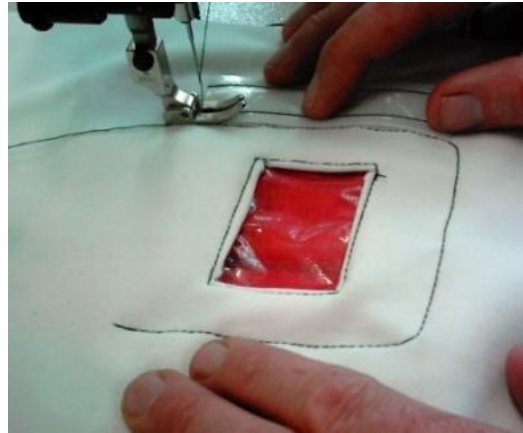


Fig R38. shows planning phase of keypad window



Fig R39. shows Red 3 keypad window



Fig R40. pocket for circuit board and button box.



Fig R41. Internal cabling of Red 3 Jacket

Reflection on Red 3 Jacket

My reaction at the completion of this stage was one of satisfaction and relief in being able to deliver a jacket that in some ways met the original objective of the project. The effort to produce Red 3 had been fairly extensive, from the design planning stage, print development, electrical integration, construction and documentation. The project was given some life with the collaboration with MIT electrical engineers. The value of being able to share ideas and include elements of electronic expertise was something I had not envisaged possible prior to this stage. While the jacket demonstrated lighting integration, the workings were somewhat cumbersome and the installation process needed refinement. In reality Red 3 really serves more of a proof of concept than it does as a finished product.

Aesthetically I felt that it is very bold and eye catching, however wearer trials to get clearer feedback on this have been fairly limited. The reason for this was been partly due to some fundamental flaws that were overlooked but now appear obvious. Firstly the choice of using the fleeced backed, stretch fabric, may offer comfort and warmth to the user but on a practical level the jacket would require regular washing. Although some electronic components are waterproof, it's fair to say that the removal and replacement of the electronics for washing would be impractical.

The screen printing process was educational and illustrated what could be achieved should this direction be pursued. However, factors of flexibility of ink colour and size combined with my lack of speed and experience lead to the decision to explore digital Textile printing for further print project developments.

Throughout this phase I constructed all my garments, while this was important to the understanding of the design integration and process, limited ability to produce a really satisfactory finish could hinder progress so professional construction help was identified for final pieces.

In conclusion the Red phase shows an experimental working process that continually asked questions of my ability as a designer. The reflection and action process used encouraged ongoing questioning and practical problem solving responses. The ability to develop electronic research relationships was important in building a deeper understanding of the cross-disciplinary considerations that define the project and the progress made during the Red phase and helped shape the rest of the study.



Fig R42. Fit & movement testing of Red 3 Jacket.



Fig R43. Fit & movement testing of Red 3 Jacket.

Green Phase Case Study

The **Green** phase concentrates on design and practical considerations while implementing the LilyPad wearable electronics system.

Green phase case study

While satisfied with aesthetic aspects of the Red 3 work, I had limited knowledge of the actual electronic development that had been carried out by members of the Manakau Institute of Technology team to help produce the finished jacket. As a result of this lack of electronic understanding, the focus for the next stage of the project was to increase my personal understanding of electronics and suitable methods of electronic integration in order to further the project. There were 2 main questions relating to wearable technologies that I wanted to explore.

- How might I increase my knowledge of wearable electronics?
- How might I develop a working method for electronic integration?

While considering how I might tackle this research I became aware of Aurdino LilyPad, a wearable electronics system targeted at crafts people and amateur enthusiasts. The phase of study, conducted in 2008 trialed the use of the Aurdino LilyPad system, as a learning tool to gain a deeper understanding of the area.



Fig G1 completed Green vest and jacket



Fig G1A Green Jacket testing

Green phase aurdino lilyPad

LilyPad was developed by Leah Buechley, Associate Professor at MIT Media Lab, Boston. The system is essentially a wearable minicomputer that contains a programmable micro processor that can be linked to a variety of components such as LEDs, switches and touch, light or sound sensors. LilyPad is part of the Aurdino group which is an open source electronics prototyping platform meaning that instructional material on how to use electronics is available. Another advantage of using this product is that the components are light, flexible and water resistant, addressing some of technical concerns highlighted at the completion of the red 3.

Buechley's initial design for the LilyPad system was developed in soft touch conductive fabric, but the practicalities of producing a low cost commercial version resulted in the change to a light weight plastic version that is claimed to be waterproof being released in October 2007. LilyPad is designed to be used with conductive thread as an alternative to electrical wire as a means to transmit an electrical signal from the control panel and power source to the LEDs.

The system seemed to address weight, flexibility and water resistance concerns as well as replacing the need to solder wires by introducing conductive threads.

Apart from practical considerations, a quality that attracted me to experimenting with the LilyPad system is the key overarching "hands on" philosophy that surrounds the product, this point was evident in the title of Buechley's presentation, "*High-Low Tech: Democratizing Engineering and Design*" given on her June 2009 visit to New Zealand. The theme of this presentation was that technology is no longer only in the hands of large companies and that with the advent of the internet "*Online communities devoted to hobbies from crafting to electronics tinkering- where people share designs and construction tips- are flourishing*" (Buechly, 2009). As a result this is "*empowering people to design, engineer, and build devices that integrate high and low technology.*" The "do it yourself" sense of experimentation while using the LilyPad electronic learning kit proved to be an important step in developing a better understanding of the electronics and the integration process.

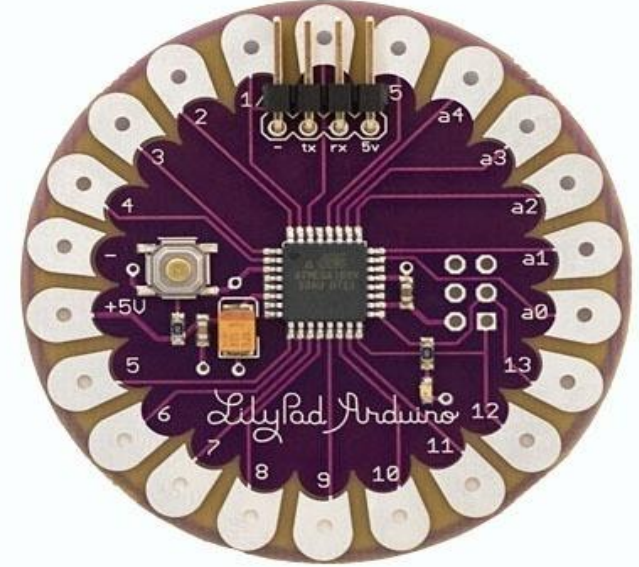


Fig G2 LilyPad Main board

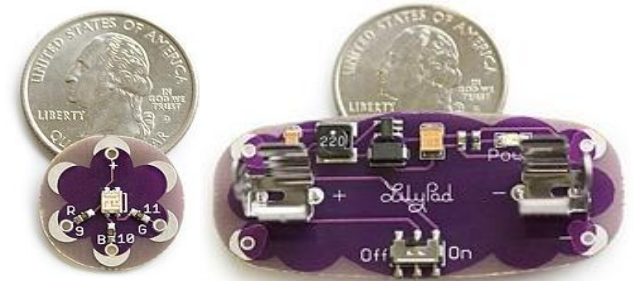


Fig G3 LilyPad Tricolor LED

Fig G4 LilyPad Power Supply

Green phase electronic experimentation

At this time the Aurdino LilyPad system was not available in New Zealand but a relatively inexpensive starter kit was easily obtained through the internet. I was not aware of any other local users of the system and saw this as potentially exciting and unique for my work. Thankfully, the Audrino LilyPad platform is supported by on line tutorials available at <http://media.mit.edu-leah/lilypad> these were useful grasping the basic programming and application stages required to get started.

My first attempts involved trialling a few LED flash timing sequences, this not only worked well as a learning tool but on a practical level I had already established that an on/off flash sequence is effective in traffic and has the added bonus of saving battery power as the lights are not permanently on.

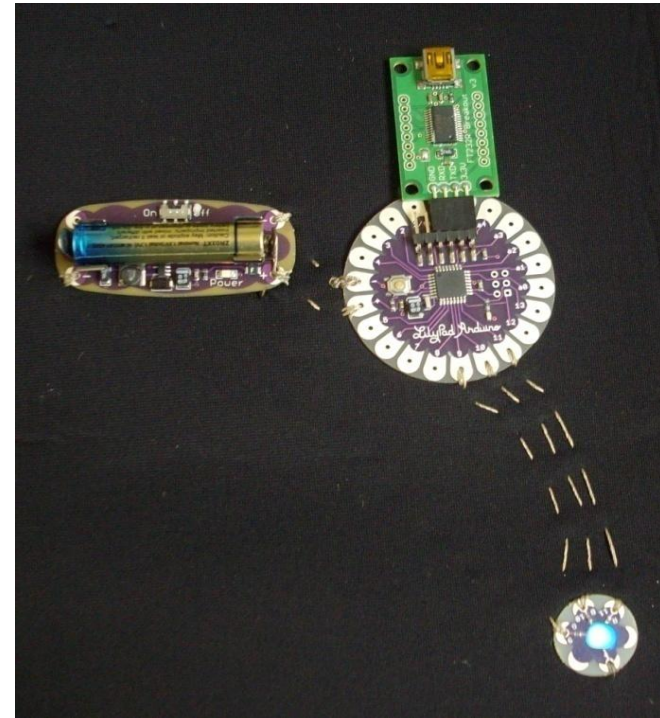


Fig G5 LilyPad circuit testing



Fig G6 LilyPad LED testing

Green phase lilypad planning

Having grasped the basic concept of using the system, I proceeded to programme a LED flashing sequence using two separate colours for a new cycling vest. Firstly the LilyPad micro processor was connected to a computer via a USB adapter. From here the Aurdino programming software (Fig G7) allows the user to determine the timing and brightness of the flashing sequence required before uploading this information directly to the LilyPad micro processor. For the purposes of initial testing I connected the battery source to the micro processor by hand sewing a conductive thread route (Fig G8), crocodile clips were then used to link the LEDs to the LilyPad unit (Fig G9). After quite a bit of experimentation I felt confident enough to re-apply this method to the green vest but chose to use an industrial sewing machine for the conductive thread for a more professional finish.

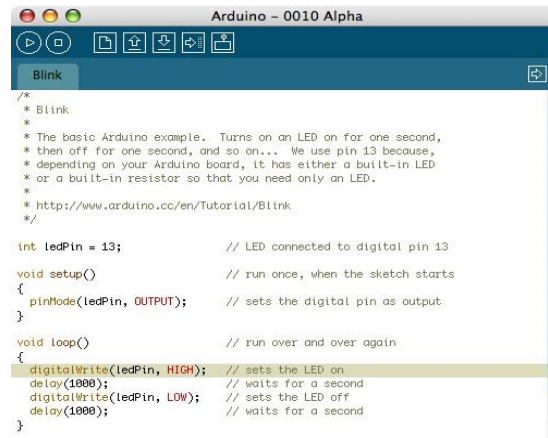


Fig G7 Aurdino LilyPad software programming



Fig G8 LilyPad circuit board placement and hand sewing of conductive thread

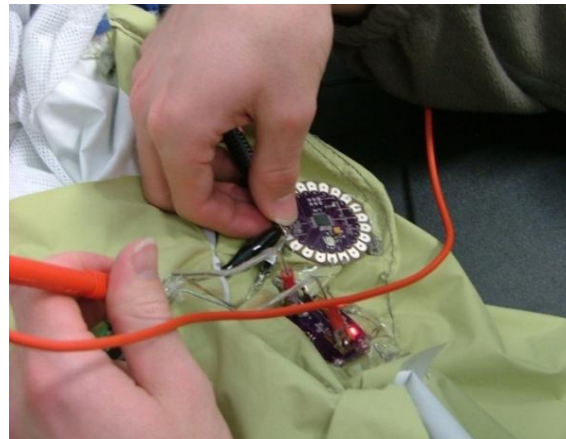


Fig G9 LilyPad circuit board testing

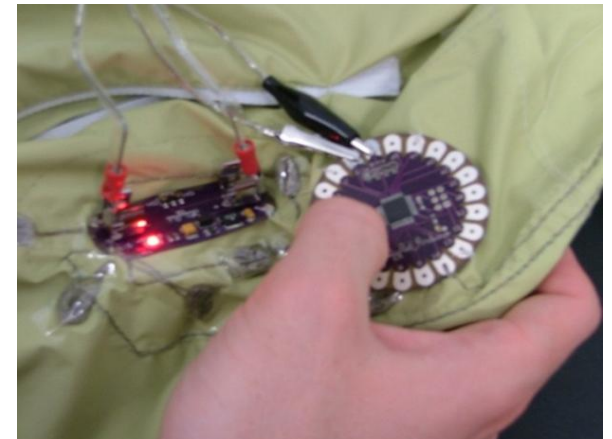


Fig G10 LilyPad power source testing

Green phase lilypad planning & installation

There are a few examples of LilyPad based projects on the internet, of this work some users have left LilyPad components and hand sewn conductive threads exposed on the outside of a garment. I on the other hand chose to conceal any traces of how the LilyPad components and LEDs were attached. With this decision came a degree of complexity to design inside pocket detailing to hide the micro controller /power supply and careful consideration of a seam route that could carry conductive thread to link to LED's.

Figure G11 shows the LilyPad connection plan by sewing directly onto the inside breast pocket bag, then following the neckline seam around the colour to the LED placement areas. Figure G12 presents the finished vest with no exposed components or conductive thread. The breast pocket gives easy access to the On/Off switch connected to the power supply



Fig G12 Green Vest

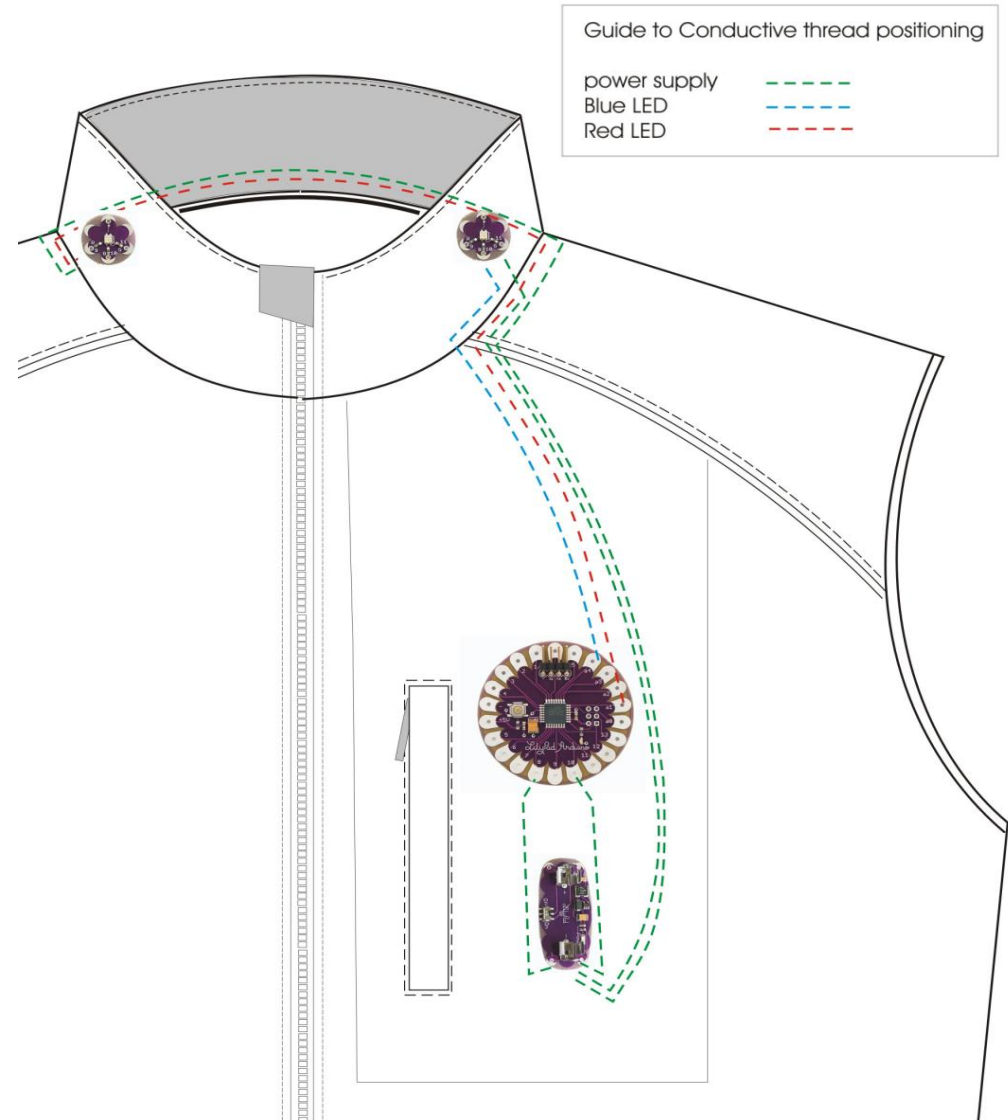


Fig G11 LilyPad circuit planning

Green phase Conductive thread

Conductive threads are typically nylon or polyester based yarns that are spun with metallic elements such as silver or stainless steel. This presents an alternative option to conventional electrical wiring for power and signal transmission. For the project I used a silver plated conductive thread that could be used with a 110 size needle to sew directly to fabric.

The main advantages of applying conductive thread for wearable electronics include:

- The thread is soft, light and flexible (can directly applied to fabric)
- Will move with the natural movement of the wearer.
- Is less obtrusive than electrical wire when placed on a piece of clothing.
- Can be washed (Although conductivity will deteriorate if metallic fibres are washed away)
- The thread can be sewn to electronic components eliminating the need to solder wires.

However the actual process of working with conductive thread was not as simple as initially envisaged and considerable experimentation was required before I finally developed a useable method of implementation. Interestingly, I had the privilege of meeting LilyPad designer Leah Beuchley in June 2009 and she agreed that there were a number of pros and cons surrounding the use of conductive threads.



Fig G13 4 ply Conductive thread

Green phase conductive thread

During the experimental stages of using conductive thread with an industrial plain sewing machine the following problems were identified and solution methods were ultimately used:

Conductive Thread Problems	Project Solutions
Loss of power current transmission when using single conductive thread over 30cm	Double up to use 2 conductive threads created the opportunity to introduce machine sewing instead of the hand sewn Lilypad method . This also helps to reduce any current loss.
The thread is coarse and prone to breakage.	Technical adjustments to machine tension and needle size helped. Although eventually discovered that thread breakage would not necessarily loose power if the current was reconnected by re-sewing over the breakage area. (Fig G15)
No covering of thread means that short circuiting can occur when in contact with another conductive thread channel.	Ensure a minimum of 8mm spacing between thread channels. On certain points when a crossover is unavoidable the placement of a non conductive fabric barrier proved to be a surprisingly effective solution. (Fig G15)



Fig G14 LED connection via conductive thread



Fig G15 Close up of Conductive thread over sewing

Green phase electronic integration

The electrical integration of Green Vest was assisted by the relative simplicity of the location of the LilyPad controller in the breast pocket being able to link directly through the neck line seam to the LED's on the collar. (Fig G16) It should be noted that the positioning of LED's on the collar were later deemed as only marginally effective when in traffic, if the rider was bending forward the lights could not be seen from behind, as a result the collar positioning was not considered for future work. (Fig G17)

Three lighting positions highlighted in figure G18 were used on the Green Jacket, left sleeve, right sleeve and lower back positions were combined with a handlebar mounted front light to offer the possibility of 360 degree visibility for a rider when in use. To transfer power to 3 separate positions required a re-design of the jacket pattern. In particular the creation of panels to form a seam route to which the conductive thread could be sewn. The panelled seams carrying conductive thread could then receive an electrical current linking the LED's to the Lily Pad circuit board which was positioned on the left sleeve.



Fig G16 Close up of Conductive thread sewn around inside of Vest collar



Fig G17 Close up outside of Vest collar

Green phase electronic integration

Conceptually the electronic integration plan made sense at the time, but in reality the practical application proved to be difficult. In retrospect the panel shapes were too angular and this caused problems with conductive threads touching and as a result this prevents an electrical signal being sent. figure G18 shows the planned power route with red circles indicating the problem areas of the back armhole. As a compromise figure G19 shows the application of conductive thread to 3 fabric strips that were positioned and attached avoiding contact with each other to overcome this difficulty.

A significant lesson was learnt when comparing the relative simplicity used for the electronic integration of the Green vest to the difficulties of the Green jacket. This was that any future garments needed to have smooth seam lines and not have areas where conductive threads could touch each other. Having pattern design skills is therefore important to create the shapes that allow electronics to work while retaining a focus on the fit of the actual garment. The sleeve pocket of the Green jacket is designed with fullness to house electronics and avoid discomfort to the wearer. (Fig G24 & G25)

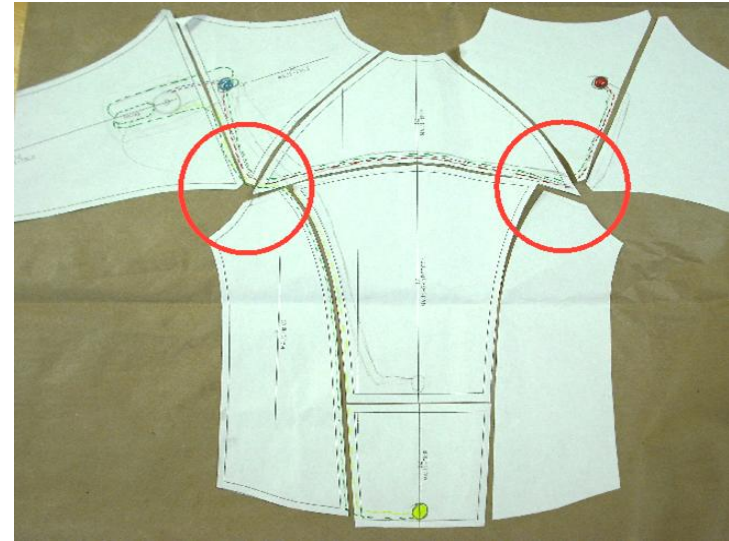


Fig G18 Identified circuit problems

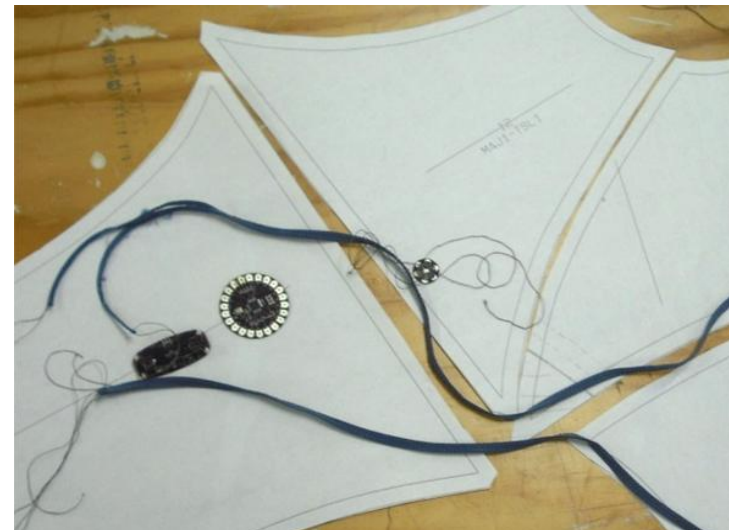


Fig G19 compromise for circuit problems

Green phase fabric and trim considerations

While there was considerable work on the electrical aspects it should be pointed out that the basic cycling jacket functionally was not entirely forgotten during this phase. The lightweight waterproof Gore-Tex fabric combined with a mesh lining gives protection against wind and rain while still allowing body temperature control due to the breathable fabrication properties.

Jacket trims include:

Press stud adjustable elastication for fitting variations. (Fig G20)

Zipper pocket to hold LilyPad componentry. (Fig G21)

A lower back zipper pocket is provided to hold valuables. (Fig G22)

The exposed LEDs on the vest collar (Fig G23 insert) did not look good and could be easily damaged. This led to applying a drilled out plastic housing used for the Green jacket. While this worked to improve the aesthetic values it did little to accentuate the lighting effect. (Fig G23)



Fig G20 elastication adjustment

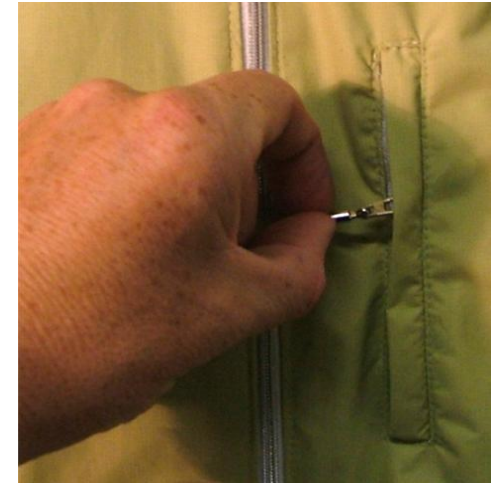


Fig G21 Zip concealment



Fig G22 rear zip pocket and reflective tape



Fig G23 LED cover

Green phase reflection

At the beginning of this phase I had identified 2 research areas to explore, namely to increase **my knowledge of wearable electronics** and **develop a method electrical integration that could be applied to performance cycle wear**. By the completion of the **Green** phase these objectives had been met through the practice based research involved in the application of the LilyPad system. Yet at the same time I review the work with an element of frustration and disappointment. Aesthetically the work lacked impact and the final look of the cycle clothing hadn't progressed beyond the work done for the **Red 3** jacket. On reflection, this can be attributed to an over commitment to developing electronic techniques and perhaps losing sight of the aesthetics and functional aspects that had previously been at the heart of the project. For example, the use of the green waterproof fabric was due to convenience of availability and the drab colour did little to promote road safety. As a result clearer design detailing and fabric print options were explored for the final phase of the project. (Fig G25)

Another disappointing element was only having 3 LED's on the final **Green** jacket which was not effective enough in night traffic. Technically the single AAA battery used produces 1.5 volts and this is only enough to power 3 LEDs. (Fig G26 and G27) At the time of study this was the maximum power output available using the LilyPad system. (Note higher voltage lithium polymer batteries are now available).



Fig G24 **Green** jacket electronics before pocket cover



Fig G25 **Green** jacket shows pocket to conceal electronics

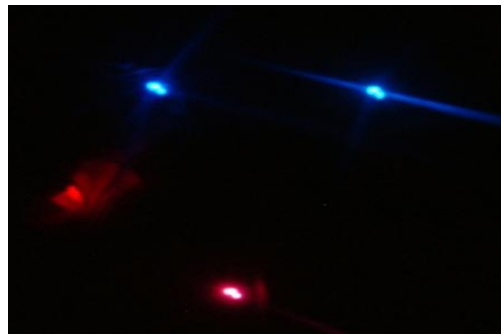


Fig G26 **Green** jacket 2 sleeves and back LED's



Fig G27 LED and Back pocket detail of **Green** jacket

Green phase reflection

An action research approach to the project was again used as I mixed existing skills with new found knowledge, Schön's quote is relevant to the research phase *"As he tries to make sense of it, he reflects on the understandings which have been implicit in his action, understandings which he surfaces, criticizes, restructures, and embodies in further action"*.(p50). Certainly by the conclusion of the Green phase, I began to realise that all the mistakes, frustrations and questions that were being asked and temporary solutions discovered were beginning to help formulate a clearer plan for a next phase that could perhaps bring me closer to a finished product. I became aware that the electrical integration had to be well planned from a technical point of view and with this certain aesthetic and functional decisions had to be reached.

The following points highlight the major lessons learned during the Green phase of study:

- That personally I had progressed to obtaining an understanding of basic electronics and terminology.
- That my electronic skills were limited and that future project work would require support.
- The Aurdino LilyPad system was an extremely useful educational tool, to gain **knowledge of wearable electronics** however the following points suggested to me that it would not be appropriate for the purposes of the active commuter cycle wear.:
 - Lack of power ...1.5volts not enough for multiple LED's.
 - LilyPad LED 's are not bright enough.
 - LilyPad LED's are problematic to mount on active sportswear.
 - General fragility of operating system.
 - On/Off switch difficult to operate.

Through experimentation with the LilyPad system I had in fact developed a working method for electronic integration. The method was to use seam channels to house conductive thread to transmit electrical signals. Certainly, the use of conductive threads gave a softness that could not be achieved using electrical wires, yet my experiences left me unconvinced that conductive thread is as durable and reliable over a period of time or should be pursued within this project. The integration experiences though proved valuable and the following points went on to influence later work:

- The application of multiple conductive threads to the Green jacket seam path was too angular and as result was less reliable than hoped.
- Seamed panels containing electrical current should follow straighter lines or a gentle arc to avoid short circuiting or disrupted signal from circuit board.
- Simplification of seam lines to be implemented to future developments.
- Fewer smoother seam lines will assist in providing a more waterproof garment (by reducing the chance of seam leakage)
- Re-designed technical seam lines can present design aesthetic possibilities.

In conclusion the Green phase was valuable in extending my knowledge of wearable electronics, the insights and lessons learnt could be used for the planning of further work. The experience also reinforced the belief that in order for the project to progress in this cross-disciplinary field external expertise would be beneficial.

White phase case study

The final White phase, documents how research understandings have been combined with expert advice and the use of technology processes to refine the final project piece.

The final case study draws together insights and research experiences gained throughout the of the project. The intention of this phase has been to show the refinement of the research in relation to the original aim of the project which was to produce a wearable electronic jacket specifically aimed at city cycling commuters. The working methods used for the creation of the final piece involved a variety of hi-tech methods specifically introduced to give the work a more professional finish. Another important factor to the success of the project was the decision to seek expert advice in the form of consultation from an electronic professional to help take the project beyond my personal electronic limitations. The consultation process involved four stages , firstly to discuss of design ideas, requirements and project planning. This was followed up with two further prototype electronic testing stages before the final implementation was carried out.

The early experiences gained throughout the project were considered to form the basis of technical and aesthetic framework for the attempt to create an 'optimum effect' for the final project piece as proposed within the New Product Design methodology (p15). The final output resulted in the completion of the White jacket which will undergo further testing with fellow cyclists to gather feedback on the effectiveness of the jacket for cycle commuting.

Two questions were posed for this stage of the research:

- To what extent would effective planning have on the final result of the White jacket”?
- To what extent did the inclusion of technology influence design decisions and approach to the final piece?



Fig W1 completed White Jacket

White phase planning

The experimental nature of the project had given some latitude to learn from mistakes, indeed much of the on-going reflection was based around things that had not gone so well. I started to recognise through the analysis of the **Green** phase that effective design planning could be a key component to the success of the project and indeed future wearable electronics work.

This recognition was based on the contention that a designer in this field should consider the effects electronics could have on a garment and the effects a garment design could have on the electronic integration process. Being able to question design decisions in a holistic way would lead to more effective planning which in turn could increase the overall success of the project. An example of this would be questioning the knock-on effect of applying heat sealing tape to garment seams to prevent water penetration. While the heat sealing process may help to create a more functional, waterproof garment; the process poses further questions to those involved in wearable electronics, which is, what effect would the high temperature and pressure required for heat sealing have on electronic wiring?

With the key aspect of design planning in mind the work for this stage was approached in more critical manner posing questions and considerations to form a holistic approach towards the goal of producing the final jacket.

Electronic questioning (p54) identifies some key issues that were discussed with an electronic consultant and are responded to in more detail on page 63.

Electronic integration and **Garment design considerations** (p64) are planning aspects that needed attention, with responses based on earlier research findings, although some responses were not immediately apparent and became considerations to reflect upon as the practical work unfolded.

Electronic questioning

A design goal for the white jacket was to create a purpose built lighting system on the basis that earlier work using adapted wearable electronics had not fully lived up to expectations. For the jacket to function well in a cycle commuting context, the following electronic improvements would be required : the overall reliability of the operating system; ease of operation; weight and size reduction. A concern was how to go about producing a lighting system that matched my ideas of improvement? It became apparent that I did not have the necessary electronic skills to develop a purpose built lighting system on my own and therefore outside help was required.

A meeting to discuss possible solutions with an electronics expert resulted in the formalisation of a professional consultation agreement that would be ultimately resulting in producing the finished lighting system. This arrangement meant that I could ask questions; raise project concerns and discuss possibilities of equipment with a trusted expert, knowing that feedback could be used directly into the work. The initial questioning centered on the following wearable electronic aspects:

- **How could the overall system be made more reliable?**
- **How could a small, light, and easy to operate circuit board be implemented?**
- **What lightweight power supply should be used?**
- **What method of Signal transmission should be used?**
- **Would it be possible to install an easy to access On/Off switch?**
- (These questions are answered on page 63)

Garment design considerations:

What fabric to use and why?

Winter conditions with lower temperatures, more rainfall and fewer hours of daylight suggested a greater need for a more robust, warmer, waterproof jacket. The fabric chosen was a lightweight Gore-Tex® fabric which is waterproof yet allows the body to breathe and is well used in the active sportswear sector. The fabric is stable so electronic connections will not break under strain as is the potential for stretch fabric. To increase visibility to traffic bright colours are favoured, white is highly reflective when car head lamps are directed towards the rider. The practicality of white fabric is that it will get dirty, especially during winter, however for the purposes of the project white was chosen as a striking noticeable option with the potential to print directly on to the surface.

- **Garment fit and shape.**
Throughout the project great care had gone into the fit and shape, so early establishment of key design features have continued through to the White phase:
- **Features include:**
- Shorter front than back to reflect cycling position.
- Sleeves pitched forward and slightly longer to reflect cycling position.
- Raglan style sleeve fit for comfort and to reduce the risk of water penetration at shoulder line.
- High close fitting collar to reduce the effects of wind and rain on the neck.
- Storm flap positioned behind centre front zip to reduce the effects of wind and rain on chest.
- Adjustment options on jacket hem and cuff.

Electronic integration considerations:

The main concerns relating to the electronic integration are largely influenced by the decisions made for the electronics and the garment design. So when deciding the best method of electronic integration the question must be asked what electronics are to be used? and what effect would this have on the garment design? and visa versa.

Insights gained from the Green phase helped to play a part in the integration decision making, while advice from both the electronic and construction consultants was also valuable in determining solutions to the following issues:

• What method to transmit electronic signal?

Conductive thread or electronic cabling?

Light weight electronic cabling was chosen as it is more robust (p44 &45)

• Simplification of seam lines to assist with electronic signal transfer.

As reflected upon in green Phase conclusion (p49)

• What is the best method to mount LED's?

Mounted on the inside of garment under a transparent plastic, giving a solid base and strong visual appearance.

• Re-designed technical seam lines to present design aesthetic possibilities.

Using function to enhance aesthetics was done applying digital print and creating LED lighting windows.

• Where will switches and micro controller be housed?

The On/Off switch on left sleeve allows for easy access particularly when riding. The micro controller is placed inside a pocket at lower back, this position is relatively unobtrusive and only needs to be accessed to when battery needs recharging (after 80 hours of life).

Solutions and visual record of Integration methods shown on page 64 &65.

Introducing New Technology

The question, “**How The inclusion of the technology influenced design decisions and approach to the final piece**”? is addressed by firstly presenting how and why High-Tech aspects were included and secondly, reviewed in the conclusion.

There is no doubt that I have been particularly fortunate to have been able to develop this stage of the project within the Faculty of Creative Technologies at AUT University. In particular, by the availability of some high-tech equipment that has helped to add a professional finish to the work. By using new technology there are aspects that had not previously been considered, particularly the design opportunities that were presented by the accuracy of computer cutting, laser cutting and digital print detail. Figure W2 shows how an accurately computer cut window (60 x7mm) was used to house LED's on the sleeve. The ability to work in such small detail is important as much of the attraction for modern electronics is based on the reduction of scale and weight, for example cell phones and portable sound devices. Likewise, the subtle integration of wearable electronics is required to ensure that the wearer does not experience physical discomfort by carrying an electrical device. So potentially technology should be considered for design aspects where both scale and accuracy are of concern. Textile artist J.R Campbell from the Glasgow School of Art applies a technology based methodology to his work, he suggests that, “....*designing potentially generates new knowledge and is thus intimately tied to new technologies*”. (Campbell 2009)

It is fair to say that the field of wearable electronics is synonymous with modern technology, the accuracy and precision required suggests that technology can have a big part to play. Digital elements of the jacket design were imported, developed and transferred into a number of different computer programmes and output devices during the course of study.

High Tech Aspects included in this Case Study:

- 3D visualisation software to revise fit and detailing.
- Computer cutting of white fabric.
- Screen printing of reflective ink details.
- Digital printing for graphics and design detailing.
- Laser cutting of plastic battery housing.



Fig W2 Shows accuracy of computer cutting and digital print used for the sleeve positioned LED. The accurately cut out shape houses the LED, the lower square facing folds back to create an inside cover to protect LED connections

3D visualisation software was used for the early development of the white jacket, in particular to revise fit, position LED's and print detailing. The particular software used has a direct interface with the computer pattern already used for the project, so pattern design adjustments could be visualised in 3D in a cycling position, eliminating some of the initial sampling procedures that would be expected using manual methods. Once a completed pattern shape was established the specifics of electronic integration adjustments were applied to the computer pattern (fig W2 is an example of such considerations). The jacket was cut using an entirely computerised method (figW5), the accuracy obtained through this method was also vital for the following print methods.

The design for the jacket included specifically placed print detail that related back to the internal cut out shapes, so the link between printed art work and garment shape was digitally registered for accuracy. Figures W7 & 8 show digital printing for graphics and design detailing (more specific details pages 60 & 61). Screen printing of reflective ink was applied using a similar method to that shown in Red 3 jacket (p31). The reflective ink was used as both an aesthetic style feature around pocket and LED shapes, but more importantly acts as additional illumination for the jacket when light is reflected off the minute glass particles present when the ink is applied to a flat surface. (fig W4)

The concept of building a purpose built micro controller and power supply unit was central to the development of the white jacket. The finished unit is housed in a insulated, light weight casing that offers protection from water and impact. The unit sits within a concealed pocket on the back of the jacket. The design of the casing was created as a computer generated digital image which was cut out using Laser cutting technology (Fig W6).



Fig W3 3D Visualisation software

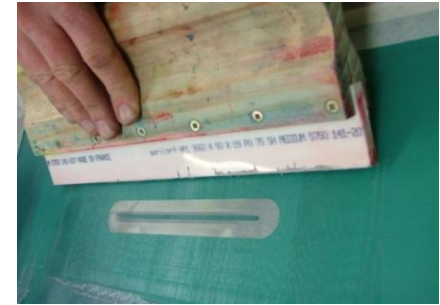


Fig W4 Screen printing of reflective ink



Fig W5 Computer cutting

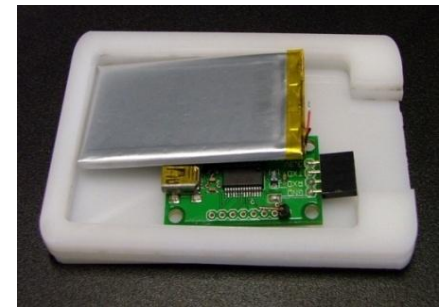


Fig W6 Laser cutting used for battery case



Fig W7 Digital Printing at Textile & Design Lab AUT



Fig W8 Digital Printing at Textile & Design Lab AUT

3D Visualisation

The pattern shape and styling adjustments required for the white phase were carried out using entirely computerised methods. This was done to ensure an accurate, professional finish and allowed for a smooth transition from the visualised concept right through to the final cutting and the digital print process.

Gerber V Stitcher is a 3D virtual prototyping programme developed by Bronzerwear in South Africa, it is intended for fit, styling and fabrication analysis. The user is invited to input pattern shapes, sizing information, fabric and construction details which can then be mapped to a selected avatar offering 360 degree viewing of 12 different positions ranging from standing or sitting through to active sports poses (Fig W9). The commercial use of this technology is aimed at eliminating the costly sampling process and creating a sharing interface between designer and customer, it is especially useful for individual client customization.

In the case of the White jacket, I was able to analyze the effect of the new pattern shapes made in response to electronic accommodation. The ability to view the virtual jacket in a cycling position was particularly useful, in fact the virtual images of the jacket give quite an accurate portrayal of what would eventuate as the final jacket as can be seen in figures W14 and W15. While it could be argued that the use of this software process was not entirely essential to the final result, it's use is valid within the high-tech approach to this stage of the project.

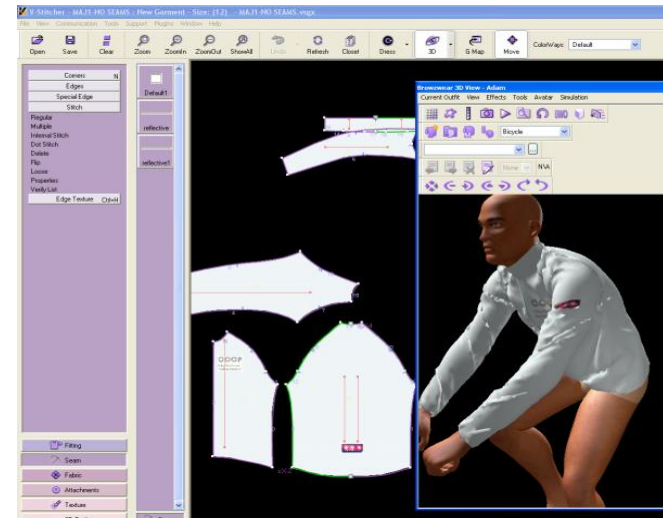


Fig W9 Screen shot Showing 3D rendering using V Stitcher



Fig W10 3D rendered image of White Jacket

Fig W11 shows mapping process used to produce the 3D fabrication movement

Pattern design development

A critical point learnt from earlier work was that the simplification of seam lines could aid the electronic integration process. The pattern shaping for the white jacket back panels follow a gentle arc between the lower back where the electronics are housed to the LED position on the sleeves (Fig W12 red line). This method proved to be successful as it eliminated the sharp angles and stress points that could cause electrical wire breakage. Likewise, the implementation of exposed conductive thread integration would benefit from this recommendation to prevent the risk of short circuiting or disrupted signal from circuit board.

While technical integration issues were important, the overall fit of the jacket was not compromised. The pattern retained the hands forward cycling position developed from earlier prototypes and the new pattern shaping presented some alternative styling opportunities that were linked to digital fabric printing.

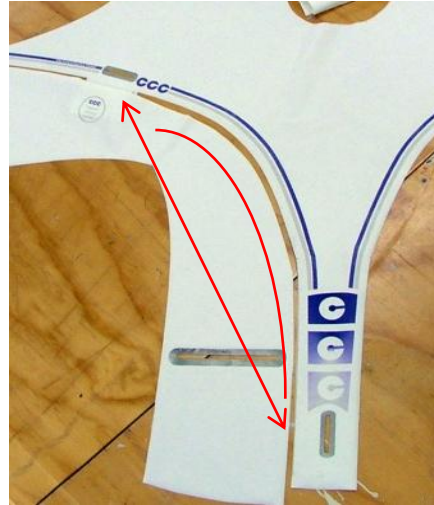


Fig W12 White Jacket back panel seaming angles

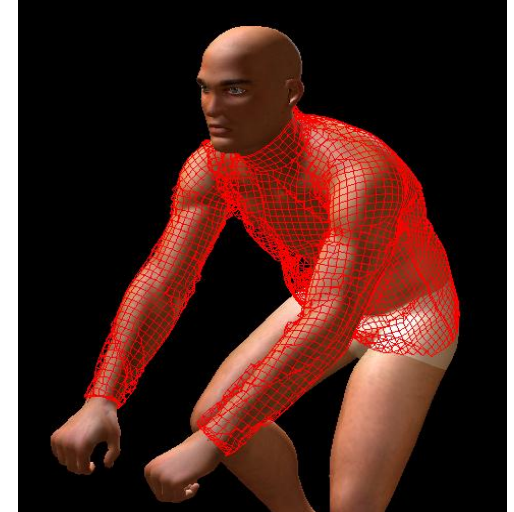


Fig W13 shows 3 dimensional mapping process of White Jacket in cycling position



Fig W14 3Dimensional rendered image of White Jacket in cycling position



Fig W15 comparison of completed White Jacket to 3 Dimensional image

Digital print

To increase the visual impact of my work I was keen to explore the use of digital fabric printing. A Digital Print Symposium held in Feb 2009 presented an opportunity to meet and attend workshops given by highly respected textile artist J.R Campbell from the Glasgow School of Art. This was valuable in both technical and theoretical levels particularly since Campbell places importance on the framework surrounding new technology and the creative design process.

Creatively, the workshops allowed me to experiment with digital print without any restrictions of electrical integration. I created a conceptual jacket (W16 &17) based around traffic symbols and road signs, with the thought that perhaps ultimately textiles could have LED lighting actually woven directly into the fabric. On a Practical level I found a method to export digital pattern shapes using a DXF file conversion format to then make aesthetic print placements using Adobe Illustrator and Photoshop. The finalised images were placed on a fabric plan that could be used on directly with a fabric digital printer. This method was later used to accurately position digital print detailing for the White jacket.



Fig W16 Front view of LED digital print Jacket



Fig W17 Front view of LED digital print Jacket



Fig W18 Pattern shapes with design image for digital print

Digital print and laser cutting

The artwork used for the White jacket was directly based on the pattern design shapes created for the fit electronic integration. By importing the pattern shapes into a vector based programme text and subtle detailing were added. The completed images were saved in Tiff format to be printed.

Prior to printing a fabric pre- treatment process is required to create a permanent bond between fabric an ink, however the water repellent properties of the white fabric meant that the ink penetration was not as strong as anticipated.

Computer cut pieces were placed on the printer bed, figure W19 shows the accuracy involved to replicate the exact design image onto cut pieces.

A similar artwork process was used to create the exact dimensions for the lighting control unit. Figure W20 shows the completed laser cut for 2 outer pieces and a single inner template to secure the components. The white plastic is 2mm deep and was bonded together once all components were housed.



Fig W19 Example of White Jacket computer art work and digital fabric print application

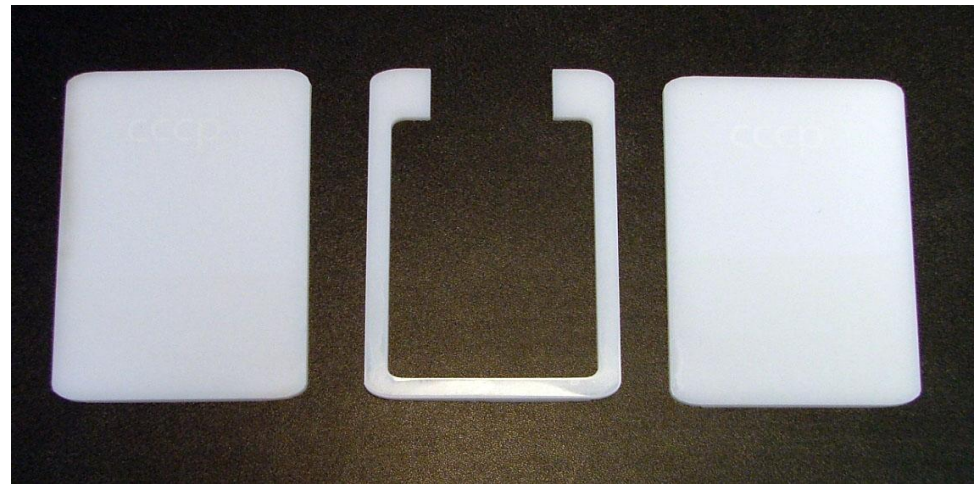


Fig W20 Laser cut casing to hold lighting control unit

Electronic Process

The physical process of creating a purpose built LED lighting system along side an electronics expert reinforced the importance of having gained some electronics knowledge as identified in the green phase. Programming the micro chip and micro processor which sends an electronic signal to the LED's was carried out using an industrial programme development kit called Programmable Interface Control (PIC) by Microchip solutions. While the complexity of the process required an experienced operator, the conceptual similarities to the programming of the LilyPad system were strikingly similar. Essentially this involves programming a code which then sends an instruction to an electronic component. Specific code programming was particularly useful for the design functional of the soft touch button and light sequence. A single touch of the button wakes the system up and start the flashing LED's, a second touch reverts back to sleep mode. While this may appear simple, it is the simplicity that allows for easy operation when cycling, particularly in winter if gloves are worn.

Some programming experimentation with the flash sequence lead to power saving. An LED flash sequence attracts more attention than a permanent light and with every millisecond off savings are made. The battery life to permanently run 9 LED's would be 8 hours, for a 50% on 50% off sequence this is doubled to 16 hours. Experimentation finally lead to a 10% on 90% off ratio increasing the battery life to 80hours before re charging is required. Remarkably the red light appears to stay on for much longer due to the speed of the flash and the light delay effect on the human eye.

The initial planning stage asked questions relating to the electronic functionality required for the jacket. With the help of an electronic consultant these questions are responded to (p 63) with description of the subsequent actions that followed .

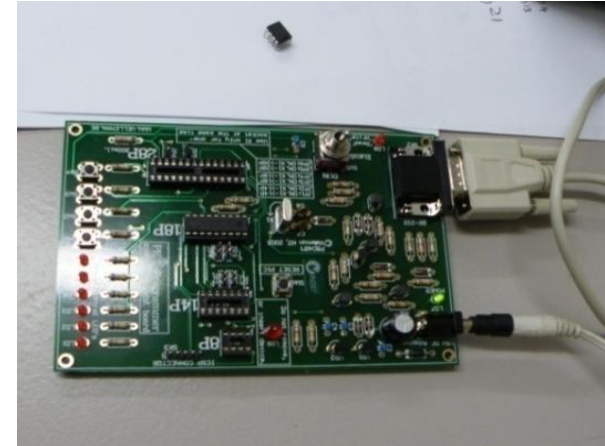


Fig W21 Programmable development kit

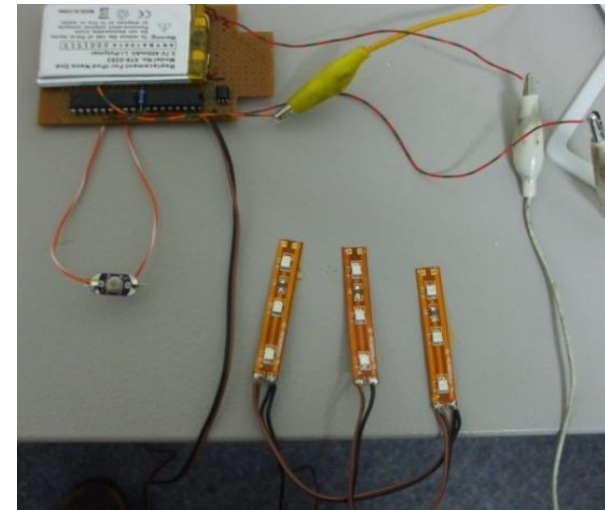


Fig W22 Test phase of lighting system

How could the overall system be made more reliable? By ensuring that power source was strong enough, improved electrical connections, stabilising electronic positioning.
(specific details below)

How could a small, light, and easy to operate circuit board be implemented? Firstly a prototype board designed to test effectiveness of design; compatibility of components; LED flash sequence; functionality and connections would be trialled. (Fig W25) Connection for a USB battery recharger is mounted in the purpose built case. (Ultimately this unit could be commissioned to an even smaller, lighter weight option, namely a printed circuit board.)

What lightweight power supply should be used? Ideally, the battery should be capable of running for up to 2 hours at a time and be re-chargeable? 6 volts of power would be required to run 9 x LED's. A solution was to use 2 x 3.7 volt lithium polymer batteries meaning that 7.4 volts could be produced. Such batteries used in music player devices and cell phones are small (57x 32mm, 2mm deep) easily obtained and can be recharged. (Fig W25 & W26). (The batteries are used in Apple iPod Nano devices)

What method of signal transmission should be used? Having experienced some limitations with conductive threads (p44,45) a decision was taken to revert back to light weight, flexible electronic wiring. To eliminate the risk of wire breakage an epoxy resin covering was applied to form a rubberised seal at electrical junction points. (Fig W23)

Would it be possible to install an easy to access on/off switch? The choice of switch would affect the design of the electronic circuit and the garment, so a search for a small low profile switch was undertaken. The smallest and flattest electronic switch available was an Arduino LilyPad product. Figure W24 shows a close up of the button switch (9mm x7mm) which was then mounted behind the CCC impact control switch logo positioned on the jacket sleeve.

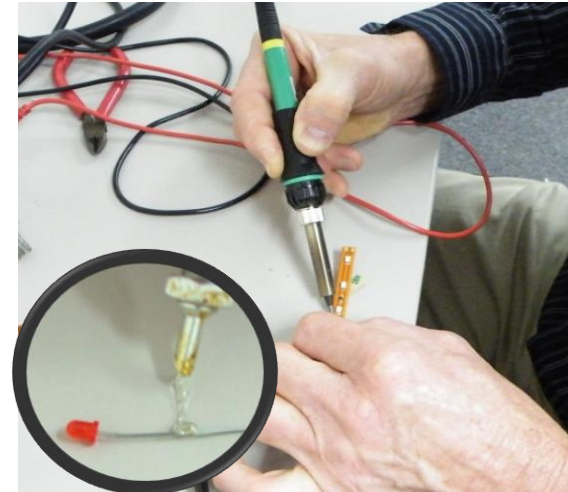


Fig W23 Securing LED's to electrical wire

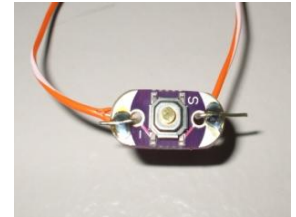


Fig W24 LilyPad on/off button mounted on jacket sleeve

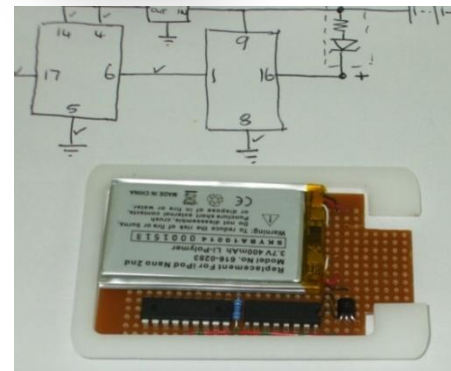


Fig W25 Prototype board with iPod Nano batteries.

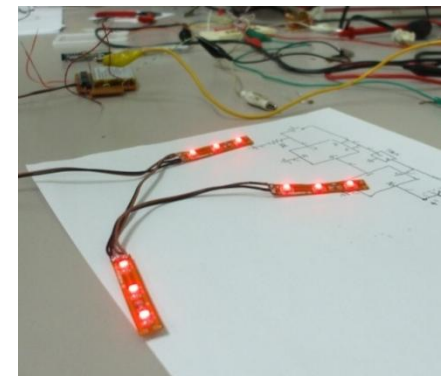


Fig W26 Test phase of LED lighting system

Electronic integration and garment assembly : stage 1

By planning how the electronics would fit into the garment the actual electronic integration and garment assembly was simplified. The earlier identification of smooth seam lines to house electronic cables and the precise positioning of electronic components had lead to technical pattern development and computer cutting for accuracy. (Fig W28) The application of digital print details on the fabric surface also gave precise stitching guides for the zip pockets and LED windows. Transparent plastic was placed and sewn to create a protective surface for the LED's. (Fig W27).

A construction method know as french seaming was used for two reasons; firstly the seam finish catches the raw edge of the seam within the seam allowance reducing the risk water penetration. Secondly the seam procedure creates created a channel in which electronic cabling can easily be housed. Cabling was positioned in the back/sleeve seam channel and electrically connected later, figures W29 and W30 show this method applied to left sleeve.



Fig W27 Sewing of LED window detail



Fig W28 Computer cut and printed pieces



Fig W29 Inside detail showing French seam and cables



Fig W30 Outside effect of LED sleeve detail

Electronic integration and garment assembly: stage 2

The final electronic connection and adhesive sealing to position LED's took place after main garment construction stage. The finalisation of the jacket involved the inserting a mesh lining and the completion of the pocket detail to house the purpose built lighting control unit. The unit contains the micro controller, batteries and connector sockets to link to the jacket.

The location of the actual plastic covered control unit was located on the inside, lower back of the jacket. The position was chosen for electronic ease but presents no discomfort when worn. Figures W31 and W32 show how the specifically designed pocket was cut to exact size with a padded lining to support the unit. A Velcro flap opening conceals the cable connectors and allows for easy access to recharge or remove the unit as required.

Heat sealing tape was considered as an alternative to French seaming for cable housing and bonding of LED positions. However the need for specialist expertise and equipment prevented this option being fully explored.



Fig W31 Inside detail showing opening of control unit pocket



Fig W32 Control unit placement and connection

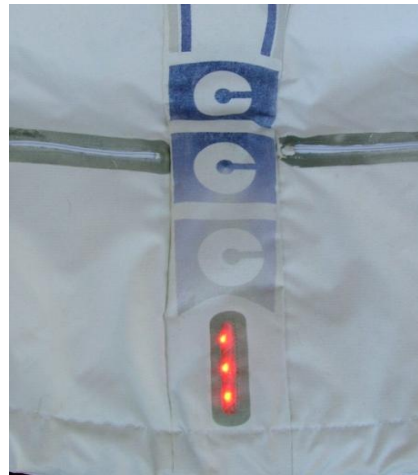


Fig W33 Outside detail of lower back LED's



Fig W34 Finished front detail showing pocket detail and sleeve LED's

To what extent would effective planning have on the final result of the White jacket”?

Earlier project experiences gave a strong indication that effective planning could be the key to a positive result for the final phase of the practical research. The planning itself for this phase was based on the responses to the considerations and questions that are posed to establish the most appropriate way to create a fully functioning electronic cycling jacket. (Pages 54 and 55) The planning and decision making can be defined into a mixture of 3 areas:

Considerations based on prior experiences.

Establishing a clear plan was based on personal experiences and lessons learnt from earlier work, much of which was taken into consideration and acted upon. The value of prior research was critical in establishing what may work for the design and execution of the finished piece. Essentially this creates a framework that ensured that the practical considerations are covered. In the case of the white jacket this meant that fabric choice and garment fit would be effective, while a clear understanding of the electronic desires was established.

New Considerations and new questions based on new experiences.

New considerations and new questions were examined as new electronics systems and methods of electronic integration were explored. The goal to introduce a purpose built electronic lighting system was made possible by the ability to successfully communicate the design idea to an electronic expert in an effective manner. The discussions surrounding how this could

be done helped to formulate the overall project plan. In essence what this meant was a re-evaluation of the general garment design considerations to establish if full electronic integration was possible. That is to ensure that the seams were suitable to contain wires and the design accommodated switches and control unit

Practical Project Planning.

On a practical level a considerable amount of time was spent sourcing components to be used as well as the practical trialling and experimentation that has been used throughout this research. So thought was given to the sequence of events to produce the jacket. For example the electronic circuit design had to be fully tested using a breadboard development kit before garment design and implementation process could be considered. In many respects this could be compared to sampling procedures of the fashion industry, light and switch options were also explored before final decisions were made. If this jacket was to be produced commercially considerable planning and quality control stages would need to be established to streamline the processes which has included: digital cutting; digital printing, screen printing; partial garment construction; insertion of electronics before completion of construction.

There are some specific areas that would be revised for further development of this project, these include: a lighter fabric option,; improved application of reflective ink detailing; deeper colour penetration of digital fabric print; an exploration into heat sealing seam options to ensure garment is 100% waterproof and a smoother seam finish.

To what extent did the inclusion of technology influence design decisions and approach to the final piece?

A major consideration for this stage of the project was the inclusion of available technology and its use in a manner that added to the final outcome of the jacket. Pages 56 to 61 document some of the actual processes used, but it is important to point out that the technology helped to create a slightly futuristic aesthetic and added to the overall functionality that was in keeping with the nature of the research.

I achieved a fit and conceptual look for initial design concept with the aid of 3 dimensional visualisation software. This meant that a clear representation of form was available. Equally the ability to create accurate design detailing to be cut and printed ensured that the planned look of the garment could be realised. The very technical nature of such processes is clearly demonstrated in the lighting windows, the digital print details and the laser cutting required for the micro controller.

While the Red and Green phases of the project also have electronic aspects, it was not until the White phase that I fully considered to what extent a wearable electronic project such as this could be influenced by technology. By choosing to follow this route greater knowledge of specialised equipment was required and as result appropriate planning was made in order to utilise equipment. Although time consuming, the long term benefits associated with the accuracy of the technology used suggest that the processes used could be repeated in a commercial setting.

On a final note, I chose to use technology to extend my work in a productive manner, as such my approach was influenced considerably but I was also mindful not to let technology dictate or lose sight of the original aim of the work.



Fig W35 Final testing of White jacket

At the completion of the White phase, the jacket was passed over to a fellow cyclist for an evaluation the jacket. The initial reaction was positive in regards to effective fit, aesthetic looks and general functionality and purpose. At this point of study a user trial has yet to be completed to assess the usability of the completed piece. so direct feedback is not available as yet.

Exhibition of final works





Conclusion

Conclusion

The City Centered Cycling project began as an exploration of design processes and considerations involved in the creation of sports apparel for cycle commuters. Throughout the investigation the target focus for the practical outputs has remained, however the research thinking that emerged during the project shifted to the exploration of design processes required to combine the separate disciplines of fashion and electronics. Ultimately the success of the investigation falls into two areas of consideration:

Whether the creation of a wearable electronic jacket has succeeded to increase safety and comfort for cycle commuters?

On the completion of the project further testing of the finished piece needs to be done to fully establish if this objective has been met. Further trials to obtain specific feedback are planned, although early indications and feedback suggest that a positive contribution has been made.

Has the investigation added to the body of knowledge around the field of wearable electronics? The publication of this research documenting insights during the research process will add to the body of knowledge.

The following key points of this conclusion are discussed from a personal viewpoint based on experiences throughout the project:

An evaluation the success of the investigation

The extent to which the research questions have been answered.

An indication of how this research has added to the body of knowledge in the field.

An indication of future research direction and possibilities as a result of this study

An evaluation of the working process used:

The three design phases presented in this exegesis, Red, Green and White case studies show stages of exploration, development and refinement, not only in the practical work but also in the understanding of the broader issues for working in the field of wearable electronics. The Red exploration phase was particularly important in establishing the parameters of the study in regards to the fit and functionality of cycle commuter wear. The phase also included a collaborative electronic venture which helped to establish basic terminology and electronic integration issues. The experience of working in a cross disciplinary manner would later become an important part of the project.

I adopted the practical approach of using the Aurdino LilyPad system as a direct response to improve my limited electronic skills during the Green phase of the project. While this encouraged a greater understanding of the intricateness of wearable technology, the work produced did not advance the project to a professional level. However, the learning experience proved pivotal in forming a framework that would be used to refine the project for the final stage of study.

Research throughout the project had helped to develop electronic confidence, technical communication and understandings of wearable technology and as such this influenced the approach taken to the final or refinement stage of the project. In particular, the White phase would place an emphasis on planning of the processes and requirements for the work. The planning itself involved the identification of a technology based design process which utilised specific equipment that was introduced to enhance aesthetics and aid electronic integration. Further planning went into the use of external support in the professional electronic and construction assistance to enable the refinement of the work to reach the project realisation.

Coming from a fashion background and with no prior electronic experience, this was a fairly ambitious project to undertake alone. The more successful and educational aspects of the project were as a result of interaction with others. My experiences lead me to believe that future wearable electronics study may benefit from introducing inter-disciplinary study options, linking students from different discipline backgrounds in a common project in an attempt to find a common language for this new field of study.

Response to project research questions.

What are the main design considerations for wearable electronic integration?

In order for the field of wearable electronics to progress beyond a vehicle to promote electronic gadgets, I would suggest that a designer should ask purposeful questions about the relationship with wearable electronics and its preserved need in society. The following questions may stimulate discussion to help establish a clear rationale:

Why should an electronic device be added to a garment?

What is the purpose of the integration?

What are the benefits or value to the wearer?

In the case of the City Centered Cycling project a human centered rationale was established (page 6), that by adding LED lights the wearer may become more visible to traffic and potentially safer. So in general once a rationale is established the considerations of blending electronics and clothing can progress with a common goal. Firstly an overarching holistic approach should take into account the various possibilities available both in the form of electronic and clothing standpoint. The electronic possibilities include: choice of components; operating platform; electronic signal method (wire, conductive thread, Blue-tooth etc) and power source. Clothing possibilities include: garment type; fabric choice; trims and components.

A third possibility is the consideration of introducing elements from outside of the obvious sources of inspiration, for example technology used in health products may be applied in a sporting context. The permutations are endless, but by selecting the most appropriate combination of fabrication, components, technology and methods the practical application involved in electronic integration can start to take place.

What practical advice can be offered to fellow researchers embarking on a wearable electronics project?

My experiences lead me to see that the management of a wearable electronics project is complex, not only are there the technical issues relating to the separate disciplines involved, the amount of time required to undertake all aspects of a project suggest that it would be difficult to do alone. A team approach would be a recommendation; however it would also be advisable for a designer to spend some time in all disciplines to establish terminology, protocols and procedures.

A designer involved in a wearable electronics project should be aware that a decision made for electronic purposes may have an effect on the overall garment and similarly, a change made to garment design may have an effect on the electronic integration process. The Green and White phases highlight some specific examples and offer advice in regards to:

The simplification of seam lines in order to prevent electrical signal failure.

(Page 65)

Issues and solutions when using conductive thread and electronic cabling.

(Pages 62,63)

To what extent does effective design planning influence a wearable electronic project?

Effective design planning is critical as a major contributor to the success of a wearable electronics project. The complex nature of working in cross disciplinary areas means that there are so many different approaches that can be taken. At its simplest level any portable electronic device could be placed on an existing garment but as a designer considers the desired functionality in terms of garment and electronic performance the approach becomes much more considered. For example if a complex heart rate monitor was to be incorporated one would need to consider how and where a sensor device would be placed in the garment to accurately detect a heartbeat. As a result the garment would need to be designed accordingly, the words Considered-Design- Planning could be aptly used to describe this process

In the white phase reflection I have proposed a specific 3 point plan that could be transferable to other wearable electronic projects. This is based on the following:

1. Considerations based on prior experiences. Essentially this is about creating a plan based on the targeted product (in this case the final white cycling jacket). An initial design framework built on existing knowledge of fabrication, fit/styling combined with electronic options and methods of integration need to be reviewed.

2. New Considerations and new questions based on new experiences. I would suggest that adequate time and resources are built into project planning to allow for experimentation, reflection and questioning. Catering for the prototyping stages that I identified in my methodology approach (p18) has proven to be critical to this particular project and the complex nature of wearable electronics suggest to me that it is important to be open to new ideas and approaches before final design determinations and refinements are made.

3. Practical Project Planning. Resource and product availability is of prime importance, particularly if the finished item is to be of a professional or commercial standard. Sourcing raw materials can be difficult, as in general most electronic components are not designed to be used in clothing and as result they are physically hard and may need to be adapted to be accommodated within a garment.

The actual electronic integration methods need to be planned in accordance with the actual garment assembly process. My experiences on the final jacket resulted in a lot of handling to take the jacket through computer cutting, screen printing, digital printing, partial garment assembly, electronic insertion, further garment assembly, electronic connectivity, final garment assembly. At a commercial level it would be difficult to envisage having the skill set of expertise and physical resources to produce the jacket without really clear project planning skills.

How this research has added to the body of knowledge in the field.

The creation of a wearable electronic jacket specifically designed for cycle commuters offers direct practical solutions for this particular user group. This research shows that focussing on a specified topic or user group may be a useful approach to deal with the complexity of combining the diverse disciplines of fashion and electronics. The transferable nature of a user centered approach could be applied to other design research projects, particularly in the emerging arena of wearable electronics. The research significance section on page 4 of the exegesis outlines the current lack of available research solely linked to the area and suggests reasons why. By making this particular piece of research accessible other researchers may benefit from advice, insights and reflection posed by the practical nature of the project. More publications such as *Fashioning Technology: A DIY Intro to Smart Crafting (2008)* by Syuzi Pakhchhyan are required to present practical approaches and design considerations to fully explore the possibilities of wearable technology.

Future research direction and possibilities as a result of this study.

On a personal level the completion of this project marks the start of fresh possibilities for further research in the area of wearable electronics. Additional refinement of the white cycling jacket will be attempted; one possibility to explore is an alternative to outward flashing lights, perhaps lights turned on the rider would cause even more illumination? The study involved for this project has informed my thinking, skills and confidence to advance beyond the level of flashing LED's. There are areas I wish to explore regarding the longevity and flexibility of wearable electronics, for instance could garments have a range of wearable electronic options that are transferable or can be updated?

In regards to further research, I recognise that a collaborative team approach would be the best option for a future wearable electronics project. A common language for this new discipline is still emerging and as the gradual acceptance of wearable electronics grows so too will research and career paths for aspiring electro-garment technologists.

Bibliography

Accouphene Tuxedo by Vincent Leclerc, Joanna Berzowska

retrieved Sept 11th 2009 from <http://www.talk2myshirt.com/blog/page/6>

Ariyatun, B & Holland, R. (2005). *A strategic approach to new product development in smart clothing*.

retrieved May10th 2006, from [http:// www.ideemployee.id.tue.nl/g.w.m.rauterberg/coferences/cd](http://www.ideemployee.id.tue.nl/g.w.m.rauterberg/coferences/cd)

Braddock, S,E,& O'Mahony, M.(2002) *Sports Tech: revolutionary fabrics for fashion and design*

Braddock, S, E,& O'Mahony, M.(1999) *Techno Textiles: revolutionary fabrics for fashion and design*

Bueachly, L . Democratization of Technology. *New Zealand, WP press*.

Burton Audex Jacket retrieved August 24th 2009 from <http://www.campist.com/archives/burton-audex-jacket-series.html>

Campbell J.R. (2009) Portfolio <http://homepage.mac.com/jrcamp/portfolio/JRPortfolio.html>

Davidson J (2005) Epidemiology and outcome of bicycle injuries presenting to an emergency department in the United Kingdom. *European Journal of Emergency Medicine*. 12(1):24-29.

Electronic Umbrella by Sockmaster

retrieved Sept 11th 2009 from <http://www.talk2myshirt.com/blog/page/6>

Human Synthesizer-textile display from Phillips Lumalive

retrieved Sept 11th 2009 from <http://www.talk2myshirt.com/blog/page/5+>

Illuminated running apparel by Jeffrey S. Engelhardt

retrieved April 24th 2009 from <http://www.talk2myshirt.com/blog/page/2>

Illuminated running apparel by Jeffrey S. Engelhardt
retrieved April 24th 2009 from <http://www.talk2myshirt.com/blog/page/2>

Johnston.B (2008) Burton Audex Jacket.
retrieved August 24th 2009 from <http://www.motorola.com/mediacenter/news/detail.jsp>

Marzano,S (2000). *The Quest for Power, Comfort and freedom, in New Nomads: an exploration of wearable electronics by Philips*. Rotterdam, 010 Publishers.

McCann,J. (2005). *Material requirements for design of performance sportswear*.
in Shishoo.R. (Ed). *Textiles in Sport*. (pp 44-70).New York, CRC press.

McCann J. (1999) *Establishing the requirements for the design development performance sportswear*.
MPhil Thesis Derby: University of Derby.

McKernon,S. (2007) *Design of Change in Cycling Commuting*. MA Thesis Unitec, Auckland
retrieved Aug 11th 2009 from [http:// www.coda.ac.nz/unitec_design_di/3](http://www.coda.ac.nz/unitec_design_di/3)

McQuaid,M. (2005). *ExtremeTextiles: Designing for high performance*.Thames and Hudson.

New Zealand Ministry of Transport report outlining crash statistics [Cyclists Crash Facts 2008 \(PDF v7.0, 340kb\)](#)
retrieved Aug 24th 2009, from [http:// www.nzta.govt.nz](http://www.nzta.govt.nz)

O'Neill NavJacket retrieved August 24th 2009 from
<http://www.navigadget.com/index.php/2007/12/13/navijacket-from-oneill-integrates-gps>

Pakhchyan,S. (2008). *Fashioning Technology: A DIY Intro to Smart Crafting*. Italy. Make Books

Scrivener,S. (2000). *Reflection in and on action and Practice in Creative-Production Doctorial Projects in Art & Design*. Retrieved Aug 11th 2006, from <http://www.herts.ac.uk/artdes1/research/papers/wpades/vol1/Scrivener...>

Seymour,S. (2008). *Fashionable Technology: The Intersection of Design, Fashion and Technology*. New York Springer-Verlag/Wien

Schön ,D, A. (1983). *The reflective practitioner: how professionals think in action*. New York: Basic books.

Smith,D. *Smart Clothes and wearable technology*. Published online July 10th 2007, Springer-Verlag London limited 2007
<http://www.springerlink.com/content/1456w48102k2q36l/fulltext.pdf?page=1>

Van Heerden,C; Mama,J; Eves, D. (2000) *New Nomads: an exploration of wearable electronics* by Philips, Rotterdam. 010 Publishers.

Wilson, J, R& Corlett, E,N. (Eds.) (1991) *Evaluation of human work : A practical ergonomics methodology*. Taylor & Francis

Wilson P. (2005) in McQuaid,M.(Ed) (2005). *ExtremeTextiles: Designing for high performance*. Thames & Hudson

Wright, R. (2000). *Non-Zero: The Logic of Human Destiny*. New York: Vintage

Glossary of Technical terms and processes

Aerodynamic: describing fabrics designed and clothes cut so that the air flows freely over the body with as little resistance as possible.

Bluetooth: A specification for short-range radio links between mobile computers, mobile phones, digital cameras, and other portable devices.

Breathable: Describing a property that allows perspiration to pass through the fabric to the outside environment. This helps maintain an even body temperature.

Circuit board: A self-contained module of interconnected electronic components.

Conductive Thread: Textile yarn containing metallic elements such as silver or stainless steel, the metallic properties allow for the transmission of electrical signals.

Crocodile Clips: (or spring clip) is a temporary electrical connector.

DIY: Do it yourself, an approach or method.

EL: Electro luminescent lighting.

Goretex: a brand of breathable, water-repellent fabric laminate used on clothing, shoes, etc.

French seam: A seam stitched first on the right side and then turned in and stitched on the wrong side so that the raw edges are enclosed in the seam.

Fullness: Describes additional fabric allowance to form around 3 dimensional shapes.

GPS: Global Positioning System.

Hem Gripper: Elasticised tape with rubberised finish to help retain a close fit to the body.

Hydro Tec: Synthetic sportswear fabric with water replant and breathable properties.

LED's (light emitting diodes): A semiconductor diode that converts applied voltage to light and is used in lamps and digital displays.

Lining: A layer of material applied to the inside of a garment. Lining fabric is usually thinner than the top fabric, except those chosen for warmth, such as fleece.

Micro Processor: an integrated computer circuit that performs all the functions of a CPU.

Raglan: A type of sleeve which is cut so that its seams run either side of the shoulder from the neckline to underarm rather than on the shoulder - roomy and practical for outdoor wear.

Reflective Ink: Ink that when under light will become reflective and appear that it is lit up.

Reflective Piping: Piping that when under light will become reflective and appear that it is lit up.

Reflective Tape: Tape that when under light will become reflective and appear that it is lit up.

Smart Fabrics: Textiles capable of sensing and responding to external stimuli, such as changes in the lighting or temperature.

SMD: surface mounted device for LEDs.

Snowboarding: 'Surfing on snow' your feet are strapped to a large board to manoeuvre down snow covered mountain slopes.

Solder: Joining two metals together by using a soldering iron.

Sportswear: Clothing specially designed for certain sports.

Sublimation: A method of heat transferring ink from paper to cloth

USB: Universal Serial Bus

Wicking: The ability for a fibre or fabric to transmit moisture; for example, sweat from the skin to the air outside the garment, where it evaporates.