



International  
Specialised  
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Institute



# The Assessment and Evaluation of the Comfort and Protection of Advanced Textiles



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ISS Institute/RMIT University Fellowship

Fellowship funded by RMIT University



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# Executive Summary

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The Australian TCF industry is restructuring and changing rapidly. Today the textile industry is involved with more than just producing fabrics for apparel applications. Performance apparel represents one of the fastest growing sectors of the textile and clothing industry. Market growth is being fuelled by the emergence of new fibres, new fabrics and innovative process technologies. The market is also being boosted by changes in consumer lifestyles. People are living longer and spending more time on leisure activities. New high-tech fabrics are being developed for a wide range of active sports such as aerobics, athletics, running, cycling, hiking, mountaineering, swimming, sailing, windsurfing, ballooning, parachuting, snowboarding, and skiing.

Exciting innovations are emerging in fire retardant materials and those that protect against extreme temperatures. Added to that is the growing market for corporate wear—which, in some cases, is becoming increasingly fashion-oriented. And, increasingly, high-tech fabrics and apparel designed for high performance wear are crossing over the boundary into everyday fashion.<sup>1</sup>

It is not always possible to find the right balance between the demands of protection and comfort, and in many cases these are contradictory to each other. For example, garments that provide protection against heat and flames are expected to resist the transfer of external heat to the body while at the same time allowing metabolic heat to escape from the body.

The products now have to be innovative, functional, customised and of a high quality. Top-quality techniques and technologies are the only possible way to ensure the innovative ability in the development of new products. Research and development, therefore, is of central importance. In particular, the advanced textiles sector relies appropriate research and development (R&D) due to its varied applications.

New technologies or technical innovations alone are unable to boost the survival and competitive ability of the industry. This is where the human involvement plays a major role. The demands towards specialised skills training are growing steadily. New technologies and strategies can only take effect and actually be used by well-trained and educated employees. The ability to assess and evaluate the comfort and protection of the advanced textiles, and the ability to adjust the range of products created towards the changing demands is where the future of the Australia's TCF industry lies.

This International Specialised Skills Institute (ISS Institute) Fellowship provided the opportunity to visit the state-of-the-art testing laboratory at NCSU (USA) and to gain a better understanding of advanced/technical textiles and their applications.

The aim of this Fellowship was to view an international testing facility at NCSU for the assessment and evaluation of comfort and protection of advanced textiles and to attain a global best practice fundamental knowledge in advanced textiles and testing procedures. It also aimed to bring back specialised testing and assessment skills that can be passed on through training programs to Australian textile students, as well as to amplify the industry awareness and confidence of the testing and assessment of these textiles for a variety of specialised end-uses.

The Fellowship investigation covered the areas of:

- Viewing and acquiring a fundamental understanding of the unique equipment required for the assessment of comfort and protective properties of various textile products.
- Collecting and recording the information related to the education and training of textile students and educators needing to adapt to new technologies/equipment used for the assessment of the protection and comfort provided by textiles.

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<sup>1</sup> *Textile Intelligence*, Performance Apparel Markets, issue 33, 2nd quarter 2010

## Executive Summary

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- Understanding a variety of testing, evaluation and assessment methods and procedures required to determine the capability of advanced textiles to provide comfort and protection.
- Analysing how international standards are used for the evaluation and analysis of advanced textiles.
- Understanding how the selection of the appropriate test and test procedures are conducted and customised in accordance with industry needs.

The time spent at the Textile Protection and Comfort Centre (T-PACC) at NCSU and the knowledge acquired were invaluable. The knowledge gained on testing and the interpretation of the test data defining the comfort performance of the textile products will be introduced into the Textile Technology program at RMIT and short courses designed and delivered to industry and staff at various faculties within RMIT.

In May 2010 RMIT University opened a new, state-of-the-art Advanced Textile Materials Laboratory, featuring equipment required to predict the protection and comfort provided by advanced textile fabrics and clothing. It has since provided opportunities to familiarise current postgraduate students with the new technology available, and provide training and hands-on experience to the teaching staff and industry experts.

In addition, the Fellowship provided the Fellow with an opportunity to view the technology research and education organisation (TC<sup>2</sup>) and to observe how body scanning is being used as a research and training tool. It was also observed how three dimensional (3D) body scanning technology could be utilised for the development and creation of various types of garments before the actual manufacturing takes place. The manufacturer was able to see how the clothing will look on the accurately portrayed virtual body, was able to ensure the correct size/fit and the placement of specific fabric constructions to the designated areas on the garment.

# Table of Contents

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<b>i</b>	<b>Abbreviations/Acronyms</b>
<b>iii</b>	<b>Definitions</b>
<b>1</b>	<b>Acknowledgements</b>
1	Awarding Body – International Specialised Skills Institute (ISS Institute)
2	Fellowship Sponsor
2	Supporters
2	Australian Organisations Impacted by the TCF Industry
<b>5</b>	<b>About the Fellow</b>
<b>7</b>	<b>Aims of the Fellowship Program</b>
<b>9</b>	<b>The Australian Context</b>
10	Current State of the Advanced Textiles Sector in Australia
12	SWOT Analysis
<b>15</b>	<b>Identifying the Skills Deficiencies</b>
<b>19</b>	<b>The International Experience</b>
19	Destination: NCSU
20	NCSU: Comfort Laboratories
32	NCSU: Protection Laboratories
37	Destination: [TC] <sup>2</sup>
<b>39</b>	<b>Knowledge Transfer: Applying the Outcomes</b>
<b>41</b>	<b>Recommendations</b>
41	Government
41	Industry
41	Education and Training
42	Community
42	International Specialised Skills Institute
<b>43</b>	<b>References</b>
<b>45</b>	<b>Attachments</b>
45	Attachment 1
56	Attachment 2

# Abbreviations/Acronyms

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ABS	Australian Bureau of Statistics
ASTM	American Society for Testing of Materials
BA	Bachelor of Arts Degree
BS	Bachelor of Science
C	Capacity
GATS	Gravimetric Absorbency Testing System
ISPO	International Exhibition for Sports Equipment and Apparel
ISS Institute	International specialised Skills Institute
ITT	Institute of Textile Technology
KES	Kawabata Evaluation System
KES-F	Kawabata Hand Evaluation System
MSA	Manufacturing Skills Australia
NCSU	North Carolina State University
NFPA	National Fire Protection Association (USA)
NIOSH	National Institute for Occupational Safety and Health (USA)
RMIT	Royal Melbourne Institute of Technology
RTD	Resistance Temperature Detectors
[TC]²	The Textile/Clothing Technology Corporation
TCF	Textiles, clothing and footwear
THL	Total heat loss. Comfort limits can also be called THL
TTNA	Technical Textiles and Nonwoven Association
TOP	Textile Online Programs
T-PACC	Textiles Protection and Comfort Centre
W	Watts
3D	Three dimensional
%RH	Relative humidity (expressed as percentage)
%RC	Compression resilience (expressed as percentage)
°	Degrees
“	Inch

# Definitions

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BA and BS	Dual degree (BA and BS) in Art and Design and Textile Technology, administered through the Anni Albers Program. The Anni Albers Program is a collaboration between the NC State University world renowned Colleges of Textiles and Design. <sup>2</sup>
C	Capacity shows the weight the water absorbed by the fabric sample.
clo	An arbitrary unit of measurement, this describes the amount of thermal insulation (1 clo is determined to be a thermal resistance value of the typical men's business suit) provided by the fabric.
Demand wettability	This term is used in conjunction with the GATS test is and refers to the steady supply of water that is available to the fabric via the perforated glass plate used in the test.
Design	Design is problem setting and problem solving.  Design is a fundamental economic and business tool. It is embedded in every aspect of commerce and industry and adds high value to any service or product—in business, government, education and training, and the community in general.  Reference: 'Sustainable Policies for a Dynamic Future', Carolynne Bourne AM, ISS Institute 2007.
G	Shear stiffness is a measurement of how easily the fibres in the fabric slide against one another when under this shear stress. The lower the G value, the less resistance there is to the shearing: this denotes a softer fabric.
gf*cm <sup>2</sup> /cm	A unit of measurement that reflects bending rigidity per unit fabric width. This value is what indicates the amount of resistance the fabric gives to the 150° bend. A higher value represents a fabric a greater resistance to bending motions.
Guarded hot plate	Used in the Cooling Ability/Breathability Test using the KESF-TL-2C, this term is used because the hot plate is kept in an enclosed space to prevent air movement near the testing area from affecting the test. Another reason for this guard is to allow the airflow to be constant and unimpeded by the surrounding environment.
Hand properties	These relate to the feel or hand properties of a material that are associated with human sensations related to stiffness, hardness, rigidity, density, thickness, bending, compression, and extensibility of the material.
im	Permeability index. This index indicates the permeability of a fabric. This is the ability of the fabric to allow the passage of moisture and heat to pass through it.
Innovation	Creating and meeting new needs with new technical and design styles. (New realities of lifestyle).  Reference: 'Sustainable Policies for a Dynamic Future', Carolynne Bourne AM, ISS Institute 2007.

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<sup>2</sup> [http://www.tx.ncsu.edu/departments/tatm/anni\\_albers.html](http://www.tx.ncsu.edu/departments/tatm/anni_albers.html)

## Definitions

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KES-FB1	Kawabata Shear tester, exclusively manufactured by KATO TECH Co., LTD., Kyoto, Japan
KES-FB2	Kawabata Bending tester, exclusively manufactured by KATO TECH Co., LTD., Kyoto, Japan <sup>3</sup>
KES-FB3	Kawabata Compression tester, exclusively manufactured by KATO TECH Co., LTD., Kyoto, Japan
KES-FB4	Kawabata Surface tester, exclusively manufactured by KATO TECH Co., LTD., Kyoto, Japan
KES-F7 Thermo Lab II	Kawabata Thermo-Lab apparatus
KESF-TL-2C	A sweating guarded hot plate apparatus, manufactured by KATO TECH Co., LTD., Kyoto, Japan
MIU	Friction Coefficient. MIU is the average value of $\mu$ in 20mm distance. The friction probe on KES-FB4 measures the Coefficient of Friction, which is a measure represented by the symbol (MIU). This frictional measurement is a value that can range from 0-1. A higher MIU denotes a fabric that has a high degree of friction.
q	Represents comfort limits of the fabric and is measured in watts/m <sup>2</sup> . There are three comfort limits: <ul style="list-style-type: none"><li>• minimum (qmin)</li><li>• comfort (qcomf)</li><li>• maximum (qmax).</li></ul> All three limits are measured in units (W/m <sup>2</sup> ). Comfort limits can also be called Total Heat Loss (THL).
Skill deficiency	A skill deficiency is where a demand for labour has not been recognised and training is unavailable in Australian education institutions. This arises where skills are acquired on-the-job, gleaned from published material or from working and/or studying overseas.  Reference: 'Directory of Opportunities. Specialised Courses with Italy. Part 1: Veneto Region', ISS Institute, 1991.  There may be individuals or individual firms that have these capabilities. However, individuals in the main do not share their capabilities, but rather keep the intellectual property to themselves. Over time these individuals retire and pass away. Firms likewise come and go.

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<sup>3</sup> [http://english.keskato.co.jp/products/kes\\_fb2.html](http://english.keskato.co.jp/products/kes_fb2.html)

## Definitions

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SMD	SMD or surface roughness shows the surface's physical roughness. The units of the SMD are microns. A higher SMD measurement corresponds to a rougher fabric in terms of geometric shape, so the larger the SMD value is the less even the surface is. A lower SMD represents a flatter fabric that has less geometric shapes.
SizeUSA	The SizeUSA size study was conducted on 10,000 men and women selected from major cities across the United States. The SizeUSA project was initially funded by the annual grant supplied to [TC] <sup>2</sup> by the US Government. Access to the data is gained by a sponsored membership. The current cost of membership is US\$20,000. <sup>4</sup>
Sustainability	The ISS Institute follows the United Nations for Non-Governmental Organisations' definition on sustainability: " <i>Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs</i> ".  Reference: <a href="http://www.unngosustainability.org/CSD_Definitions%20SD.htm">http://www.unngosustainability.org/CSD_Definitions%20SD.htm</a>
Wicking	Wicking is defined as the movement (absorption and transportation) of moisture within a fabric by capillary action, usually along the fabric surface, to where it can evaporate quickly. It usually refers to the ability of a fabric to move moisture (sweat) away from the skin to the outer layer of fabric where it can evaporate more easily, thus helping to keep the skin dry.
%EMC	This is the value that represents the degree of compressibility of the fabric (expressed as the percentage of the fabric original thickness).
%RC	This value represents the compression resiliency of the fabric.

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<sup>4</sup> <http://www.sizeusa.com>

# Acknowledgements

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## **Awarding Body – International Specialised Skills Institute (ISS Institute)**

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the ISS Institute are our Fellows. Under the **Overseas Applied Research Fellowship Program** the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

1. Preparing a detailed report for distribution to government departments, industry and educational institutions.
2. Recommending improvements to accredited educational courses.
3. Delivering training activities including workshops, conferences and forums.

Over 180 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.

International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.<sup>5</sup>

In this context, the ISS Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see [www.issinstitute.org.au](http://www.issinstitute.org.au).

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<sup>5</sup> Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010', pp. 1-2  
[http://www.skillsaustralia.gov.au/PDFs\\_RTFS/WWF\\_strategy.pdf](http://www.skillsaustralia.gov.au/PDFs_RTFS/WWF_strategy.pdf)



## Acknowledgements

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### Fellowship Sponsor

This Fellowship has been sponsored by RMIT University, Australia. Education, training and workforce participation are central to the RMIT University goal of building a productive and socially inclusive nation, one that values diversity and provides opportunities for all Australians to build rewarding social and economic lives. RMIT's support of this Fellowship is greatly appreciated.

### Supporters

#### In Australia

- Carolynne Bourne AM, former CEO, ISS Institute
- Chris Clark, Programs Manager, RMIT University
- Keith Cowlshaw, Head of School, Fashion and Textiles, RMIT University
- Claire Fitzpatrick, Australian Fashion Council
- Peter Kreitals, Manager, Australian TFC Technology Network
- Joseph Merola, International Fibre Centre
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### Australian Organisations Impacted by the TCF Industry

- Australian Fashion Council – Claire Fitzpatrick, General Manager
- CSIRO (Materials Science and Engineering Division)
- Deakin University (Centre for Material and Fibre Innovation)
- International Fibre Centre, Geelong Technology Precinct
- Manufacturing Skills Australia (MSA)
- RMIT University, School of Fashion and Textiles – Keith Cowlshaw, Head of School
- Technical Textiles and Nonwoven Association (TTNA) – Kerryn Caulfield, Executive Manager
- The Council of Textile & Fashion Industries of Australia – Jo Kellock, Chief Executive Officer
- Victorian TAFE Institutes Including:
  - Box Hill Institute TAFE
  - Gordon Institute of TAFE
  - Kangan Institute TAFE
  - Central Gippsland Institute of TAFE

## Acknowledgements

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### Industry Sectors

- Australian Technology Network (ATN) – Peter Kreitals, Managing Director
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- L & B Williams nominees Pty Ltd – Lloyd Williams, Managing Director
- Therapist Support Laboratory Pty Ltd – Lina Cannalonga, Managing Director
- Ventou Garment Technology – Vlad Libeson, Product Development Manager
- Wilson Fabrics Australia
- Yakka Pty Ltd – Nicki Rowse, Senior Product Manager
- Zedtex Australia Pty Ltd – Wesley Touzel, Managing Director

# About the Fellow

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**Name:** Inna Konopov

**Employment**

- Teacher, RMIT University, School of Fashion and Textiles

**Qualifications**

- Master Of Technology by Research, RMIT University (in progress)
- Bachelor of Applied Science (Textile Technology), RMIT University, 2000
- Diploma of Textile Manufacturing Technology, Melbourne Institute of Textiles, 1997
- Bachelor of Science (Specialist in Textile and Knitted Fabric Technology), Ukrainian State Academy of Light Industry, Ukraine, 1996

Inna Konopov commenced her working life in the Textile, Clothing and Footwear (TCF) industry in Australia working in non-woven product design and the manufacturing sector, with a role in raw material sourcing, product development and the design of high quality bedding and furniture products exclusively to customer requirements. Konopov was directly involved in creating and launching a top collection of brand new, innovative chemical-free Alpaca bedding products, including pillows, quilts and under-blankets to the Australian market.

Konopov then undertook the role of Research Assistant working on the industry funded research project Ergonomic Performance Seam-Free Apparel for Active Wear at RMIT University, where she was directly involved in the product development of merino seam-free apparel for active wear. In this role, Konopov was responsible for planning and sourcing raw materials, evaluation of performance of the different types of raw materials, yarn assessment and selection.

The Fellow also conducted research into garment construction, styling and design, and assisted in the creation and design of a new innovative sample garment. The outcomes of this research included body-mapping and body-zoning for performance sportswear, and the development of seam-free apparel with specialised, specific body zones that have differential performance parameters, such as moisture management, air permeability, heat transfer, etc. These ergonomic seam-free garments were exhibited at the International Exhibition for Sports Equipment and Apparel (ISPO) in Munich, 2007. These garments received very positive feedback from a number of European outdoor apparel brands.

Konopov then decided to change direction in her career and took on education and teaching as a new pathway. She undertook a training program at Shima Seiki, Japan, and became a specialist in knitted product planning, design, virtual sampling and production.

Konopov is an experienced teacher at the School of Fashion and Textiles, RMIT University, specialising in knitwear production with a strong emphasis on sport and protective apparel; textiles design and engineering; and comfort and performance of textiles for specialised functional applications. In her current role she is responsible for delivering a comprehensive range of courses in various areas of textile technology that help students to develop the technical expertise and analytical skills needed for the design, development and manufacturing of engineered textile materials. She prepares students for careers in design development and the manufacture of textile products in a variety of applications, such as automotive, apparel, sports and many others.

Konopov is currently completing her Masters of Technology by research at RMIT University, investigating the aerodynamic and comfort performance of knitted fabrics for high-speed sports.

Konopov has research interests in:

- The development and engineering of advanced textile materials for functional applications, such as performance sportswear and protective apparel.
- Comfort properties of textile clothing and materials, heat and moisture transfer in textile structures, and the objective measurement of fabric hand.
- Thermal protective performance of textile fabrics and clothing, and heat transfer mechanisms in intense heat exposures.
- Analysis of thermal and mechanical properties of textile fabrics and textile measurement technologies.
- Assessment of human sensory and physiological response to clothing comfort.

# Aims of the Fellowship Program

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The intention of the Fellowship was to undertake an overseas study in protective and comfort assessment, and testing of advanced textiles at North Carolina State University (NCSU) College of Textiles, North Carolina, USA. NCSU is a comprehensive university known for its leadership in education and research, and globally recognised for its science, technology, engineering and mathematics leadership.

The study provided a better understanding of advanced textiles and their applications, internationally used testing methods and protocols for the support of the Australian TCF Industry. It was also envisaged that the Fellowship would incorporate learning that would then be transformed into teaching and learning strategies in the higher educational environment in order to increase innovation in the Australian TCF Industries and give them a more competitive edge.

The aim of this study was to view an international state-of-the-art facility for the assessment and evaluation of comfort and protection of advanced textiles, and to attain a global best-practice fundamental knowledge in advanced textiles and testing procedures. The overall aim of the Fellowship was to focus on the following specific areas of study and development:

- To become skilled in the evaluation and assessment of advanced fibres, yarns, fabrics and finishes suitable for use with advanced protective textiles and that produce safe clothing.
- To gain an understanding of the latest internationally used testing methods and protocols for the evaluation and analysis of advanced protective textiles and assemblies.
- To become skilled in the identification of the protective performance capabilities of advanced fabrics for extreme environments.
- To become skilled in the selection criteria of advanced protective fabrics that are suitable for extreme environments.
- To become skilled in selecting the most appropriate test methodologies and the methods for assessing comfort and protective properties of advanced textiles and assemblies.
- To become skilled in identifying the main performance requirements of protective textiles and assemblies and adapting these to Australian conditions.
- To investigate the latest technologies and laboratory equipment used internationally to determine the protective effects of advanced textiles and assemblies.
- To develop advanced skills in comfort and protective testing technologies for the Australian TCF Industry.
- To raise a profile of the Australian Fashion and Textiles Industry internationally.

# The Australian Context

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The Australian textile industry is involved with more than producing fabric and apparel. Composites, artificial organs, fireproof materials and other advanced textiles are just a few of the modern products in the textile industry.

As an example, climate change, in addition to low humidity, heat and sun and the scarcity of water, inevitably increases fire activity. The devastating Victorian bushfires showed our general lack of preparedness for changing environmental conditions and the lack of knowledge of advanced textiles and how they may 'assist' in such circumstances. In many professions, advanced protective textiles are required as personal protective equipment. The current performance of the advanced textiles and the way they are assembled is problematic, in many instances they lack moisture absorbency and the excessive weight of the garments increases the likelihood of personal injuries such as heat stress.

Fundamental knowledge is desperately required in Australia to be able to:

- Investigate the possibilities of maintaining the protective effects of advanced textiles.
- Develop systems for evaluation of the protective effects and comfort performance of advanced textiles.
- Relate the international standards for determining the protection and comfort capacity of advanced textiles to Australian conditions.
- Measure and quantify the performance of advanced materials and the way they are assembled.
- Gain knowledge in laboratory tests, testing methods and translating instrument readings so that they can be utilised to predict injuries to the human body.

Advanced textiles are, *"textile materials and products manufactured primarily for their technical performance and functional properties rather than their aesthetic or decorative characteristics"*.<sup>6</sup> Advanced textiles are about function not fashion. Another distinguishing feature of advanced textiles is that unlike the traditional use of ordinary textiles in apparel and furnishing, they are primarily utilised by industrial professionals in different types of high performance and heavy-duty applications in non-textile industries.

The leading international trade exhibition for advanced and technical textiles, Techtexil (organised biennially since the late 1980s by Messe Frankfurt in Germany and also in Osaka, Japan), defines 12 main application areas for Advanced Textiles:

1. Agrotech: comprising agriculture, horticulture, aquaculture and forestry.
2. Buildtech: comprising building and construction.
3. Clothtech: comprising technical components of footwear and clothing.
4. Geotech: comprising technical components of geotextiles and civil engineering.
5. Hometech: comprising technical components of furniture, household textiles and floor coverings.
6. Indutech: comprising filtration, conveying, cleaning and other industrial uses.
7. Medtech: comprising medical field and hygiene.
8. Mobiltech: comprising automobiles, shipping, railways and aerospace.
9. Oekotech: comprising environmental protection.
10. Packtech: comprising of packaging.
11. Protech: comprising personal and property protection.
12. Sporttech: comprising sports and leisure.

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<sup>6</sup> 2000 *Handbook of Technical Textiles*, 2000, edited by Harrocks, AR; Anand, SC @ Woodhead publishing, page 5.

Usage and significance of advanced textiles:

- They play a significant role in space exploration, and space suits are created with a layered fabric system to provide protection to the astronaut.
- Space vehicles are made up of specialised advanced textiles so they can withstand a temperature of several thousand degrees.
- Specialised advanced textiles are used in aeroplanes, environmental protection and highway construction.
- Advanced textiles are used in the production of artificial kidneys used during dialysis of patients. They are also used in other medical situations such as the treatment of burns and wounds. The greatest advantage of these textiles is that they not only possess strength, flexibility and elasticity, but also offer various design options.
- Advanced textiles are widely used in military applications to provide greater protection to soldiers.
- Advanced textiles are widely used as effective protective clothing during activities such as conventional and extreme sports, police operations, agricultural and industrial working and fire fighting.

Australian Bureau of Statistics (ABS) figures show that the Australian advanced textiles industry is worth approximately \$1.5 billion, and research indicates that the global industry is growing by about 4% per annum.<sup>7</sup>

### Current State of the Advanced Textiles Sector in Australia

Australian firms and foreign-owned subsidiaries with operations in Australia have enjoyed variable success in the development of advanced technical textiles. However, that success has been fragmented due to a number of reasons. The key causes include:

- Domination by a small number of foreign-owned companies that undertake their activities with high levels of secrecy.
- A significant lack of awareness of the opportunities that exist in the sector.
- The absence of a high performance, fibre manufacturing base in Australia.
- The absence of tertiary education in advanced textiles and management areas.

The advanced textiles industry is regarded as the most thriving and the fastest changing sector of the global and the Australian textiles industry. The technical textiles often go unnoticed. Much of the broader textile industry produces products for aesthetic and decorative purposes (fashion apparel, clothing, soft furnishings, fashion accessories), whereas the technical textiles, fibres and yarns have a more functional purpose. They are frequently used in a range of 'downstream' applications in other manufacturing and service industries and thus, are not highly visible in the retail market. In contrast to the popular perception of the broader Australian textile industry—that is, an industry that is decreasing rapidly and going off shore—the Australian advanced textiles sector of the TCF industry is using high-level technology and high value-adding manufacturing procedures.

The Australian advanced textiles sector is located mainly in Victoria and NSW, with a considerable number of people employed in regional areas including Gosford (NSW), Albury (NSW), Stawell (Vic), Southport (Qld), Wangaratta (Vic).<sup>8</sup> These regional locations are significant in terms of regional development and employment in Australia. Collectively these companies employ almost 1,000 people. In terms of training, the regional base emphasises the importance of forming training partnerships with local and national training providers.

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<sup>7</sup> *Innovation in Australian Business (2006a)*, 2005, ABS (Australian Bureau of Statistics, 2005)

<sup>8</sup> *The Australian Technical Textiles & Nonwovens Industry Profile*, May 2006, Prepared by: The Technical Textiles & Nonwoven Association, on behalf of Manufacturing Skills Australia, page 6.

The advanced textiles industry draws on a wide range of skills. The industry need for a high level of technical skill is evident. Jocelyn Probert concluded that, “*technological innovation is central to the development of the modern textile and clothing industries. Drawing on international experience, it is evident that success in current Australian textile industry can only be achieved by innovation intensity*”.<sup>9</sup>

Currently, innovation in advanced textiles is being driven by the R&D emanating from the CSIRO (Materials Science and Engineering Division) and Deakin University, (Centre for Material and Fibre Innovation), but commercial development still lags behind many other developed countries. Much research and development is focused on developing new technologies for advanced textiles. Some technologies are at an advanced stage of research with existing prototypes while others are still very much at the concept stage.<sup>10</sup>

It has to be mentioned that the CSIRO is the only facility in Melbourne that has the flexibility to produce one-off samples or do specialist runs. Commercial mills often lack the flexibility to switch equipment from commercial production runs to one-off samples or special runs. Prototype production can disrupt long commercial runs, adding to the expense of product development.

An advanced textile sector is composed of small- to medium-scale companies and it is apparent that the existing companies dealing with advanced textiles in Australia are too small to fund the necessary research and that the industry is too diverse to support the breadth of skills required and the expertise needed to cover the range of activities in sufficient depth.

Australia is fortunate to have an established network of education and training providers, but they need to adapt their training and educational programs to create the intellectual capital and skilled personnel to populate the industry.

The industry needs to become known for:

- undertaking innovation in design
- providing quality products
- reaching and leading the markets of the world
- branding and creating product design presence throughout the world
- skilling in adding value to our natural resources
- researching technology to achieve a competitive edge
- understanding and using design as a business tool
- meeting the dual challenge of identifying and filling skills deficiencies as well as skills shortages
- working in collaboration along the value chain with communication at all levels across the professions and trades
- establishing a Master Artisan credential and a pathway for lifelong learning.<sup>11</sup>

Professor Roy Green highlights that “*it is generally recognised that Australia’s TCF industries, as in other developed, high wage economies, face the challenges of low cost competition in high volume ‘commoditised’ market segments, pressure for constant and creative evolution of value adding fashion products and a relentless demand for new technologies and skills across the industries, especially in technical textile production and ‘smart fabrics’ where competitive advantage is increasingly driven by knowledge and innovation*” is essential.<sup>12</sup>

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<sup>9</sup> *Building Innovative Capability*, 2008, Review of the Australian Textile, Clothing and Footwear Industries, page 99.

<sup>10</sup> *Building Innovative Capability*, 2008, Review of the Australian Textile, Clothing and Footwear Industries, page 40.

<sup>11</sup> *Discover ISS Institute*, 2009, International Specialised Skills Institute, Melbourne, Australia, July 2009.

<sup>12</sup> *Building Innovative Capability*, 2008, Review of the Australian Textile, Clothing and Footwear Industries, page viii.

The traditional textiles sector has declined and industry has focused on cost and maintenance of traditional skills and not invested in graduates. Australia has an educational infrastructure in place that can be developed and positioned to meet industry needs. Today, the educational institutions servicing the TCF industry need to respond quickly by developing new training programs and systems that will respond to the changing requirements of the TCF industry. The Industry needs new people with new sets of skills and new mindsets to commercialise those skills at both a professional and trade level.

The necessity of the developing a new program to support the advanced textiles sector in Australia was highlighted in a recent report by Professor Roy Green. He recommended that it is vital to *“have as a priority the improvement of R&D performance in Australian TCF firms, especially technical textiles”*.<sup>13</sup> The report has been presented to the Federal Minister for Industry, Innovation, Science and Research, the Hon Kim Carr. The Green report confirmed that technical textile manufacturers have achieved *“significant positive progress on an international level over recent years”* and highlighted the importance of the technical textiles sector within the \$16 billion Australian TCF industry.<sup>14</sup>

The Australian Government, unfortunately, has not acknowledged the contribution of the technical textiles industry and not supported the industry’s endeavours to continue its *“restructure whilst developing leading edge operational and production efficiencies, innovation, new technologies, ethical and environmentally responsible manufacturing process”*.<sup>15</sup>

Technical Textiles and Nonwoven Association (TTNA) Executive Officer, Kerryn Caulfield said that, *“at this crucial period in the Global Financial Crisis (GFC) that will have such long lasting and profound impact on Australia’s long term economic well being—it was incomprehensible that the Government would not support industry and businesses that are involved in the development of new technologies committed to delivering significant benefits for Australian innovation and employment opportunities. On the other hand, TTNA support and will continue to provide an incentive for Australia’s most promising entrepreneurs, researchers and businesses to seek more favourable commercial environments and opportunities within advanced technical textiles sector of the Australian TCF industry”*.<sup>16</sup>

There are many skills that are required to understand and successfully apply advanced, protective and technical textiles and their assemblies. Specialised skills are currently not taught and are not offered in the training packages in Australia. Therefore, it is vital to take the responsibility to advance knowledge, transfer technology, and discover innovations to be able to incorporate them into Australian textile technology education.

## SWOT Analysis

### Strengths

- Large existing technical knowledge base.
- Effective sourcing of the materials.
- Established testing facilities.
- Demand for knowledge from prospective students.

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<sup>13</sup> *Building Innovative Capability, 2008*, Review of the Australian Textile, Clothing and Footwear Industries, Recommendation 12, page x.

<sup>14</sup> *ibid.*

<sup>15</sup> Technical Textiles and Nonwoven Association (TTNA) Executive Officer, Kerryn Caulfield, *TTNA, Media Release 923KC*, 29 May, 2009.

<sup>16</sup> *ibid.*

- Demand for change from consumers.
- Industry networks are already in place.
- Innovative and entrepreneurial attitude of industry participants.

### Opportunities

- Developing a collaboration program with international researches.
- Defining existing markets better and develop new products for market.
- Adapting internationally recognised training and education programs to create the intellectual capital and skilled personnel in order to populate this new industry.
- Incorporating new training programs for the existing industry.
- Encouraging existing industry participants to follow up on the market and research developments.

### Weaknesses

- Industry reluctance to change.
- Confusion over comfort and protection.
- Lack of capital investment to purchase new testing equipment.
- The absence of new products.
- Lack of local R&D.
- Lack of understanding and use of design as a business tool.
- Not identifying skills deficiencies.
- Lack of collaboration between professions and trades.
- Lack of lifelong learning pathways, particularly in the trades.

### Threats

- Promoting materials without showing their real properties.
- Changing of conditions requires constant updating of test data.
- Changing Australian standards.
- Imports increasing.
- Higher education sector not delivering solutions.
- Lack of government support.

# Identifying the Skills Deficiencies

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Technical textiles are widely regarded as the most thriving and fastest changing sector of the global textile industry. Innovation in new materials, processes and applications are expanding in non-traditional end applications for both new and existing textile products. Technical textiles are about function, leading-edge technology and high value-adding activity. Currently, the textiles industry and its students do not have sufficient knowledge of the different technical textiles available. It is of vast importance to conduct further research into the properties of the advanced textiles available. It is also crucial to understand how testing and evaluation of these textiles are conducted. Since the industry and students currently lack this knowledge, they do not have the confidence to explore the use of these textiles. However, full understanding of the properties of the advanced textiles, would give the industry and its students an advantage in today's a very competitive Textile industry.

North Carolina State University (NCSU) are internationally recognised as a centre for the research and development of advanced textiles. They are leaders in developing procedures and techniques associated with the evaluation of the comfort and protective properties of these materials. Observing and researching the NCSU model and meeting with leading experts and professionals in this specific field has given the Fellow the opportunity to return to Australia with new, broad knowledge and skills in this area. The Fellow has acquired knowledge on short courses and specially tailored workshops. She has found that the implementation of courses and workshops based on the NCSU model could be tailored to the TCF industry in Australia and advice could be provided on specialised program structure, new technical textiles, and comfort and protective testing. These courses could be introduced into Australia's current textile technology programs.

The aim of this Fellowship was to improve current skills and gain new knowledge in the properties of advanced materials and their assemblies, their applications and their testing and evaluation procedures. In order to obtain the necessary skills, knowledge and understandings, the following activities were undertaken during the course of the Fellowship:

## **1. Evaluation and assessment of advanced fibres.**

Inspect and evaluate testing and analytical services for determining the physical properties of advanced fibres, yarns, fabrics, and other textile products. Conduct interviews with experienced technicians in relation to the performing tests to a variety of standards, and gain an understanding in order to tailor the testing procedure to specific needs.

- How the fibres, yarns and fabrics are tested to estimate/determine their physical performance?
- What system of instruments is used to measure properties of textile fabrics?
- How the aesthetic qualities of how fabrics will be perceived by human touch can be predicted?
- What is the bending test? Why is it important to conduct it to evaluate the performance of fabrics?
- The stress/strain test is measured at the maximum load set for the material being tested. How is the maximum load determined? How can it be tailored to specific needs?
- Why is it important to conduct surface properties testing?
- How do the variables of fibre, yarn, fabric construction and finish contribute to the perception of softness to the skin?
- What is the cool touch test? Why and how it is performed?

## **2. Interpretation of international standards.**

To analyse how international standards are used for the evaluation and analysis of advanced protective textiles. Develop an understanding of how test results data is recorded. Generate a fundamental knowledge of the expectations of international markets in relation to advanced protective textiles performance.

- What international standards are used to evaluate the performance of protection and comfort of advanced textiles?
- How is test data received and recorded?
- How can protocols be designed to determine subjective ratings or rankings of fabric softness?
- How human panel evaluations are used for engineering desirable hand qualities into textile materials.
- How the participants used in critical evaluation of the properties of advanced textiles are selected?
- How the Kawabata Evaluation system is used to make measurements?

### **3. The identification of protective performance capabilities of advanced textiles that are of great importance to textile service providers.**

To analyse how performance tests, carried out by leading scientists, determine which advanced textiles carry the capabilities to withstand extreme climatic conditions.

To observe procedures involved in comparative evaluation and quantification of the performance of advanced materials. To perform tests under the supervision of leading scientists.

- What is the conductivity test? Why is it important to conduct this test and how does it determine the advanced textile's capabilities to withstand extreme environments?
- How comparison analysis is performed after the test has been conducted to rank the fabrics?
- How can climatic conditions be simulated in a laboratory environment?
- What is the procedure for changing the conditions in a laboratory environment?

### **5. Selection of the appropriate test procedures for the assessment of the comfort and protective properties of advanced fabrics and assemblies.**

To inspect and view textile comfort and protective testing facilities and equipment required for human textile comfort response protocols. Conduct an evaluation of the important aspects of protection including resistance to chemical, aerosol and biological agents.

- What parameters are of critical importance for the evaluation of the comfort and protective properties of fabrics?
- How does the Advanced Sweating Thermal Manikin operate?
- How is it possible to assess the influence of clothing on the thermal comfort process for a given environment?
- How are heat and moisture simultaneously transported through the clothing system, over different parts of the body? How can both the variations in these properties and the way heat and moisture are transported be quantified?
- How are the fabrics and fabric assemblies' protection against hazardous conditions measured?
- How is 'full garment burn' test conducted?
- How are the results interpreted and recorded?

### **6. Identification of the main performance requirements for protective textiles and assemblies in order to meet Australian conditions.**

To record information on the main performance requirements needed for protective fabrics. To gain an understanding in the methodology involved in evaluating the performance of thermal protective assemblies that provide protection against fire exposure using a mannequin specifically designed for such purpose.

- How does the PyroMan manikin operate?
- How is the computer system used to control the test?
- How is the data acquired by the computer system then interpreted to predict the burn injury?

### **7. Fundamental understanding of the equipment used for the testing/evaluation of advanced protective textiles.**

To appraise the state-of-the-art manufacturing and laboratory facility. To record and analyse the information sourced via interviews with appropriate personnel.

- What equipment is used to spin fibres for R&D?
- What equipment is used to manufacture woven and non-woven samples?
- What equipment is used to manufacture knitted samples?
- How is the Knitting and Weaving Laboratory designed to fit the educational needs of the students in order to allow them to conduct applied research?
- How are the testing procedures tailored to meet specific needs?

### **8. Selecting appropriate textiles for particular applications.**

Protective and sportswear clothing that is comfortable to wear plays an important part in ensuring that the wearer feels physically at ease doing his job/activity and is motivated to perform well. Many different aspects are involved in defining comfort, but it is no longer correct to assume that this is a subjective criterion. Comfort characteristics can be measured objectively.

To gain an understanding in the methodology involved in selecting the appropriate constructions and materials of the underlying fabrics from which the garments are made, in order to make predictions about the comfort characteristics of the finished garment for a particular application.

- How the sensorial comfort can be quantifiably assessed?
- What are the special measuring procedures used to assess the sensorial comfort?
- How is the extent to which a fabric 'clings' to skin when wet with sweat measured?
- What equipment is used to measure the number of contact points between the textile and the skin, and the sorption index?
- How are the fitting tests performed?
- How are the textiles/constituted fabrics and the complete garments tested for harmful substances?



# The International Experience

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The overseas program was designed to explore the identified skills deficiencies and to acquire the information necessary to return to Australia equipped with the broad knowledge and innovative ideas to support training, improve education, and encourage more research into and people working in the technical textiles sector of the Australian TCF industry.

## **Destination: NCSU**

**Centre for Research on Textile Protection and Comfort (T-PACC), North Carolina State University (NCSU)<sup>17</sup>**

### **Contacts:**

- Dr Roger Barker, Professor of Textile Engineering Chemistry and Science, Director of the T-PACC
- Gail Liston, Research Technician
- Kevin Ross, Research Assistant

North Carolina State University (NCSU) is an internationally recognised centre for research and development of advanced technical textiles. While at NCSU, Konopov visited its centre for Research on Textile Protection and Comfort (T-PACC). T-PACC incorporates a comprehensive infrastructure of equipment and personnel to address the need for integrated research into all aspects of the protection and comfort of clothing. T-PACC is a broad base facility with unique scientific abilities. They conduct scientific investigation into the comfort and protection provided by fabrics, from the fabric-swatch level to full-ensemble systems.

Konopov met with Dr Roger Barker, Professor of Textile Engineering Chemistry and Science, Director of the T-PACC, and lead researcher in the area of textile comfort and protection; Gail Liston, Research Technician; and Kevin Ross, Research Assistant. They discussed the learning/teaching issues related to student education in the area of testing and evaluation, the performance of technical textiles, and the unprecedented opportunities available at NCSU. This also provided Konopov with the opportunity to discuss scenarios for a similar facility to be set up in Australia.

During the eight days spent at T-PACC, Konopov viewed the following facilities:

- Comfort Laboratories
  - Fabric Hand laboratory
  - Micro Climate Analysis laboratory
  - Absorbency laboratory and
  - Garment Comfort Laboratory
- Protection Laboratories
  - Thermal Protection Laboratory
  - Barrier Fabrics Laboratory

At each of the facilities the equipment and testing processes were observed and photographed. It was clear that the specialised skills and equipment seen at NCSU were unique and not available in this combination in Australia. Through this Fellowship, a comprehensive knowledge was obtained of the various testing techniques and methods, test results interpretation and evaluation, and testing equipment.

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<sup>17</sup> [www.tx.ncsu.edu/tpacc/](http://www.tx.ncsu.edu/tpacc/)

### Objectives

- To gain a comprehensive knowledge on various testing techniques and methods.
- To gain a comprehensive knowledge of test results interpretation and evaluation.
- To expand an understanding of specialised testing equipment.
- To be able to select the most appropriate test procedures for a specified end use.
- To gain a better understanding of the selection of the most appropriate textiles for a particular application.

### Outcomes

- Gained an understanding of the Kawabata Evaluation System (KES) and the five tests that this system can perform.
- Observed and learnt how various testing equipment and instruments operate.
- Learned and gained an understanding of what methodologies are involved in evaluating the comfort properties of fabrics and garment assemblies.
- Gained an understanding of how the results data obtained from various testing techniques are recorded and analysed.
- Gained an understanding of how results obtained from these tests can be quantified and used for the evaluation of comfort of various textile products, including apparel, non-woven, home, medical, sports, technical and special niche textiles.

## NCSU: Comfort Laboratories

### Fabric Hand Laboratory

The Fabric Hand Laboratory contained the KES instruments that measure the properties of textile fabrics and predict the aesthetic qualities of fabrics, as they would be perceived by human touch. The KES instruments measure fabric bending,<sup>18</sup> shearing,<sup>19</sup> tensile and compressive stiffness,<sup>20</sup> as well as the smoothness<sup>21</sup> and frictional properties<sup>22</sup> of a fabric's surface. This evaluation includes the heat transfer properties of the fabric and the coolness of the garment on the skin during wear. The KES provides the unique capability not only to predict human response but also to provide an understanding of how the variables of fibre, yarn, fabric construction, and finish contribute to the perception of softness.

While visiting the Fabric Hand Laboratory, Konopov learnt how specially designed protocols are used to determine subjective ratings or rankings of fabric softness. The Fellow observed how the test results are interpreted by the laboratory staff members in order to evaluate the texture, softness, and other hand properties of fabric materials. She also witnessed how the special human panel evaluations are used in conjunction with the KES for engineering desirable hand qualities into textile materials.

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<sup>18</sup> [http://www.tx.ncsu.edu/tpacc/comfort/bending\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/bending_test.html)

<sup>19</sup> [http://www.tx.ncsu.edu/tpacc/comfort/tensile\\_shear.html](http://www.tx.ncsu.edu/tpacc/comfort/tensile_shear.html)

<sup>20</sup> [http://www.tx.ncsu.edu/tpacc/comfort/compression\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/compression_test.html)

<sup>21</sup> [http://www.tx.ncsu.edu/tpacc/comfort/surface\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/surface_test.html)

<sup>22</sup> [http://www.tx.ncsu.edu/tpacc/comfort/surface\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/surface_test.html)

### The Kawabata Evaluation System (KES)

The KES is used to make objective measurements of hand properties. The KES instruments measure mechanical properties that simulate the fundamental deformation of fabrics in hand manipulation. The KES is the most widely accepted method for the objective measurement of fabric hand.

*"S. Kawabata began his theory of fabric hand measurement based on the assumption that 'fabric hand' is the accumulation of fabric properties such as stiffness, softness, and roughness. Kawabata's second theory was that the final determination of 'fabric hand' is biased depending upon the end use intended for the fabric."*<sup>23</sup>

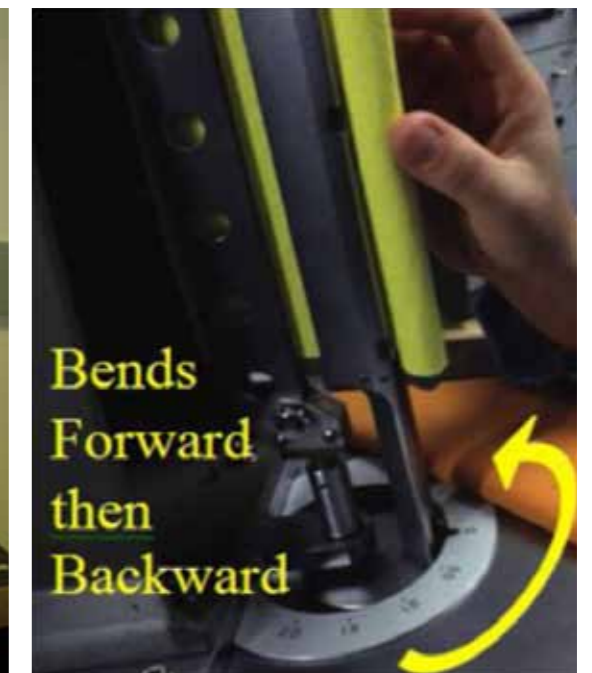
*"The KES's biggest advantage is the ability that the machines in the system have to measure very small strain values with a high degree of sensitivity and accuracy. This capability allows very specific properties, such as shear, tensile, compression, bending, and surface, of 'fabric hand' to be separately and accurately measured. This advantage makes the KES the most advanced measurement tool for the objective measurement of 'fabric hand'."*<sup>24</sup>

Konopov's observations at Comfort Laboratories covered a range of testing techniques and instruments used in the evaluation and prediction of the comfort properties of different types of textiles. Five different tests can be performed using the KES. These tests, and the main mechanical characteristics produced, are described below

#### 1. Bending Test Using the KES-FB2



Bending Tester KES-FB2



Showing the forward and backward bending motion of the KES-FB2.

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<sup>23</sup> R. L. Barker, 2002 'From fabric hand to thermal comfort: The evolving role of objective measurements in explaining human comfort response to textiles'. *International Journal of Clothing Science and Technology*. (14), 181.

<sup>24</sup> *ibid.*

## The International Experience

This test is done in three replications in a fabric lengthwise direction and three replications in a fabric width-wise direction, using three 20 cm x 20 cm fabric samples. This test is performed by fastening a section of fabric firmly to a stationary hold point, and then to a moving hold point that rotates about the axis of the stationary hold point.

This moving point bends the fabric to approximately 150° from the stationary point, applying pressure to the material. The KES-FB2 measures the force required to bend the fabric to the 150° point in both directions, meaning the fabric is bent to 150° in one direction and then the moving point travels back past the stationary hold point and then 150° in the other direction.

The measure provided by the Bending test is called bending rigidity and is represented by the symbol (B). The units of bending rigidity are  $\text{gf}\cdot\text{cm}^2/\text{cm}$ : these reflect bending rigidity per unit fabric width. This value is what indicates the amount of resistance the fabric gives to the 150° bend.

A higher B value represents a fabric that has a greater stiffness and a greater resistance to bending motions, while a lower B value represents a fabric that gives less resistance to bending motions, and displays lower stiffness. A lower B value fabric is ideal for athletic use. This is also a good predictor of drape.

### 2. Compression Test Using the KES-FB3

The KES Compression Test is performed using the KES-FB3. This test stands apart from the other KES tests because it is the only test that uses a differing sample size, and the fabric is moved in only one direction. This fabric is only moved in one direction and the test is done by applying pressure onto the face of the fabric, with the skin side facing downward.

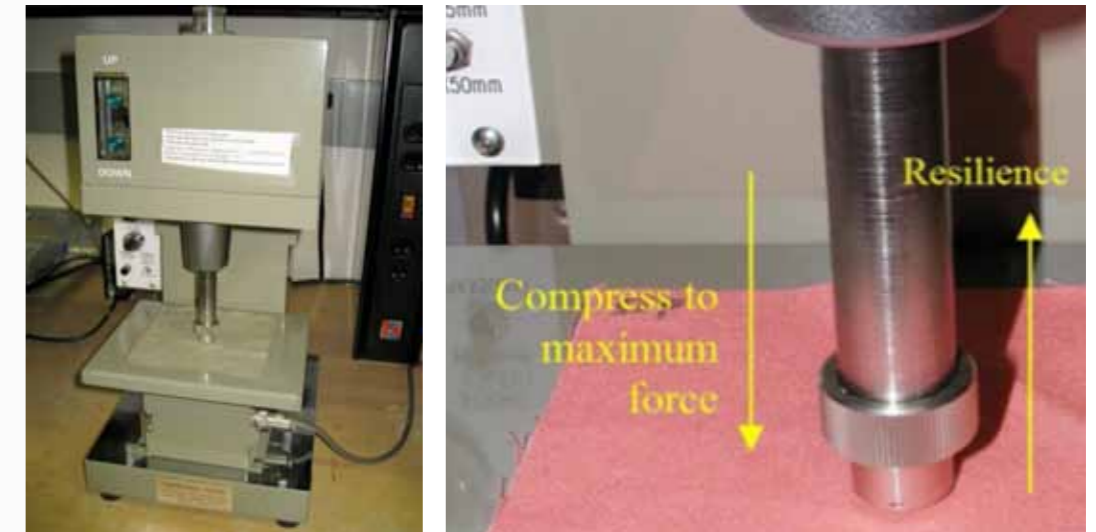
There are three 5" x 5" samples used in this test to provide three replications of test data. The test operates with a small 2  $\text{cm}^2$  circle in the bottom of the surface of the tester. A small column also 2  $\text{cm}^2$  then slowly lowers onto the fabric at the location of this circle. The column lowers at a rate of 1 mm/sec and eventually applies a force of 50  $\text{gf}/\text{cm}^2$  to the fabric. During this process the KES-FB3 measures the compression properties of the 2  $\text{cm}^2$  area of fabric being impacted.

There are three measurements provided by the KES Compression Test. The first is compressibility, which is denoted by the symbol (%EMC). This value represents the percentage of compression as calculated by comparing the initial thickness of the fabric to the thickness of the fabric when it is under the full 50  $\text{gf}/\text{cm}^2$  load. The higher the %EMC, the greater the fabric's compressibility is, while a lower %EMC represents a fabric that resists compression. A higher %EMC is a plus for general comfort during wear, due to the impact that compressibility has on the sensation of softness.

Another measurement provided by this test is compression resilience, which is represented by the symbol (%RC). This value is also expressed as a percentage, and measures the recovery the fabric demonstrates after the force has been removed. This is achieved by comparing the thickness before the force is applied to the thickness after the force has been removed. A higher %RC shows that a fabric has greater resilience and is able to spring back to 85% of its initial thickness after having been subjected to a downward force upon its face. A lower %RC shows that a fabric has a low recovery capability.

The final measurement provided by the KES Compression Test is thickness. The thickness of the 2  $\text{cm}^2$  area is measured at the point at which the force has reached only 0.5  $\text{gf}/\text{cm}^2$ , at the initial contact between the column and the fabric surface. This value is used in the calculation of both %EMC and %RC, and gives a general understanding of how thick the fabric is. Images of both the KES-FB3 and of the action of the compression test are seen in the photos on the following page.

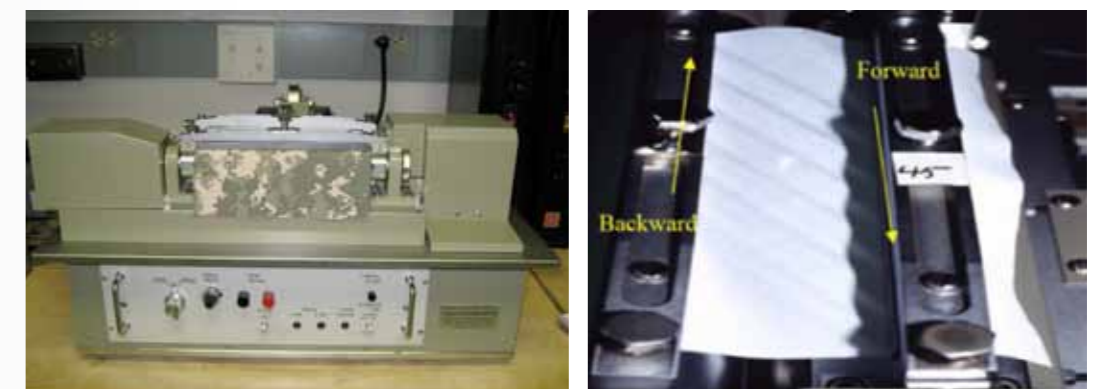
## The International Experience



The Compression Test using the KES-FB3 The compression motion of the KES-FB3

### 3. Shear Test Using the KES-FB1

The KES Shear Test is designed to determine how the fabric resists to the shearing movement corresponding to a softer material having better drape. In shear testing, the KES-FB1 Tensile-Shear Tester applies opposing, parallel forces to the fabric that are asserted at opposite ends of the fabric and in opposing directions. This applies stress to the yarns being tested, whether it be in the lengthwise or width-wise direction. Three fabric samples are usually used in this test. The size of each sample is 20 cm x 20 cm. Three replications are performed in each direction. Before the test begins the fabric is loaded onto the KES-FB1, this is shown below left. A constant tension of 10  $\text{gf}/\text{cm}^2$  is placed on the sample to hold it fast during the test. These parallel forces move in opposite directions until they have caused the yarns in the fabric, which are perpendicular to the forces, to be moved to an angle of 8° from the resting point or true perpendicular, this is shown below right. The measurement generated by this test is called shear stiffness and is represented by the symbol (G). Shear stiffness is a measurement of how easily the fibres in the fabric slide against one another when under this shear stress. The lower the G value, the less resistance there is to the shearing: this denotes a softer fabric. A lower G value is also an indicator of a fabric that will have better draping properties. For athletic purposes a lower G value is ideal, due to the fabric providing less resistance to movement. This means greater mobility in the garment during physical activity.



The Shear Test using the KES-FB1

Fabric sample going through the shear testing process

### 4. Surface Test Using the KES-FB4

The KES Surface Test is performed using the KES-FB4. Again, there are three samples used in this test to provide three replications of test data. Three replications are performed in both the lengthwise and width-wise directions. The fabric samples used in this test are again 20 cm x 20 cm. One difference with the KES-FB4 is that the samples are mounted with the skin side facing up, as opposed to the rest of the KES tests: these have the skin side of the fabric facing downward. This is done in order to measure the surface properties of the side of the fabric that will be coming in contact with skin when the garment is being worn.

This test is performed by clamping the fabric onto a roller and then having the fabric span an open area. The fabric is draped down over another roller where a clip, weighing 120 grams, hangs from the other end of the fabric. This allows a steady, light tension to remain on the fabric in order to ensure that the surface of the fabric in the open area remains flat and does not droop into the opening. The roller then turns and drags the fabric across the open area.

Two different probes touch the fabric from the top (on the skin side) and measure two distinct properties as the fabric is dragged beneath them. One probe is the roughness probe and the other is the friction probe. These probes can be seen below. The roughness and friction probes supply the two measurements used in the surface test. The Friction probe measures the coefficient of friction, which is represented by the symbol (MIU). This frictional measurement is a value that can range from 0–1 MIU. A higher MIU denotes a fabric that has a high degree of friction and resists drag. A lower MIU represents a smoother fabric that has a lower amount of friction and less resistance to drag.

The other measurement provided by this test is geometric roughness as symbolised by (SMD). A higher SMD measurement corresponds to a rougher fabric in terms of geometric shape. A lower SMD measurement represents a flatter fabric that has less geometric shape and less drag. Both lower MIU and SMD are positives for athletic use, and they cause less irritation to the skin during activity. The KES-FB4 and the action that takes place during the KES Surface Test is shown below.



The Surface Test using the KES-FB4



Fabric sample going through the surface testing process

### 5. Warm-Cool Touch Test Using the KES-F7 Thermo Lab II

The KES Warm-Cool Touch Test is performed on KES-F7 Thermo Lab II and determines whether the fabric has a warm or cool feeling when it comes in contact with the skin. This feeling is represented by 'comfort limits'. Comfort limits are represented by the symbol (q). A higher q value denotes that there is more rapid movement of heat from the body to the fabric surface resulting in a cooler feeling fabric.



The Warm-Cool Touch Test using the KES-F7



The fabric sample going through the warm-cool touch testing process

### Micro Climate Analysis Laboratory

The Micro Climate Analysis Laboratory houses research instruments that measure the heat and moisture transfer properties of fabrics related to thermal comfort. The conductivity, thermal insulation, and moisture vapour transmission rates of the fabrics are measured. Predictions of the thermal comfort and heat stress of materials are made using 'sweating skin' models. To simulate heat loss from sweating skin, the heat transfer through the test fabrics is measured using a sweating hot plate housed in an environmental chamber. The temperature, humidity, and wind speed are controlled to create climatic conditions. Resulting thermal comfort and heat stress indices are useful for comparing materials on the basis of their ability to provide thermal comfort to the wearer. They can also be used to measure the insulation properties of the fabric.

Another mechanism can be employed to study the heat and moisture transport properties of fabrics. A unique device developed at NCSU enables the measurement of transient microclimate temperature and humidity changes that occur during and after a sweat pulse. The ability of fabrics to provide a buffer against moisture vapour and the different types of fabric assembly can also be modelled and evaluated.

### Cooling Ability/Breathability Test Using the KESF-TL-2C



The Cooling Ability/Breathability Test using the KESF-TL-2C

While this test shares the name Kawabata with the KES system, it measures a very different fabric quality. The KESF-TL-2C, also known as the 'sweating guarded hot plate' or 'small hot plate', is concerned with the quantitative measurement of the cooling ability and the breathability of fabric. In short it is designed to measure the thermal comfort properties of the fabric. This test is performed on the KESF-TL-2C and is performed in a controlled environment at 21 degrees Celsius and 65% RH]. This test uses three 5 " x 5 " fabric samples to provide three replications of test data. This test is not performed directionally (lengthwise or width-wise) because the nature of this test is a through-fabric and not an along-fabric test. There are two versions of this test: a dry test and a wet test.

In the dry test, the hot plate produces heat but does not produce moisture. In the wet test, the hot plate produces heat, while at the same time emitting water from pores in the plate to maintain the moisture level of a pre-wetted membrane in order to simulate the sweating skin of a human.

The fabric is tested skin side down. The hot plate is meant to simulate the behaviour of human skin in both dry and wet conditions. A fan is placed at the top of an enclosed space to provide airflow to the surface of the fabric during testing. The hot plate produces heat, and the fan is used in order to adjust the temperature of the plate. The term 'guarded hot plate' is used because the hot plate is kept in an enclosed space to prevent air movement near the testing area from affecting the test. Another reason for this guard is to allow the airflow to be constant and unimpeded by the surrounding environment. This is important, as the airflow is an integral part of this test. An image of the KESF-TL-2C was presented on the previous page.

### Dry Test Using the KESF-TL-2C

The Dry test is performed first, and uses no moisture. The heater is turned on inside the hot plate and so is the fan at the top of the unit. The fan is adjusted so that the bare hot plate maintains a temperature of 35 degrees Celsius using 2.8–2.9 Watts (W) of power. The output of the KESF-TL-2C is exactly the wattage required to maintain the hot plate at this temperature when it is bare; therefore, not covered by a test sample of fabric. Thus, the power required to keep a bare plate at 35 degrees Celsius is higher than the wattage necessary to keep a fabric-covered plate at this temperature because the fabric will hold in some amount of this heat stopping it from escaping into the surrounding air. With this test the insulating capacity of the fabric can be ascertained. The measurement derived from the dry test is the thermal resistance value, represented by the symbol (clo). The origin of clo is that it was determined that 1 clo was the thermal resistance value of the typical men's business suit.

### Wet Test Using KESF-TL-2C

The wet test is very similar to the dry version with the exception of a pre-wetted membrane being placed over the top of the hot plate before the fabric is placed on the plate. This membrane is designed to hold moisture and to simulate wet skin at 35 degrees Celsius. The hot plate itself very slowly emits water from holes in the plate in order to maintain the moisture level of the membrane between tests. The water flow is turned off during the 5-minute tests and the moisture level is replenished between tests. This is done to simulate sweating skin, as sweating skin is a continual source of moisture. Due to the presence of moisture, the plate is inclined to cool quickly, again, like sweating skin, so the wattage required to maintain 35 degrees Celsius is much higher in the wet test than in the dry test. The required wattage is 9.4–9.8 W. The plate is returned to this condition between each test. Once the fabric insulates the plate then the wattage required to maintain the 35 degrees Celsius will decrease.

There are a few measurements derived from the wet test combined with the results from the dry test. One of these is the permeability index represented by the symbol (im). This index indicates the permeability of a fabric. This is the ability of the fabric to allow the passage of moisture and heat to pass through it. Permeability index is rated on a scale of 0–1. A permeability index of 0 denotes a fabric that is completely impermeable to the passage of moisture or heat through its surface. A permeability index of 1 would denote a fabric that is completely permeable, allowing the passage of moisture and heat through its surface. While it is impossible for a fabric to have a permeability index of 1; the higher the permeability index, the more suited a fabric is for athletic performance in a hot climate. This is because it will allow sweat and heat to move away from the skin's surface.

Another measurement that can be gained from combining the results of the wet and dry tests is the comfort limits. Comfort limits are represented by the symbol (q). There are three comfort limits: minimum (qmin), comfort (qcomf) and maximum (qmax). All three limits are measured in units (W/m<sup>2</sup>). Comfort limits can also be called Total Heat Loss (THL). Qmin is the total heat loss associated with a completely dry skin surface. Qcomf is the total heat loss associated condition in a resting state. Qmax is the total heat loss the skin experiences with 100% skin moisture. This is designed to reflect the skin when the body is in a period of extremely high activity or in a stressed state.

The figures obtained from the KESF-TL-2C testing of fabrics are usually compared with figures obtained from another test called the 'sweating manikin'. The results from these two tests are compared in order to determine how the same fabric behaves in a garment configuration on the body of a manikin.

### **Cooling Ability/Breathability Test Using the KESF-TL-2D Large Hot Plate**

The heat and moisture transfer properties determined using this method of testing are calculated from measurements of thermal transport or made with the large skin model hot plate instrumentation. As stated in the National Fire Protection Association's (NFPA's) 1971 Standard on 'Protective Ensemble for Structural Fire Fighting', measurements are made based on the requirements of the American Society for Testing of Materials (ASTM's) F1868 'Standard Test Method for Thermal and Evaporative Resistance of Clothing Materials Using a Sweating Hot Plate', Part C.



The front view of the KESF-TL-2D Large Hot Plate equipment.



The Cooling Ability/Breathability Test using the KESF-TL-2D Large Hot Plate

The purpose of this instrument is very similar to the small plate. The thermal and evaporative resistance of large fabric sample is determined and the THL parameter is reported. This parameter denotes the amount of heat that can be transferred from the large plate (simulant of the skin) through the fabric to the outside environment.

Firstly, heat transfer is measured. It is the measurement of heat flow from the calibrated test plate (heated to a skin surface temperature of 35 degrees Celsius) through the test material and into the test environment (25 degrees Celsius, 65% RH). Heat transfer is determined for both simulated dry and wet skin conditions. Then, THL (watts/m<sup>2</sup>) can be determined. THL is an indicator of the heat transferred through the fabric.

THL, measured at a 100% wet skin condition, indicates the highest predicted metabolic activity level that a wearer may sustain and still maintain body thermal comfort while in a highly active or stressed state in the test environment.

### **Absorbency Laboratory**

At the Absorbency Laboratory Konopov observed a system that is used to evaluate the moisture management properties of fabric.

**The Gravimetric Absorbency Testing System (GATS)**

The Gravimetric Absorbency Testing System (GATS) is used at NCSU to analyse the transport mechanism of moisture and how it relates to fibre type, yarn and fabric finish. This provides the important engineering information necessary to design improved materials. The transport of moisture and the ability of fabrics to remove moisture from the skin is often the key to comfortable clothing. For products such as nappies, sanitary hygiene products, sponges and wipes, the ability to rapidly absorb and hold large amounts of fluid is important and this testing becomes crucial.

While the KES tests are concerned with the ability of the fabric to move heat and moisture away from the skin, the GATS is solely concerned with the moisture management properties of the fabric. There are five replications performed in this test. The test is non-directional as it is concerned with the passage of moisture from the skin side through to the face side of the fabric. The skin side is placed down onto the testing surface to simulate it being next to sweating skin. The size of the fabric sample used in this test is a circular dye-cut sample 3.5 " in diameter. It is also important to note that this test is performed in a controlled environment of 21 degrees Celsius and at 65% RH. There is no heat generated in this test, only the constant supply of moisture from which the fabric can pull water.

The test apparatus consists of a scale, accurate to 0.000 grams, on top of which sits a reservoir. In this reservoir is iodised water. A tube runs from this reservoir to the bottom of a platform. In a circular aperture in this platform sits a perforated glass plate.



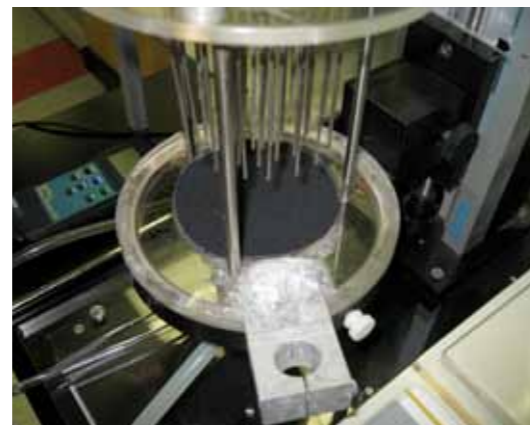
The glass plate has been aerated and has a great number of tiny holes, similar to foam. The aerated nature of this glass allows water to be drawn up, via capillary action, from the bottom to the top of the plate.

The water supply remains constant as the plate is at a lower level than the reservoir, meaning that the water flow is driven by gravity. This, however, is not what the term gravimetric means. Gravimetric means pertaining to measurement by weight, and is used because the water evaporation and absorption is measured by the weight change in the reservoir. This reservoir can be seen in the images presented here.

The Gravimetric Absorbency Testing System apparatus



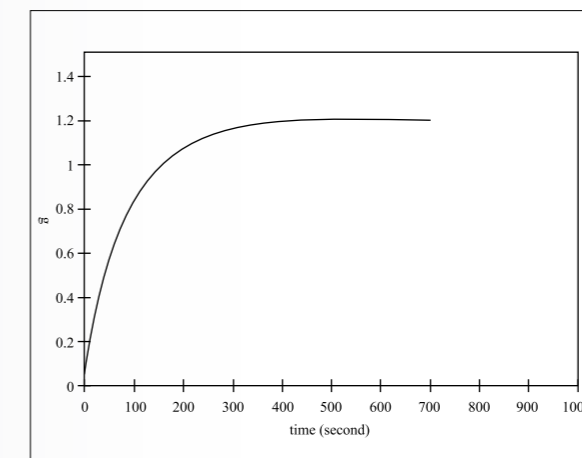
Lifting the glass plate for the insertion of the fabric sample



The fabric sample in the apparatus ready to be tested

The term used in conjunction with the GATS test is 'demand wettability'. This refers to the steady supply of water that is available to the fabric via the perforated glass plate. With a constant and monitored supply of water in place it is possible to measure the wicking ability of the fabric as well as the water absorption of the fabric. There is a 1.5 m/s airflow applied to the specimen test plate during the test, which lasts for 1000 seconds or a little over 16-and-a-half minutes. This allows evaporation to take place more readily.

There are many measurements provided by the GATS test but the only measurement that changes during the test is the weight of the fabric. The specimen weight is measured and recorded both when it is dry and after the test when it is fully saturated. From these two numbers an important measurement that can be gathered is the Capacity, represented by the symbol (C), of the fabric. Capacity here refers to the amount of water in units of grams that the fabric sample could hold. Capacity is calculated by subtracting the dry sample weight from the wet sample weight, leaving only the water weight absorbed by the sample.



A typical graph of the amount of liquid absorbed against time

In the graph, the area before the slope changes represents the graphical depiction of capacity. The weight in water evacuated from the reservoir by the fabric is graphed in real time as the test progresses.

The first portion of the test has a rapid incline in water evacuated due to the absorption of the water into the sample. After the sample has become saturated the line flattens out to a much shallower incline as the rest of the water evacuation is due solely to evaporation.

These two phases of water evacuation on the graph intersect, and at the point of intersection is where the measurement of time is recorded.

Time is represented by the symbol (T). This is the measurement of the time at which the two segments of the graph intersect, or the time at which the fabric stops absorbing and evaporation becomes the primary means of fluid evacuation.

**Garment Comfort Laboratory**

The Garment Comfort Laboratory contains facilities for the full-scale evaluation of the comfort test garments. Two types of garment comfort studies are conducted: controlled wear trials (subjective), using human evaluations of comfort response to clothing; and manikin trials (objective), using an instrumented manikin to provide measurements of thermal comfort and heat stress. Full-scale clothing comfort studies use an environmentally controlled chamber designed to permit realistic simulations of climates ranging from subfreezing to hot and humid.

**Controlled Wear Trials**

The subjective garment evaluation study is based on the approach developed by Norman Hollies at the Gillette Institute. This wear trial approach gathers human responses to test items while participants follow a schedule of specific activities. A customised test protocol is developed to include periods of physical activity alternating with periods of rest in both moderate and mildly warm climatic conditions. Prior to donning the test ensemble and beginning a test session, there is a preconditioning period where evaluators sit quietly upon arrival for 15 minutes to come into a relaxed state. An important part of the activity routine is the exercise period that makes the participants sweat.

The test garments are randomly assigned to evaluators so that different types are worn in each test session. This practice ensures that independent ratings are obtained. Additionally, evaluators are instructed not to discuss the test garments or their ratings. A customised evaluation form is designed to obtain ratings of comfort sensory, and tactile properties for each of the periods outlined in the protocol. Customarily, the first three items on the evaluation form require evaluators to rate overall comfort, warm/cool feeling of the garment on the skin, and the softness of the material. Normally, rating values of these items, as they appear on the evaluation form, range from 0–7. Seven represents the most comfortable, coolest and softest garment.

Descriptive terms are selected to be representative of the fabric properties that are most relevant for the test garment application. The descriptors are stated negatively because individuals are better able to discern degrees of tactile unpleasantness than degrees of tactile pleasantness. Values of 1–5 are assigned in these ratings with one meaning 'totally unpleasant' and five meaning 'no sensation' (do not sense any negative quality). Higher values denote a more desirable quality.

Evaluators, typically 30–40 participants, are used in a study depending on whether the study is for males or females or a combination of both. Evaluators are obtained from the NCSU, T-PACC subject pool that includes persons, primarily students, who through a screening process are determined to be healthy, non-smoking individuals between 18 and 35 years of age. Experienced evaluators who have participated in previous studies are considered first. All evaluators receive an initial orientation regarding the requirements of being a wear trial participant.

### Manikin Trials

The objective garment evaluation study involves a fully instrumented, life-sized, Advanced Sweating Thermal Manikin called Coppelius that is housed in the environmental chamber. Coppelius is one of only two 'sweating manikins' in the world and allows T-PACC to make objective, safe and precise predictions of human comfort response and heat stress under diverse climatic and work load conditions. Coppelius is used to assess heat loss through clothing, including the evaporative heat loss encountered due to sweating. Coppelius sweats through 187 individually controlled glands and the manikin's surface is divided into 34 separate sections, each of which has its own sweating, heating, and temperature measuring system. With the exception of a small portion of the face, the whole manikin surface can continuously sweat. Coppelius is used to study the cold weather insulation properties of garments, as well as to predict the contribution that clothing systems have on human heat stress. Simultaneous heat and moisture transport through the clothing system, and variations in these properties over different parts of the body can be quantified.



Front view of a Sweating Thermal Manikin

While fabric-level testing reveals many things about the comfort properties of the test samples, all of these tests are done with *flat* samples of fabric on *flat* surfaces. The garment-level testing phase allows specialists to take these results to the next level and utilise a manikin to test garments made of these same fabrics.

With a garment, there are air pockets and spaces that are between the test surface and the fabric, caused by draping; whereas, in fabric level testing the entire surface of the fabric is in complete contact with the surface of the test area.

Having the fabric in a garment configuration adds a new element. Manikin testing of garments helps to bring the quantitative measures of the fabric-testing stage one step closer to the qualitative evidence experienced by the athletes who use these products.



The NCSU's Advanced Sweating Thermal Manikin, Coppelius

Inside Coppelius an internal sweat control system distributes moisture to 'sweat glands' across the surface of the manikin. This preheated water comes from a reservoir outside the environmental chamber and is delivered to Coppelius via a pump. Water supplied to the simulated sweat glands is controlled by the operator and maintains the desired sweat rate for the manikin.

A software-controlled routine individually calibrates each sweat gland and the calibration values are used to maintain the sweat rate of each body section. Water emitted from each simulated sweat gland is absorbed by a custom-made body suit.

This specially designed suit acts as the manikin's 'skin' during sweating tests. It is form-fitted to the manikin to eliminate air gaps and provides a wicking action to evenly distribute moisture across the entire manikin's surface. This suit is made from non-woven material that absorbs the water from the sweat gland and distributes it across a larger area. On top of this non-woven material is a microporous membrane that acts as the skin's surface and allows the distributed moisture to penetrate to the exterior of the manikin.

The body of the manikin is designed to simulate a man who has a chest circumference under the arms of 40 ", waist size of 34.25 ", an inseam of 30.5 ", and a sleeve inseam of 20.75 ". Coppelius is also equipped with prosthetic joints in the elbows, hips, and knees. This aids in the process of being able to dress the manikin. Even though there are joints on this manikin all testing is done with the manikin in a stable and static condition. This means that the manikin cannot be used for motion testing.

A process control unit that uses analogue signal inputs from separate Resistance Temperature Detectors (RTDs) is used to enable the continuous temperature control of all the manikin's body segments. These evenly distributed RTDs are used instead of point sensors because they provide temperature measurements in such a manner that all areas are equally detected.

Distributed over an entire section, each RTD is embedded just below the manikin's surface and provides an average temperature for each section. The software establishes any discrepancy between temperature set point and the input signal, and adjusts power to the section heaters as needed. The temperature controls can be adjusted by the operator for each heater control.



A diagram illustrating the different sections of an Advanced Sweating Thermal Manikin

Two tests are performed with the Advanced Sweating Thermal Manikin: the dry manikin test and the wet manikin test.

In both testing instances, a computer generated graphic analysis of the tests is conducted to produce predictions of comfort.

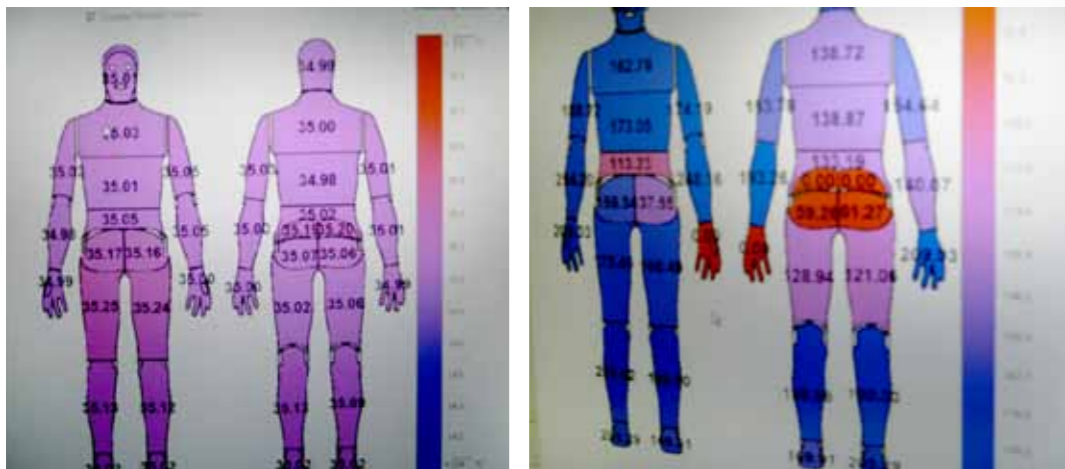
The heat resistance and evaporative resistance of the clothing systems could be calculated and then used to determine the amount of heat in Watts released into the atmosphere from the surface of the manikin, or THL.

## The International Experience

Konopov observed Kevin Ross while he was performing the Dry Manikin testing as detailed in the photos below.



These three images show the dressing of the Advanced Sweating Thermal Manikin in a garment ready for testing



These two diagrams illustrate the predicted thermal qualities of the undressed manikin

### NCSU: Protection Laboratories

The Protective capacity of textile materials is critical for many reasons, from the need to protect firefighters from heat and flame, and from protection from potentially toxic chemicals to the need to protect medical personnel from the threat of bloodborne pathogens.

#### Thermal Protection Laboratory

T-PACC at NCSU has constructed an 11-foot x 18-foot fire resistant room to hold PyroMan—the hottest man in the world. The PyroMan Thermal Protective Clothing Analysis System is a fully instrumented, life-sized manikin capable of providing measurements for evaluating the performance of thermal protective clothing. The PyroMan system has 122 individual heat sensors placed throughout the manikin's body.

The potential tissue burn damage to the garment wearer is predicted by the manikin's exposure to a realistic simulation of a flash fire condition. PyroMan is one of only a few manikins of this type in the world, and the only one of its kind in a university research setting in the United States.

## The International Experience

This is a highly sophisticated facility that features computerised, animated analysis of the response of the manikin's heat sensors, when exposed to testing, to enable the study of the garment and body reactions to intense heat and flames. The PyroMan Thermal Protective Clothing Analysis System consists of a number of components, designed to work together to measure the performance of protective clothing under full-scale, flash fire exposure conditions.

The PyroMan manikin is designed to simulate a size 40 regular male. PyroMan is made from a flame resistant polyester resin reinforced with fibreglass. There are sockets for 122 heat sensors that are uniformly distributed on the surface of the entire manikin body. Leads from each sensor are taken to the data acquisition unit through a guarded, heat-shielded cable. The manikin is suspended from the ceiling of the burn chamber on an adjustable fixture.

The computer system controls the test procedure, acquires the data from the instrumented manikin, calculates the results and produces a report of the test. The test sequence includes dressing the manikin in the test garment, interacting with the computer to ensure safe conditions, lighting the pilot flames, exposing the garment to the flash fire, acquiring the data, and running the fans to vent the chamber. The data acquired by the system is used to calculate the incident heat flux and predicted burn injury for each sensor during and after the exposure.

The most important requirements of the flash fire system are safe operation and reproducibility. Eight industrial burners, which have been modified, are carefully positioned to create a large volume of flash fire that fully engulfs the manikin. Each burner has a pilot flame that is tested before the gas is supplied to the torch. The gas control panel monitors the state of each pilot flame and prevents opening of the exposure torch valve if there is no pilot flame present. This feature provides both safety and control over the position and number of torches used in each test. The gas control panel also monitors the condition of the gas supply line and safety devices, and will shut the system down and vent the gas in the supply line in the case of a malfunction.

The criterion for protective performance is the ability to reduce heat transfer to the manikin. This is reported as predicted burn injury. The calculated incident heat flux is used to determine the temperature of human tissue at two levels below the surface of the skin, one representing second degree burn injury and the other representing third degree burn injury.



Typical garment assembly worn by firefighters



The T-PACC poster showing the different stages of thermal protection testing



## The International Experience



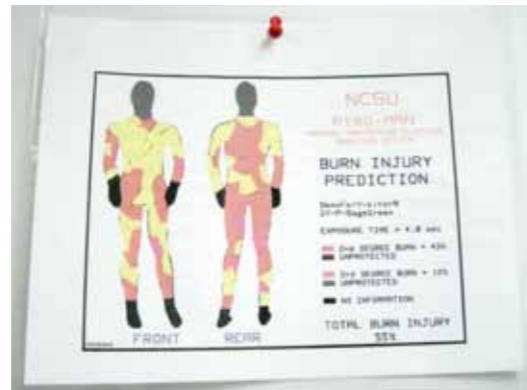
The T-PACC member of staff dressed in the typical protective garments of a firefighter ready for the test



The T-PACC poster showing the thermal protection testing process



The T-PACC member of staff dressed in the typical protective garments of a firefighter inside the testing chamber



The T-PACC poster showing the different degrees of burn injury prediction

While at the protection laboratory Konopov was permitted to observe and photograph the test specifically arranged for the USA Army and performed by John Morton-Aslanis, a highly experienced member of the T-PACC.



The US Army's garment assembly that was supplied for testing



Preparation of the chamber for testing

## The International Experience



T-PACC staff member displaying the tested garment to the US Army representative

It has also to be mentioned that Konopov and Professor Roger Barker discussed during their meeting the current research project that researchers at NCSU are conducting to redesign the traditional firefighters glove to provide fire protection with less bulk and greater hand dexterity.

The Fellow found it was interesting to discover that one of the biggest complaints firefighters had regarding their job was about their gloves. While the current gloves are designed to provide protection against extreme temperatures, they are often bulky and inflexible.

"Firefighters frequently say that bulky gloves impede their ability to pick up things and turn knobs—which can be critical in emergency situations...There have been improvements in fabrics over the years. What we need now are advances in the functional design of the glove itself, to go along with the advances in glove materials." —Professor Roger Barker

This topic is particularly crucial for Australia due to our unique climatic conditions and our devastating, continually occurring bushfires. Professor Barker and his team at NCSU have already begun their research by speaking with firefighters to discuss what they need and want in a glove. Based on their feedback, the researchers have tested a variety of textile materials for thermal protection, grip, breathability, insulation and flexibility—among other characteristics—and will design prototypes of the next generation of firefighter's gloves.

The testing of the gloves will be conducted on T-PACC's state-of-the-art PyroHands Fire Test System—a life-sized hand manikin made from a flame resistant composite that provides a realistic simulation of a human hand's response to intense heat exposure.

PyroHands, which was developed with a grant from the USA Department of Defence, has 21 sensors—20 in the palm, back of the hand and wrist; and one in the middle finger—that provide valuable data about the level of heat exposure and the predicted burns as result of a fire. PyroHands is an extension of NCSU's PyroMan.



The PyroHands Fire Test System used to test protective glove prototypes



The burns sustained by the PyroHands Fire Test System after the test has been conducted

*“By using PyroHands to test glove prototypes, we will be able to measure the distribution of fire protective insulation over the surface of the hands. This should help us develop improved glove designs by showing the locations on the glove where thickness and bulk might be reduced without compromising thermal protective performance.”* —Professor Roger Barker

This project is the latest of several grants NCSU has received to support research that benefits the firefighting industry. In 2003, Professor Barker and the team received a grant from the USA Department of Homeland Security to develop a prototype of new firefighter turnout gear that offered increased protection against heat, chemical and biological agents, while also improving comfort and durability. Earlier in 2009, Professor Barker’s team received grants from the National Institute for Occupational Safety and Health (NIOSH) and the National Fire Protection Association’s (NFPA’s) to develop a testing apparatus and measurement protocols that allow firefighter suits to be evaluated for their ability to prevent stored heat burns.

### Barrier Fabrics Laboratory

The Barrier Fabrics Laboratory has innovative equipment for research in the following areas:

- Biological hazards: medical pathogenic barrier.
- Chemical hazards: penetration and permeation of potentially toxic chemical liquids and gases.
- Aerosol and particulate hazards: filtration and transmission of particulates and aerosols.

Whilst at NCSU, Konopov found that the T-PACC laboratory’s US\$21 million facility is the only academic centre in the USA with manikin capabilities for comfort, thermal, and chemical testing, and with a state-of-the-art Man-In-Simulant test laboratory. Used in conjunction for research, PyroMan and Coppelius provide an unparalleled capacity to generate information used for developing materials and garments with superior comfort or reduced heat stress, while maintaining the essential ability to protect against hazardous thermal exposures.

As part of NCSU’s College of Textiles, T-PACC benefits from the involvement of NCSU’s highly skilled professional and technical personnel, as well highly motivated students. Faculty from the College of Textiles and other colleges at NCSU participate in long- and short-term research projects. The collaboration between T-PACC laboratories and the aforementioned NCSU faculties is appreciated by all the parties involved. Together these parties represent a multitude of expertise in the various areas of textiles, material science, and engineering, as well as the experience required for the measurement and analysis of textile comfort and protection. Recently, an international team of scientists has been assembled at NCSU to supplement the existing skills in specialised areas of comfort and protection. In addition, the staff members support the research of graduate students pursuing Master’s degrees, and PhD projects in the area of textiles protection and comfort.

Konopov spent time with Professor Barker discussing possible future cooperation between NCSU’s College of Textiles, T-PACC and the School of Fashion and Textiles at RMIT University. She was subsequently introduced to Dr Nancy Cassill, Professor and Department Head, Textile and Apparel Technology Faculty. She was then taken to visit different schools within the College of Textiles. Dr Cassill spent time with Konopov, acquainting her with the facilities, introducing her to staff members and discussing the content of their programs. The possibility of student exchange and joint research were discussed at length.

The university runs programs in Fashion and Textile Management, Textile Technology, Polymer and Colour Chemistry, and Textile Engineering, along with four Master’s degrees and two Doctoral degrees. With the College of Design, NCSU offers a dual degree (BA and BS) in Art and Design, and Textile Technology. An in-depth knowledge in medical textiles is offered in the Textile Technology degree and it is the only known program of its type in the nation.

The Polymer and Colour Chemistry degree also offers a component in medical sciences. Graduate students accepted into the Institute of Textile Technology Fellows Program will earn a Master of Science degree in two years and will experience unique educational opportunities. Textile Online Programs (TOP), the oldest distance education program on campus, offers over 50 courses for online education. All programs include excursions and work experience in the industry and the staff members have very good links with the textile companies in USA. Due to these links students are able to see the industry up close and experience opportunities otherwise not available to them.

Approximately 958 undergraduate students and 158 graduate students are currently enrolled in NCSU’s College of Textiles programs. The College of Textiles is educating the most students in its history. Since 1949, over 500 students have earned their Master of Science in Textile Technology from the Institute of Textile Technology (ITT), which has been housed at the college since 2003. The largest college-based scholarship program exists at NCSU with approximately 25% of incoming freshmen receiving scholarships. Each year, up to 10 new students receive the prestigious Centennial Scholarship valued at US\$45,500. Starting salaries for College of Textiles graduates range from US\$24,000 to US\$80,000 with the average at US\$44,465. The college visits between 150–200 schools in over 50 different North Carolina counties each year, seeing approximately 10,000 high school students.

For 2008–2009, sponsored research expenditures were more than US\$5.5 million and were made possible through grants and contracts from federal, state, and private agencies. The TexLabs complex houses six processing, testing and service laboratories equipped with state-of-the-art equipment. During 2008–2009, the labs supported 2,544 hours of undergraduate class support, 1,535 hours of graduate research and 3,936 hours of industry support for a total of 8,015 hours of service. The Institute of Textile Technology, founded in 1944, provides industry-driven applied research, collaboration, and innovative product development through the ITT/NCSU Textile and Material Research Consortium.

In 2008–2009 the faculty submitted 25 invention disclosures and received four patents. The College of Textiles is responsible for 19% of all invention disclosures and 7% of all patents issued for NCSU in 2008–2009.<sup>25</sup>

### Destination: [TC]<sup>2</sup>

#### The Textile/Clothing Technology Corporation, Cary, North Carolina, USA

**Contact:** Dr David Bruner, Vice President of Technology Development

Based in Cary, North Carolina, this apparel technology research and education organisation is funded by the United States Department of Commerce and by private firms in the soft goods industry. [TC]<sup>2</sup> provides a range of solutions for the global soft goods industry specialising in technology development and supply chain improvement. Its initiatives include the broad investigation and demonstration of advanced technologies, and education, training and consulting for brands, retailers, manufacturers, and suppliers.

[TC]<sup>2</sup> is well known for its ability to strategically and tactically align business practices; implement three dimensional (3D) body scanning and related fit/shape analysis methodologies; and help companies streamline operations to reduce unproductive activities and processes. Konopov met with, Dr David Bruner, who provided an overview of [TC]<sup>2</sup> and gave a PowerPoint presentation on ‘Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements – The [TC]<sup>2</sup> Avatar Engine’ and [TC]<sup>2</sup>’s new ‘Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences’. See Attachments 1 and 2.

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<sup>25</sup> *By the numbers*, January 2010, NCSU

## The International Experience

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Konopov was given the opportunity for an individual 3D scan. As the relationship between the body and clothing is complex and often unclear, garment fit is a difficult concept to research and analyse. Yet, the garment fit and the amount of pressure a garment places on a specific body part plays a crucial role when performance garments are developed. Current objective methods of analysing garment fit involve comparing the garment measurements to the body measurements using linear measurements and utilising pressure gauges to measure the amount of pressure a garment places on a specific body location.



The [TC]² body scanner

Although these traditional and other manual methods are useful for evaluating simple garment fit issues, they are not adequate to investigate the complexities of the multifaceted relationship that exists between the body and clothing. Both provide only limited information about the human body shape and proportion. On the other hand, the body scanner has the ability to obtain 3D data of the surface of the human body, providing valuable information to improve garment fit.

Body scanning technology collects data that can be analysed using non-linear measures such as surface area, volume, or data from body slices that may be better able to comprehensively analyse the human body and address problems with garment fit.

Dr Bruner also presented the data that could be applied for the purpose of pattern development, with examples of grading applications according to SizeUSA size definitions. A photograph of the 3D scanner is presented above.

Konopov also attended a seminar '3D Scanning Application — Is that What You Really Look Like'. The seminar provided a hands-on experience and gave an understanding of how 3D models created from scanned data can be utilised by the end user, the apparel designer and merchandising professional. It was presented with the appropriate retail software so that consumers can see how clothing will look on their accurately portrayed virtual bodies, or to track their progression in body shaping. Konopov was shown how the underlying survey data could be utilised by brand owners to create a specific fit and size range for their target market. The seminar finished with a discussion and examples of creating models and avatars to be used in convincing simulations.

Konopov spent time talking to Dr Bruner about the possibility of using the 3D scanner for educational purposes and was advised that NCSU's College of Textiles has been successfully using the 3D scanner in various teaching programs in which subjects such as patternmaking, grading and costing engineering are delivered.

# Knowledge Transfer: Applying the Outcomes

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It is crucial that knowledge transfer occurs. It is envisaged that this knowledge be imparted via a series of industry seminars and workshops demonstrating 3D body scanning and applications, by individual knowledge transfer, such as teaching activities to students groups and training activities delivered to work colleagues.

The opportunity to undertake this study has provided insights and knowledge into the value of developing advanced skills in the accurate testing, assessment and evaluation of the comfort and protective effects of advance textiles and assemblies.

Following Konopov's findings and visit to NCSU and [TC]² the following has been achieved:

- RMIT has purchased a new updated version of the KES-FB4-AUTO-A Automatic Surface Tester from KATO TECH CO., LTD. The instrument was installed at RMIT's new sustainability laboratory in February 2010. Appropriate members of the staff were trained during a two-day training session by an experienced Japanese technician. To ensure that the knowledge is transferred, an introductory one-day workshop for Master and PhD students was offered in March 2010.

The purpose of this Worksop was to:

- Familiarise current postgraduate students with the new technology available.
- Provide training and hands-on experience on the surface tester (KESF4-A)
- Explaining the automatic measurement system, data processes and calibration procedures.
- Explaining how the data received is recorded and interpreted.

It is also planned that RMIT will offer a two-day workshop to the mentoring staff, testing laboratory staff and industry members towards the end of 2010.

- Sweating manikin 'Newton' was purchased by RMIT University. The installation of the new state-of-the-art apparatus took place on 15 February 2010. A technician from Measurement Technology North West, USA, conducted staff member training with subsequent online training sessions to follow.
- A two-day training session plan was developed and the training was conducted to 'transfer' the knowledge to current Master and PhD students. It is planned to use the facility extensively to assist in current research conducted at RMIT University in the area of Performance and Sports Apparel Textiles. This cluster covers research into the interface between human body and the designed objects and environments they interact with, and into the diverse emerging materials and technology relevant to performance apparel and apparel assemblies.

RMIT Master and PhD students are currently using the latest machinery in their research and studies. Companies such as Bruck Textiles Pty Ltd and Therapist Support Laboratories Pty Ltd have already expressed their interest in participating in workshops and attending short course programs.

- [TC]² Body Scanner was purchased and installed at RMIT University on 22 of March, 2010. Appropriate members of the staff were trained during a two-day training session. The topics included:
  - Representation of the human body through 3D body scanning/measurements.
  - Customising measurements.
  - Overview on applications of 3D technology: body shape analysis, automatic size extraction, and database manipulation.
  - Developing a creative model (an avatar) for enabling 'true to life' 3D visualisation and design of garments and materials.

It is also planned that RMIT will conduct industry training workshops titled 'Is that what you really look like?' targeted to Technical Designers/Product Developers—anyone interested in sizing research and optimising fit to build brand loyalty. Marketing and Apparel managers and anyone interested in incorporating 3D data, for style simulation and fit recommendation, into their marketing

- Dr Christy Cagle (Director of International Programs at NCSU) visited RMIT University in April 2010, with the main purpose of organising student and staff exchange opportunities within undergraduate programs and to seek any research collaboration possibilities. As a result of this visit a 'Student Exchange Agreement' was signed by both parties.

*"The intent of this agreement is to initially develop stronger links between RMIT School of Fashion and Textiles and NC State College of Textiles through student exchange. From this beginning it is intended to further develop the relationship to for staff exchange and research collaborations. NC State is a leader in Textile Education and research. Developing a relationship with NC State will allow the school to develop international linkages facilitating cultural exchanges, learning and teaching concepts and develop research collaboration. These objectives are consistent with the University priorities: Build a Global University and development of areas of excellence in research and scholarship",* said Keith Cowlishaw, Head of School (Fashion and Textiles, RMIT).

Following the Fellow's findings, the recommendations outlined below were suggested.

## Government

- Continue to maintain a high standard of fashion and textile training facilities and highly skilled trainers.
- Create accessible funding for industry and educational bodies to maintain world-class and leading practises.

## Industry

- The industry professionals to utilise the equipment/knowledge available for research and advances in their field.
- Utilise state-of-the-art unique testing and development equipment and make it as a unique resource available to industry for development and evaluation of innovative textile materials.
- Industry is to focus on professional development of their staff and utilise the highly skilled professional and technical personnel within RMIT.
- The industry is to use new equipment to enhance and develop products that perform highly in critical areas such as comfort and protection.
- To ensure that the Australian textile industry retains a world-class textile manufacturing capacity by bringing together manufacturers and researchers.

## Education and Training

- The Fellow to conduct series of intensive workshops focused on the introduction of the equipment currently available as well as testing techniques to trainers in educational institutes and industry.
- Trainers from educational institutes to then apply it to the teaching and learning programs.
- The Fellow to promote the unique facility now available at RMIT to local industry and internationally as a premier facility for research on textiles for protection and comfort.
- The Fellow to use the new equipment as the research and teaching tool to transfer the knowledge for students at TAFE, graduate and postgraduate level, and to apply this knowledge in designing new technologically advanced textiles.
- RMIT to design small intensive workshops delivered by their testing professionals to industry needs and customise the program accordingly.
- Source and maintain international network and leverage relationships for future collaborations on all levels. This has already been acted on to a certain extent by the 'Student Exchange program' where four students from RMIT have registered to study at NCSU for the first semester in 2011, and five students from NCSU will be studying at RMIT in 2011. This is also critical for ensuring educational programs are catering to industry needs both locally and internationally and are able to share knowledge with other institutes.
- Visiting NCSU and Textile Protection and Comfort Centre particularly showed the value of the new equipment as a research and teaching tool for textile students at all levels. It is recommended that appropriate testing techniques and procedures be taught in all textile related programs to assist students to gain a competitive advantage in today's global environment.
- Teaching staff are to be skilled in the appropriate procedures and techniques associated with the evaluation of the comfort and protective properties of textile materials. These are mostly available overseas.

## Recommendations

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- To maintain staff development in this niche, highly technological and sophisticated area of textiles, various international conferences on 'Performance Textiles' should be attended regularly. This will also give an opportunity to maximise networks and knowledge transfer.

### Community

The consumer should be made fully aware of the development and the evaluation of textiles is critical for applications such as compression garments for athletes and protective wear for factory workers in Australia. They should be encouraged to seek Australian made garments with confidence in their fellow citizen's professional expertise.

### International Specialised Skills Institute

- To continue to support bringing skills and knowledge to the Australian textile industry both locally and internationally.
- To continue to provide access to the textile industry networks (locally and internationally) and support to the industry by:
- Providing workshops to encourage and facilitate the importance of new, creative and forward thinking, as well as the importance of understanding new technologies and equipment in the highly competitive textile environment.
- Assist in establishing and maintaining networks on a local and international level.
- Be a source of encouragement for the professionals in the local textile industry to attend and/or participate/present research papers at international textile conferences and events.
- Through access to a wide range of industry networks, encourage collaboration between international textile professionals overseas and those in Australia.
- Continue to be a source of encouragement, assistance and funding for skills and knowledge development in the Australian textile sector.

## References

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- Barker, RL 2002, *From fabric hand to thermal comfort: The evolving role of objective measurements in explaining human comfort response to textiles*, International Journal of Clothing Science and Technology. (14), 181.
- Green, R 2008, *Building Innovative Capability: Review of the Australian Textile, Clothing and Footwear Industries*, Commonwealth of Australia 2008.
- ISS Institute 2009, *Discover ISS Institute*, International Specialised Skills Institute, Melbourne, Australia, 2009.
- TTNA 2009, *Media Release 923KC*, Technical Textile & Nonwoven Association 29 May, 2009.
- Harrocks, AR and Anand, SC 2000, *Handbook of Technical Textiles*, CRC Press, Cambridge, UK.
- MSA 2006, *The Australian Technical Textiles & Nonwovens Industry Profile*, prepared by: The Technical Textiles & Nonwoven Association, on behalf of Manufacturing Skills Australia, May 2006.
- <http://www.tx.ncsu.edu/tpacc>
- [http://www.tx.ncsu.edu/tpacc/comfort/bending\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/bending_test.html)
- [http://www.tx.ncsu.edu/tpacc/comfort/tensile\\_shear.html](http://www.tx.ncsu.edu/tpacc/comfort/tensile_shear.html)
- [http://www.tx.ncsu.edu/tpacc/comfort/compression\\_test.html](http://www.tx.ncsu.edu/tpacc/comfort/compression_test.html)
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- [http://www.tx.ncsu.edu/college/collegenews/textiles\\_by\\_the\\_numbers\\_1\\_10.pdf](http://www.tx.ncsu.edu/college/collegenews/textiles_by_the_numbers_1_10.pdf) (*By the numbers*, January 2010, NCSU)
- <http://www.tc2.com>

# Attachments

## Attachment 1

Utilizing SizeUSA Data with  
Principal Component Analysis  
to Create Lifelike Human Models from Few  
Input Measurements – The [TC]<sup>2</sup>  
Avatar Engine



Body Scanning enables the possibility of high quality Avatars that actually look like the consumer.

3D Avatar meshes are directly morphed to match 3D body scans.

The Avatar Engine is created from the statistical data of 1000's of body scan avatars



PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements – The [TC]<sup>2</sup> Avatar Engine'.

## Digital Humans (Avatars) from 3D body scans and the Avatar Engine

- Virtual Communities – Social Networks
- Private Environments – **personal Virtual Dressing/Virtual Fashion**, Virtual Fitness Assessment
- Entertainment Networks – multi-player gaming, content creation
- Business Networks
  - Online Conferences, speeches, interviews, product research

Industrial/Technical Applications –Ergonomics

- **Create Statistically valid human models based on spec measurements for which no exact 3D scan matches**

Allen, Curless, Popovic – Siggraph 2003  
University of Washington

The space of human body shapes:  
reconstruction and parameterization from range scans

Brett Allen Brian Curless Zoran Popović  
University of Washington

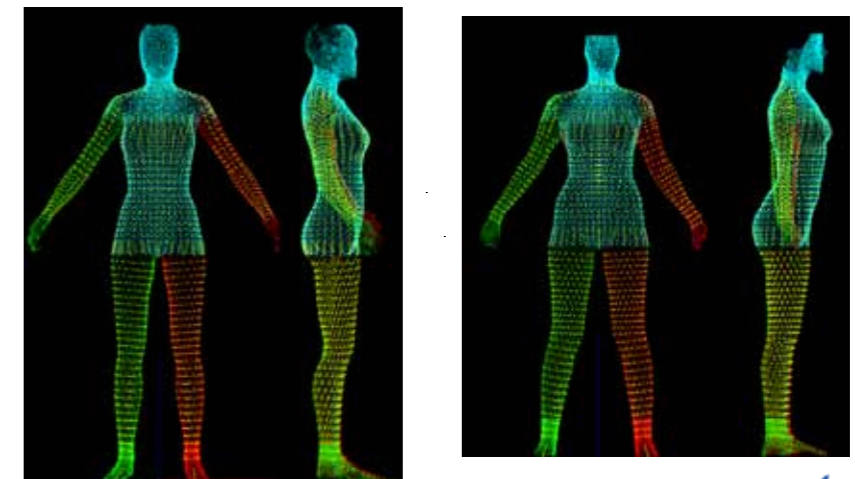


## Long time vs Real time

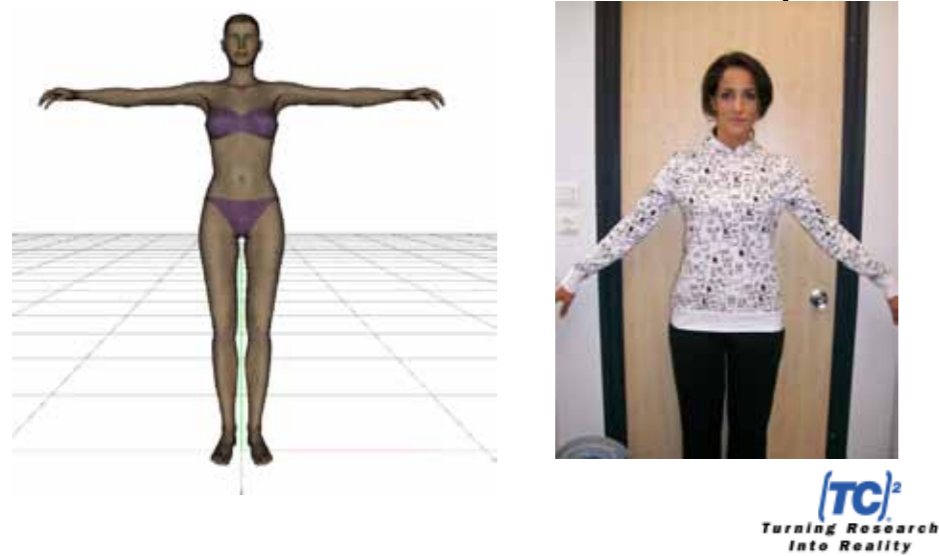
- Key Similarity – morphing a pre-existing template mesh to 3D scan data
- Key Difference – Allen uses sparse (70) manually placed landmark markers vs. [TC]² dense (3,000) automatically extracted markers
- Key Difference – Allen process takes >30 minutes - [TC]² takes 3 seconds



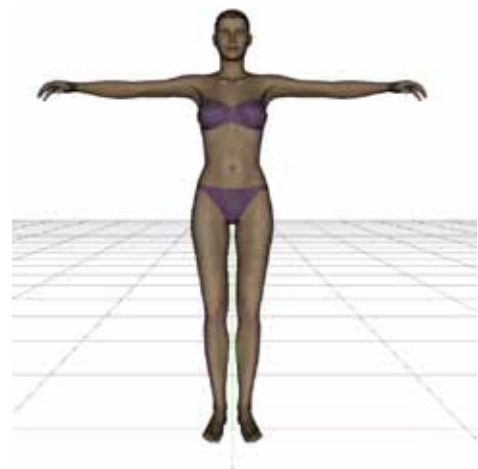
Basic idea – drag template mesh to the 3D scan geometry using a common distribution of dense landmarks as the guide



### Reference Mesh – Scan Subject



### Template Mesh



### Resulting Avatar



### Avatar Engine - Avatars can be created with key measurement inputs...

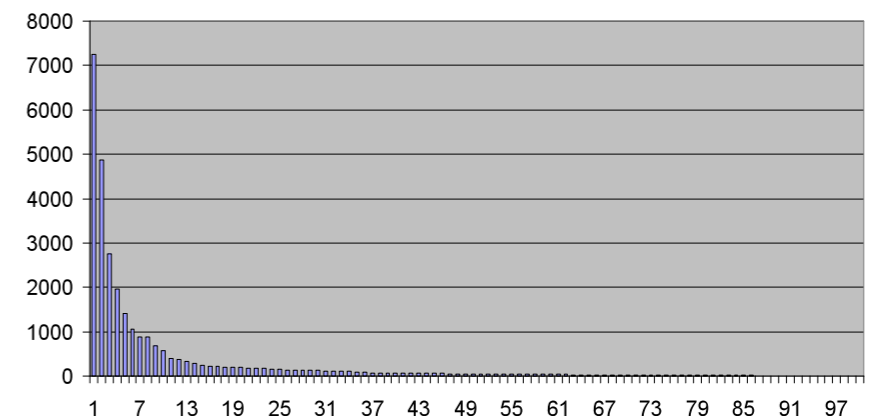
Based on statistical information derived from the SizeUSA database using Principal Component Analysis

Error Checking (against 3D scans) shows body measurement replication possible to ~1 cm (given accurate input measures)

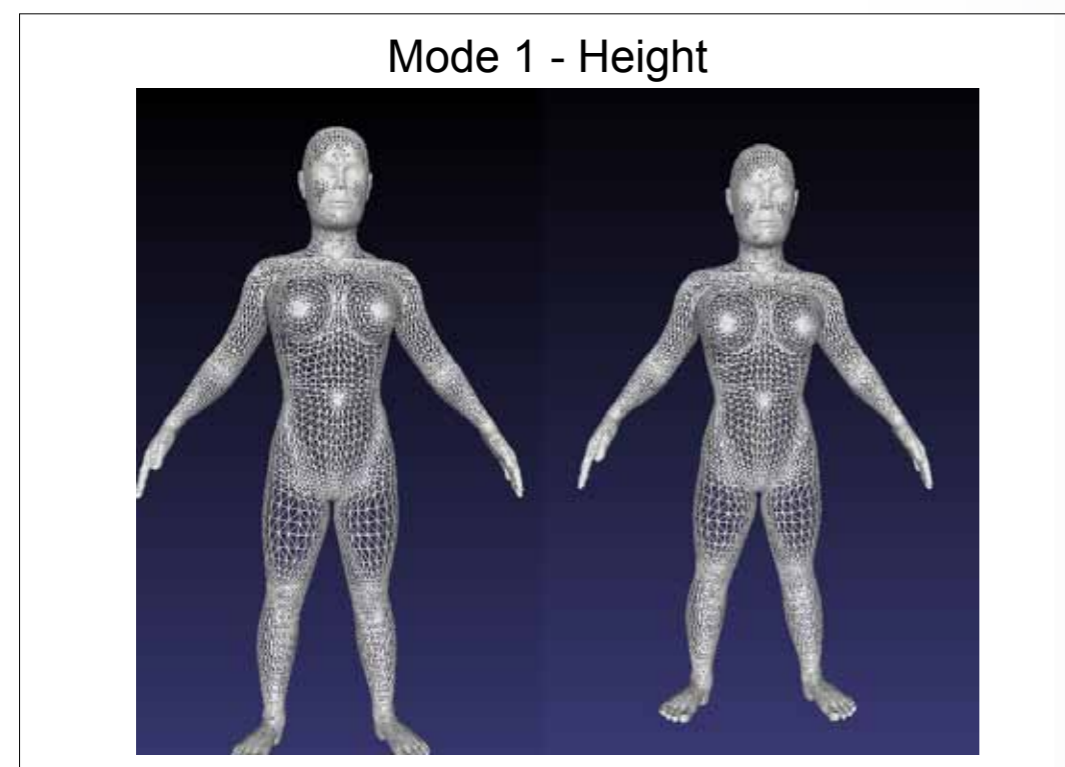
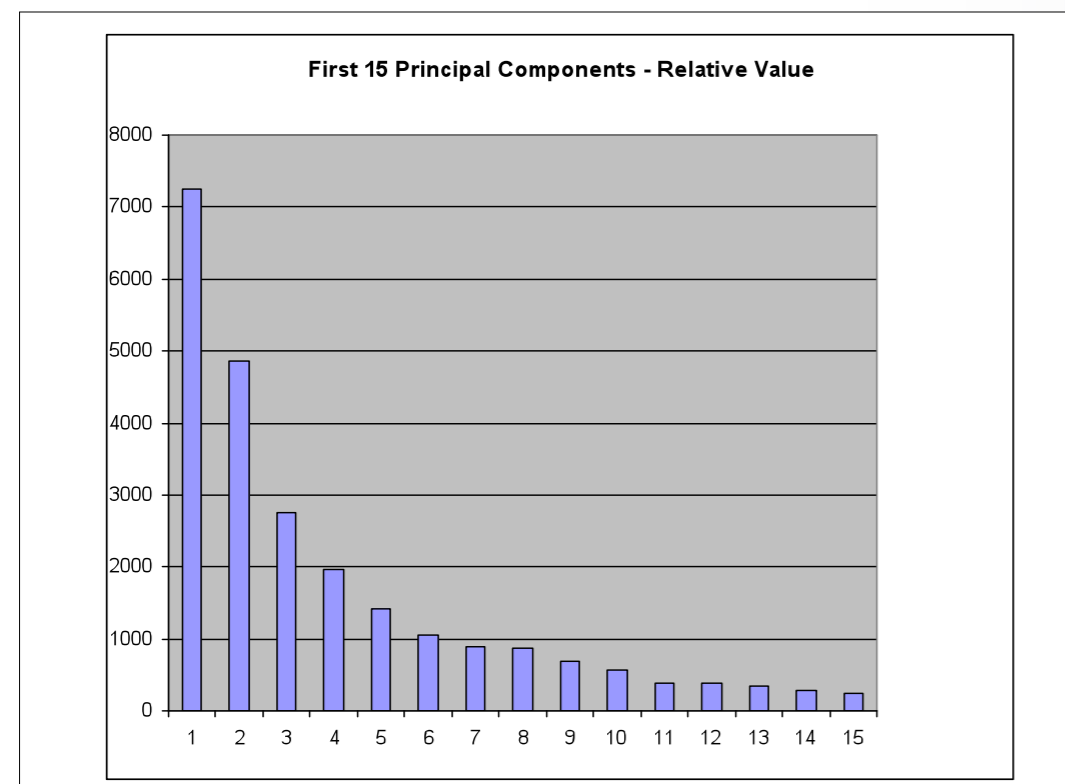
Only possible using hundreds of principal components and 1000+ body scan avatar inputs.



First 100 Principal Components Shapes - Relative Value







PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements - The [TC]<sup>2</sup> Avatar Engine'.

## Other Shapes

Mode 2 – height plus arm position

Mode 3 – Weight (Waist/Hip) Plus body Forward and back

.....shapes combining posture, proportion, and weight

Mode 9 – left/right unsymmetry

Mode 10 – Low Shoulder

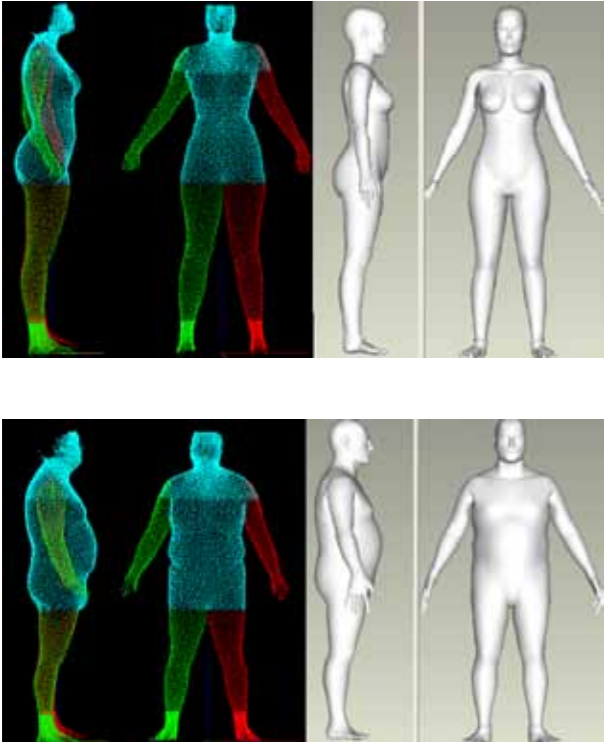
\*\* Some Eigenshapes relate to shapes typically analyzed for apparel fit – but some do not. Apparel fit must incorporate considerations not only of the body but also of the garment.

\*\* Postures and Body Proportions are represented roughly equally in the main shape modes

\*\* Shape and Weight are statistically integrated when analyzing the full range of the population

\*\*\*Interesting new work – if excess weight subjects are eliminated from consideration – are classical apparel based body shapes apparent in the PCA?

PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements - The [TC]<sup>2</sup> Avatar Engine'.



Sample Avatars from a dozen inputs  
(Using statistics from reference scan population)

**(TC)<sup>2</sup>**  
Turning Research Into Reality

### SizeUSA and The Avatar Engine

*More Human Models for Analysis than available anywhere*

- 10,800 Unique 3D body scans – statistical source for Avatar Engine
- Avatar Engine Based on 5 Basic Measures  
Height, Inseam, Bust, Waist, Hip


**Yields 3.2 million unique 3D Human Models for analysis with 1/2 inch increments!!!**

**(TC)<sup>2</sup>**  
Turning Research Into Reality

PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements – The [TC]<sup>2</sup> Avatar Engine'.

### Principal Components – Weight loss

realistically vary any key parameter



**(TC)<sup>2</sup>**  
Turning Research Into Reality

[www.imageTwin.com](http://www.imageTwin.com)



**My ImageTwin Weight Loss Simulation**

Enter your personal measurements to create a silhouette of your body shape. To visualize weight loss, select the goal amount of weight loss and click on "Show My Weight Loss!" A red silhouette will appear that represents the change in your body shape with the selected weight loss and a prediction of your new measurements at that weight will be shown.

Click here to order your free 3D avatar.

**Measurements** Provide measurements in inches. Click here for measurement instructions.

Height	31"	Weight	130	Gender	Woman
Bust	37.7	Before	34.1		
Waist	28.1	After	24.1		
Hips	40.7		32.1		
Inseam	31.5		23.5		
Full Underbust	30.2		28.7		
Right Thigh Girth	25		22.5		

(Select Your Shape)

Body Fat % Before: 23.4 Body Fat % After: 11.6

PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Utilizing SizeUSA Data with Principal Component Analysis to Create Lifelike Human Models from Few Input Measurements – The [TC]<sup>2</sup> Avatar Engine'.

## Coming Soon.....

- Virtual Fashion Avatar Engines
- 3D Humans For Everyone...



### Virtual Fashion Avatar Engines – for the web



From 3D body scan



From Measurements- Avatar Engine

## Human Avatars for All – Today



## Scan From Photo



Avatar Engine

*High Quality 3D Models at 1/10 the cost of 3D scanners*



Attachment 2

[TC]<sup>2</sup>'s new Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences

...and **Converting Scan Data to Alternate Poses** Enabling Expanded Data Analysis Options



Virtual Fashion by Garment Morphing...what is it?

- A 3D garment model is made in a traditional 3D garment creation system
- It is "referenced" by the [TC]<sup>2</sup> Software System
- And morphed to match the shape of the any scan subject in just seconds fully automatically.
- Enabling in-store or over the web virtual fashion.

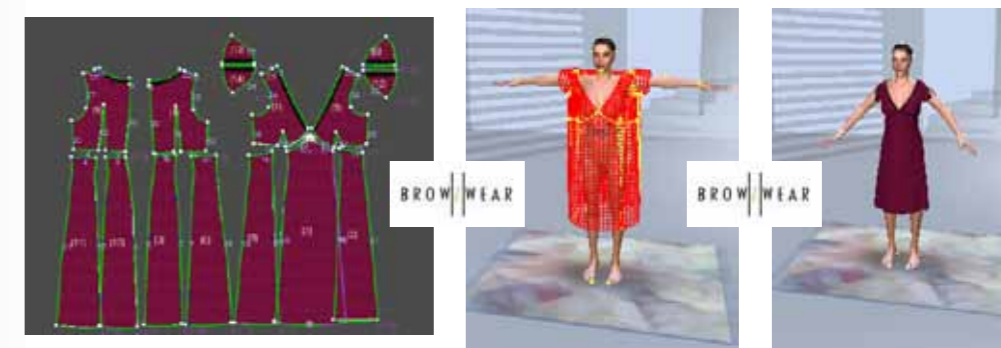


**Comparison**  
Garment Morphing vs Draping from Patterns

- Reference 3D Garment needs to be created only one time
- The garment/avatar morphing process takes only a few seconds
- The morphed garment has no relationship to the garment patterns sizes – only the color and style
- Generally, garment morphing is for consumer visualization, or when the visual must be available immediately

- Garment is re-draped each time the body model or garment pattern size selection changed, but directly references garment patterns
- Draping solutions may take many minutes or even hours
- Draping software is offered by CAD companies, some allow body scan body data import – others do not.
- Generally, pattern draping is for Product Development, or when immediate viewing is not critical

3D Garments by Simulated Draping



Import Garment Pattern Pieces, Define Textures, Fabric Properties, and Piece Connectivity → Place around body model, run drape simulation → Finished 3D Model of Garment



### [TC]<sup>2</sup> Garment Morphing

Start with 3D garment and reference mesh model already created – apply morphing instructions (difference from body scan and reference mesh) to create customer mesh with garment

Ingredients for Virtual Fashion

3D Clothing Draping And Models

Avatar Morphing Technology

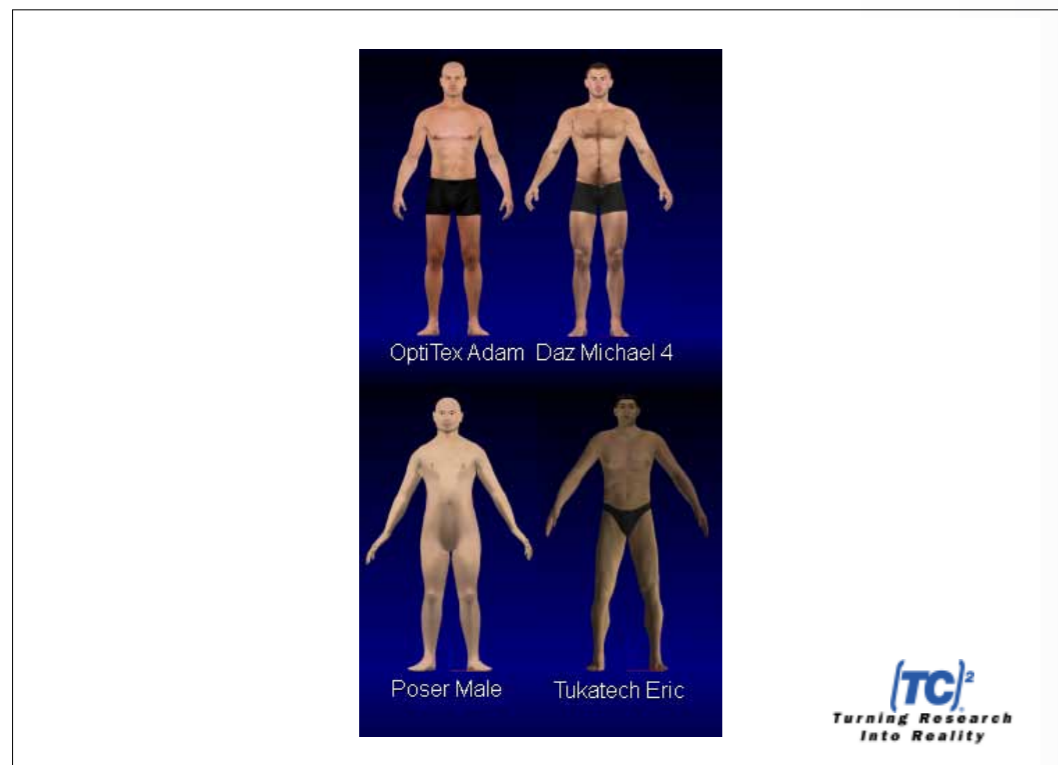
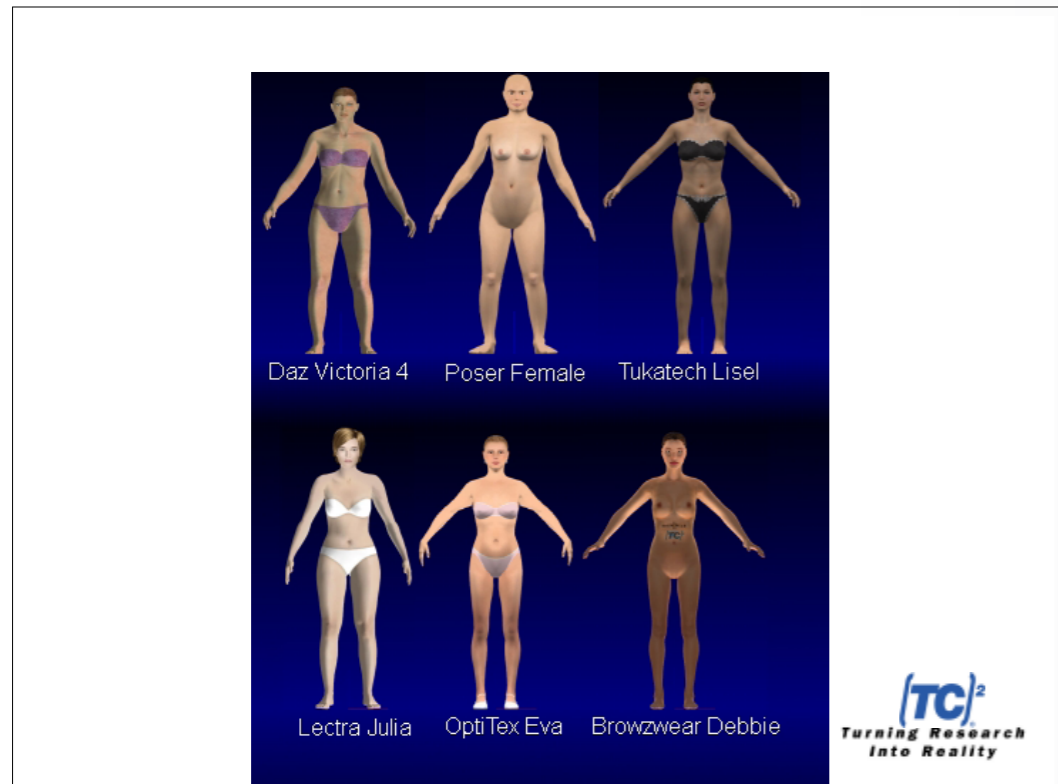
PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.

3D Body Model

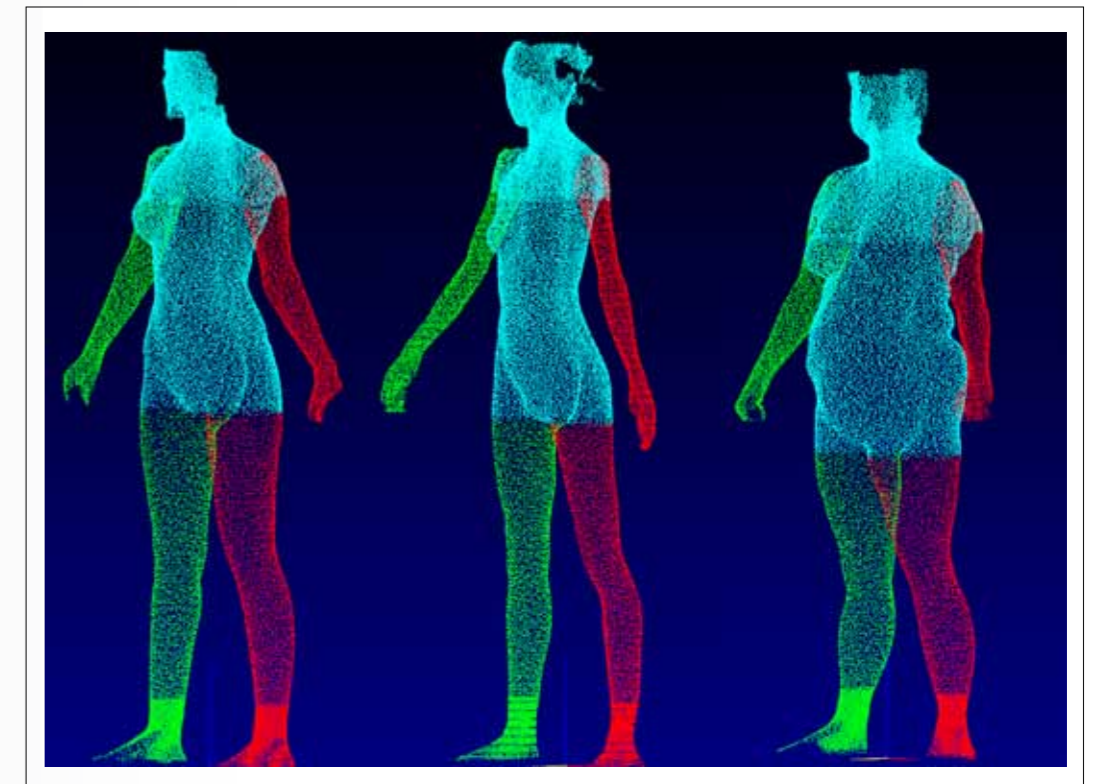
Full Avatar

Avatar Points

PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.



PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.



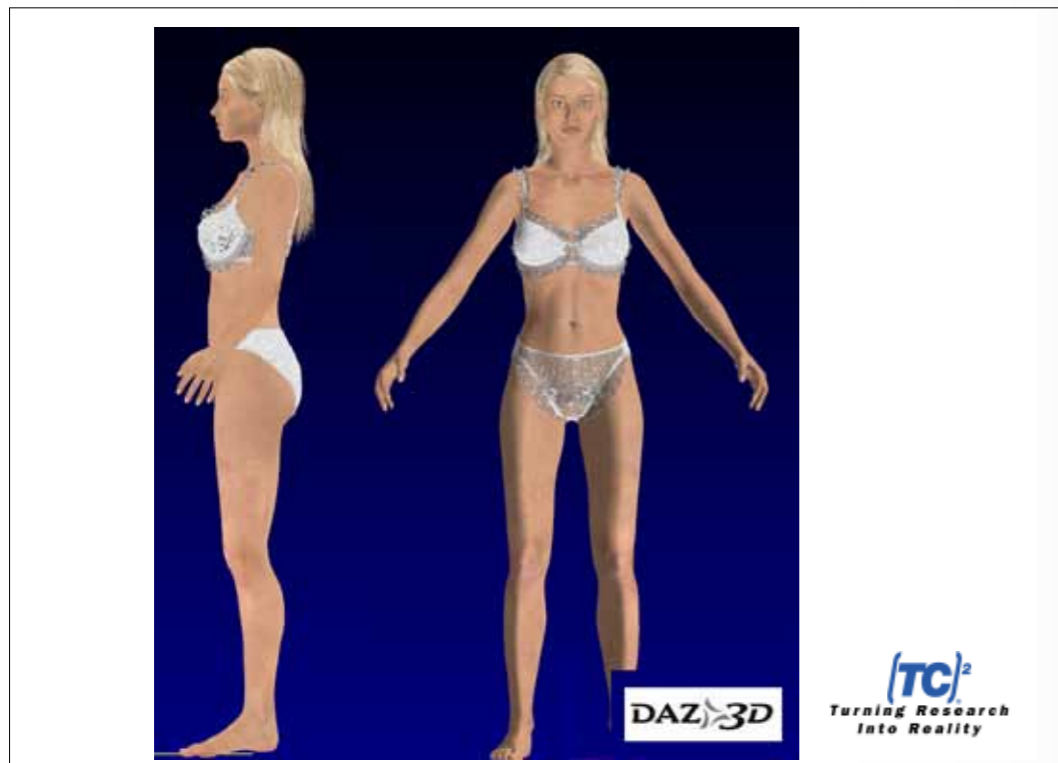
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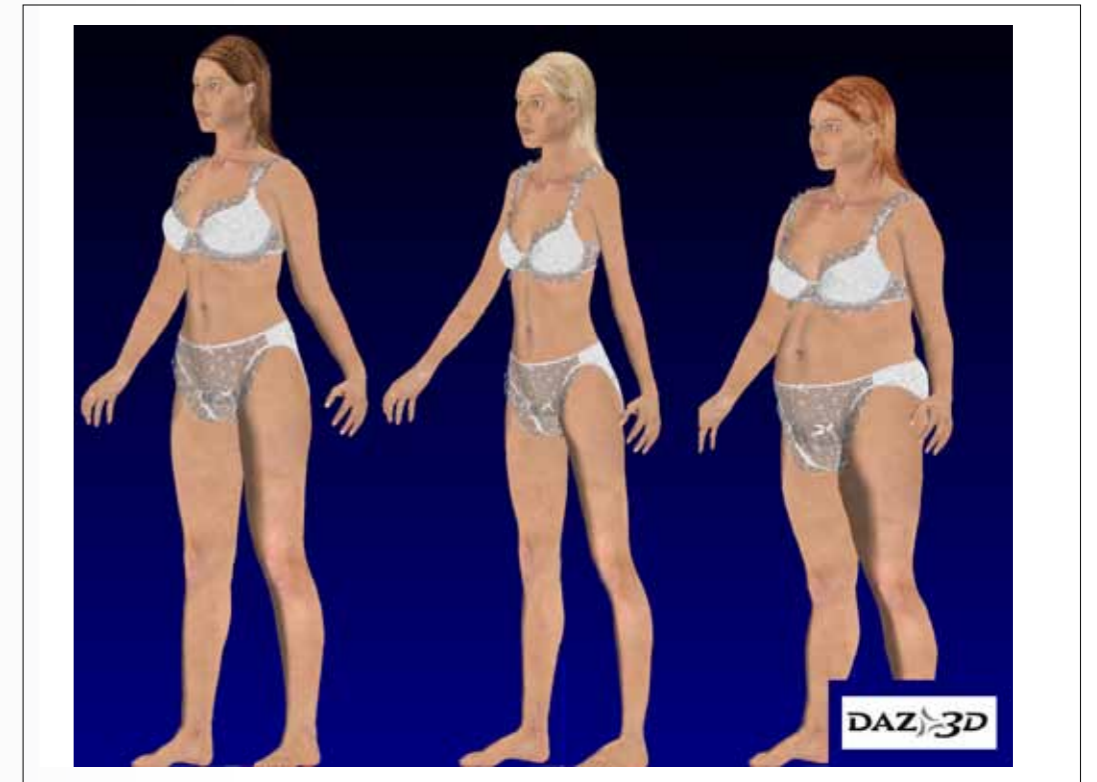
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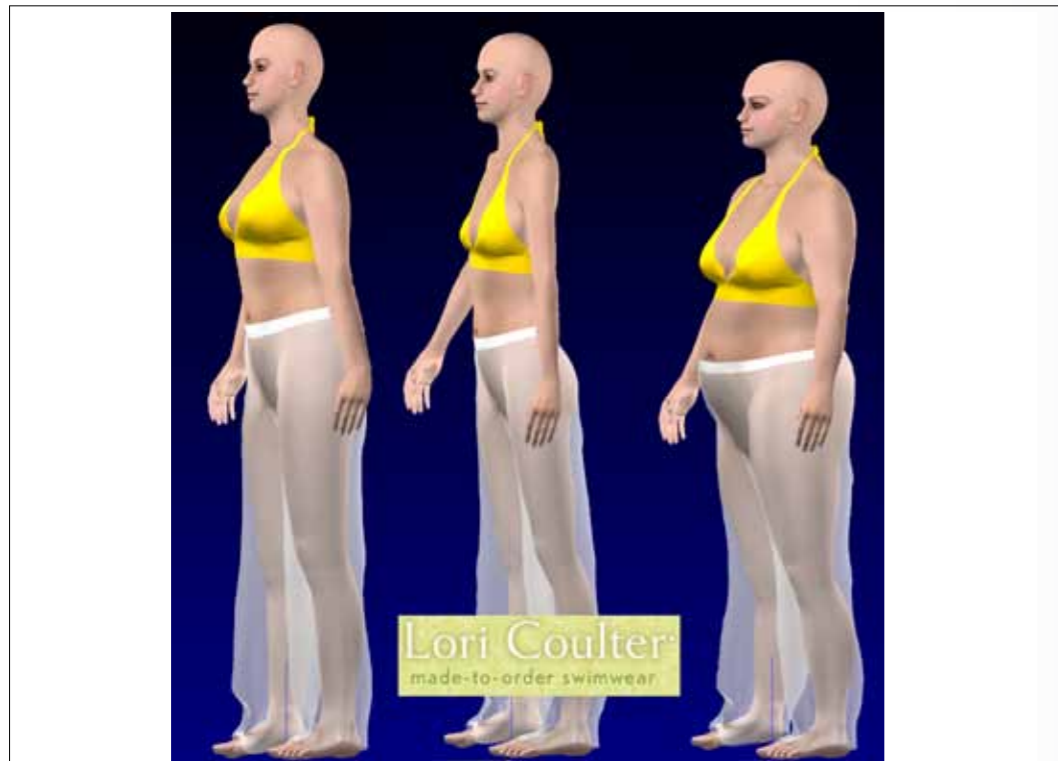


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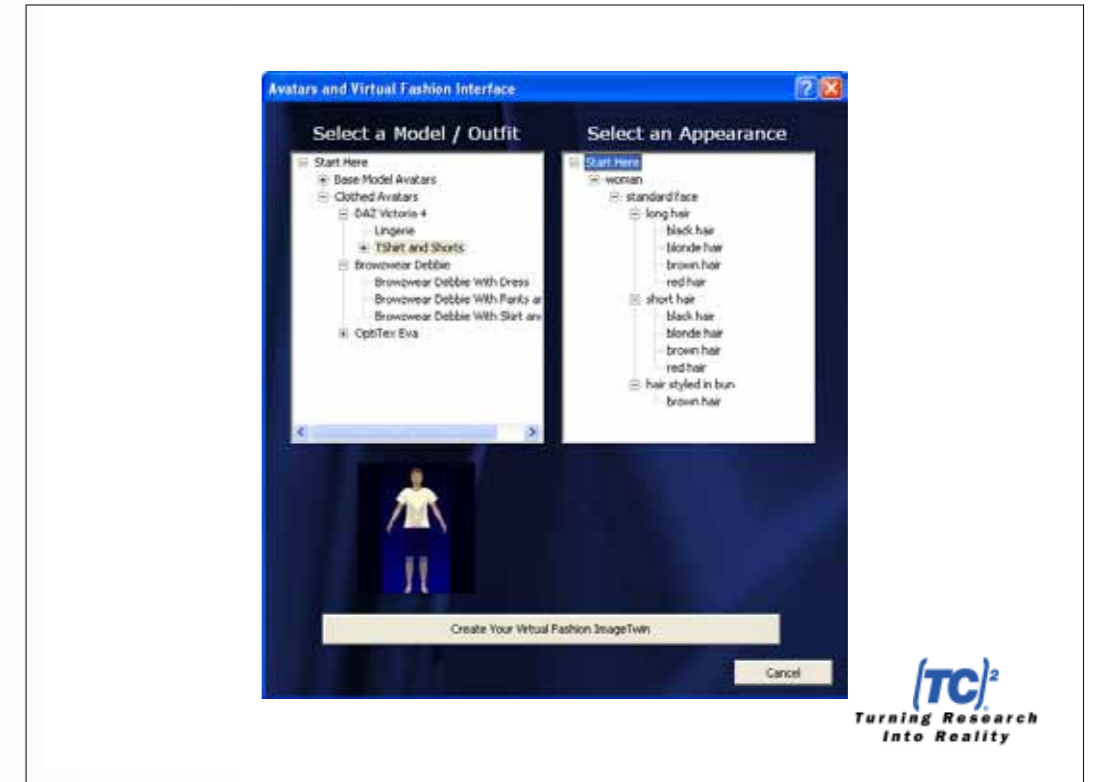


PowerPoint presentation given by Dr David Bruner, [TC]² on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.





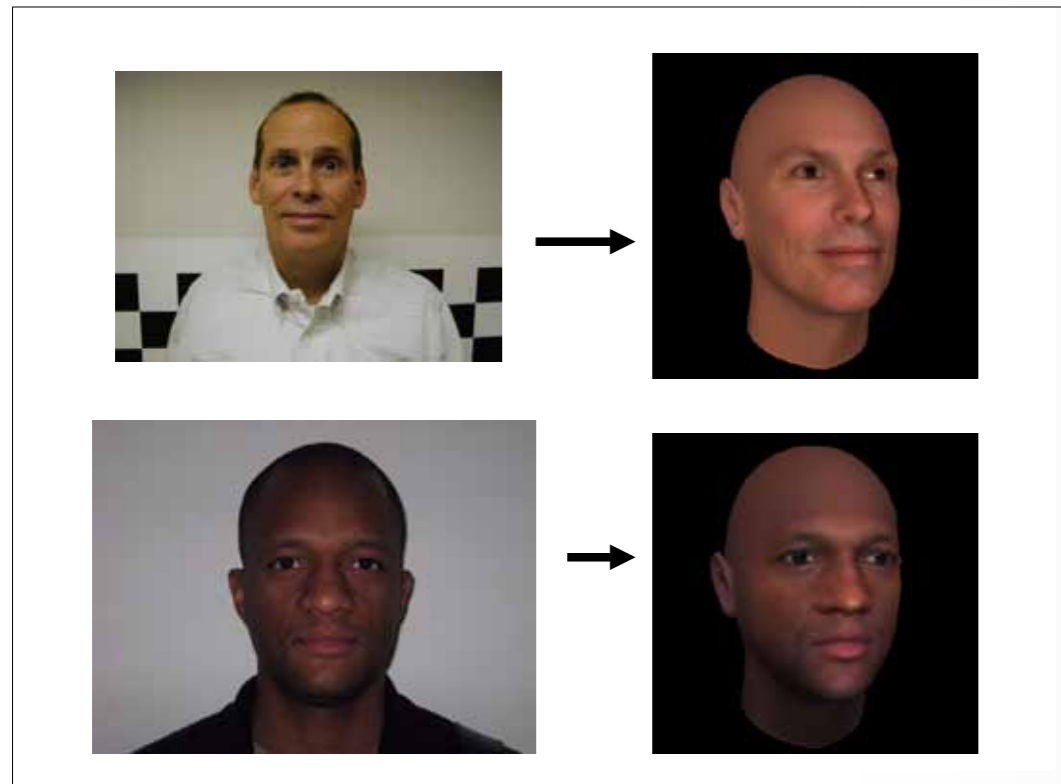
PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.



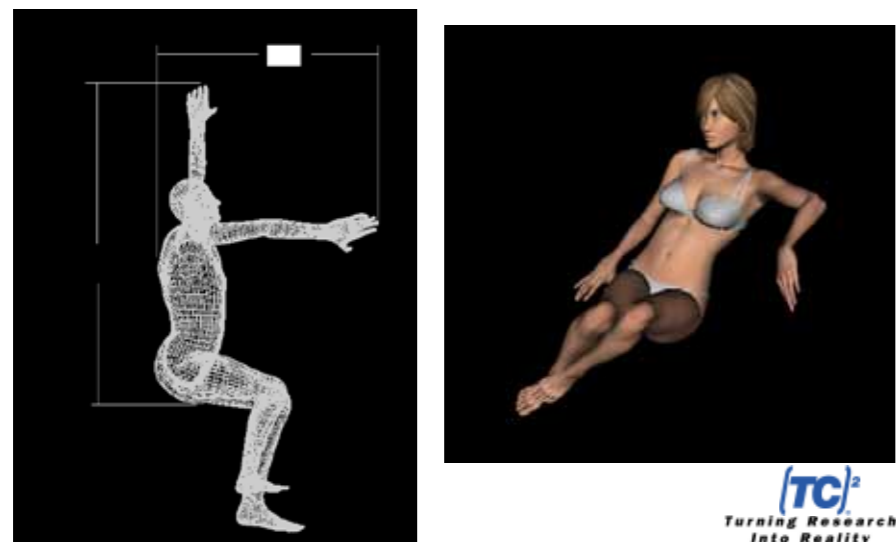
### Coming... New Features this Fall!

- Texturing the Avatar Face from a Photo
- Reposing the Avatar for Technical Analysis or Aesthetics
- Avatar Animation using Morphing

PowerPoint presentation given by Dr David Bruner, [TC]<sup>2</sup> on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.



### Alternate Poses – From Standing Pose Scan Data



PowerPoint presentation given by Dr David Bruner, [TC]² on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.

### Animation and Re-Posing Examples



Thank You for Participating in the 2009  
SizeUSA Webinar! The chat window will  
remain open for questions until 2PM EST.

If questions for this or other presentations  
have not been answered during the  
webinar – we will try and get them posted  
on the web.



PowerPoint presentation given by Dr David Bruner, [TC]² on 'Virtual Fashion Technologies for Garment Visualization in Static Poses and Animated Sequences'.