
Modularity in Apparel Production: An Industry-Integrated Investigation

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*I would like to express my deepest gratitude to my supervisors
Deb and Sandy who made even the most challenging tasks
feel achievable.*

*Also to my parents, you have supported my decisions with
unwavering support for as long as I can remember and made
possibilities feel limitless.*

*To my corner, the family we choose; thank you all for loving, hyping
and feeding me.*

*As for my four-legged study buddy Bandie, thank you for being
adorable and delightful beyond comprehension.*

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whose patience and understanding continues to astound me.*

Ka nui taku aroha mōu.

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Abstract

The central focus of this project, as outlined in the industry brief, is to develop the workflow and manufacturing capabilities of the apparel company Kapinua, through expansion of the brand's 3D-integrated, customer driven, e-commerce platform. Based in Levin, New Zealand, Kapinua is a vertically-integrated manufacturing and retailing company. Specialising in made-to-order (MTO) digitally printed garments, Kapinua have developed an online platform that allows its users to select and customise garments from their web browser. With the support of New Zealand government organisation Callaghan Innovation, Kapinua wishes to expand, develop and refine this digital asset. Through iterative design practice, analysis of Kapinua's systems and processes, reflective documentation, and literary research, this work looks to explore possible applications of customisation and modularity in the production of apparel. Informed by client needs, the primary project outcomes are relevant sizing charts informed by parametric research; grading rule tables; modular pattern templates; a library of products prepared for Kapinua's 3D-integrated, online platform; and a structured filing system to organise and access digital assets. Further objectives include improved efficiency through workflow streamlining and early iterations of resources designed to assist with future product development within the company. More broadly, this research poses the question: How can digital technologies help create economically-viable, structurally customisable patterns - and how can this increase customer satisfaction, garment fit, and improve the way we engage with clothing?



Introduction

This project formed late-2017 from New Zealand company Kapinua's desire to further expand and develop their online garment customisation platform. Kapinua is a textile printing and garment manufacturing company based in Levin, New Zealand, owned and operated by Ingo and Grit Schleuss (Kapinua, "About" par. 5). Specialising in sublimation printing technology, Kapinua uses a vertically-integrated manufacturing process to produce mostly streetwear, activewear and team uniforms (Kapinua, "About" par. 6). The possibilities beyond this are extensive, however, and Kapinua strives towards actualising all manner of unique requests (Kapinua, "About" par. 6). Having primarily sourced their patterns from third-party patternmakers, Kapinua saw the value of an in-house patternmaker to cater to the individual requirements of their clients and business (Schleuss, "Personal Communication. 21 Nov. 2017"). This role extends beyond traditional pattern making as Kapinua's apparel production methodologies deviate at times from commonly used industry practices. Kapinua's specifications, which serve as the foundation of this project, involve dealing with modular product architecture, and the application of Computer-Aided Design (CAD) and 3D drape simulation technologies - design approaches that are revolutionising the way we create and retail clothing ("Kapinua (Company Branding Shop) R&D Project", 1). Through design-lead research, this work looks to explore not only what this kind of development could mean for Kapinua's business, but for the globalised fashion industry and its users. Posed are the following research questions:

How can digital technologies help create economically-viable, structurally customisable patterns, and how this can increase customer satisfaction, garment fit, and improve the way we engage with clothing?

In order to develop a project brief (full document included as an appendix), Kapinua worked with New Zealand University Massey, and Callaghan Innovation - a government agency who work with innovation-focused New Zealand businesses (Callaghan Innovation, "About Us" par. 1). Callaghan Innovation offer industry expertise,

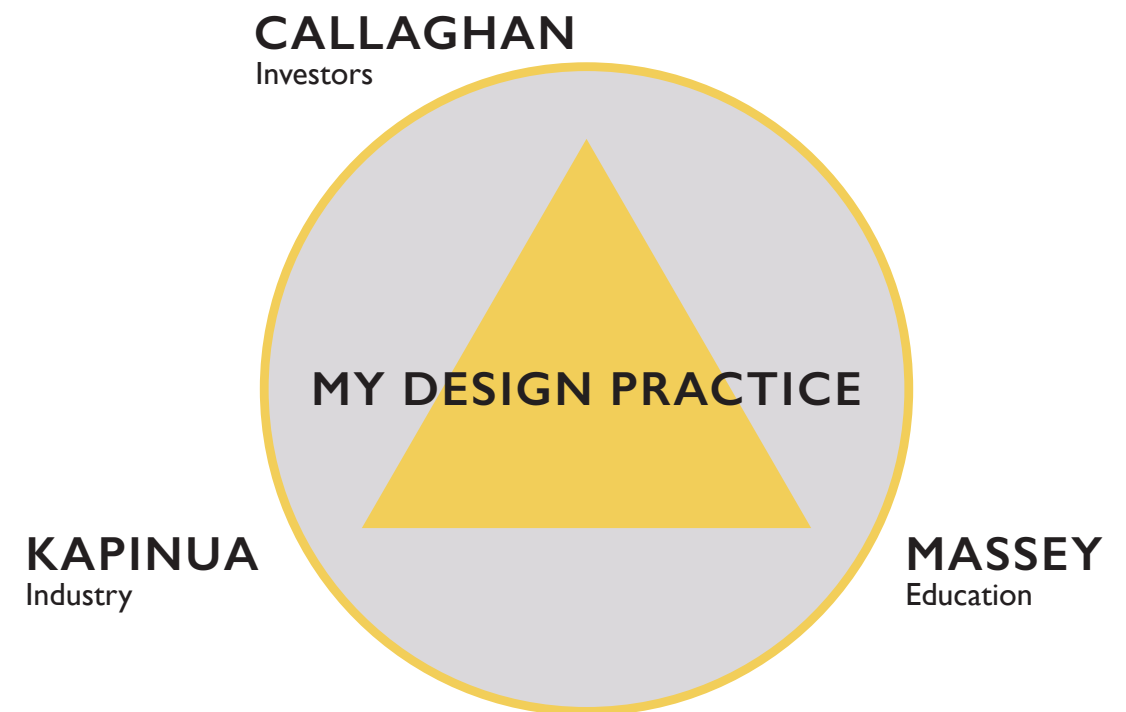
(Opposite) Figure 1. *4-View Men's Round Neck Raglan Tee*, personal image by author and Ben Reyburn, 15 Dec 2018.

funding, and assistance with establishing research and development programs (R&D), and are interested in seeing positive growth in the businesses they work with (Callaghan Innovation, “About Us” par. 2). Massey University has previously facilitated a number of industry-integrated projects, which allow their students to engage in synthesised practice-based research and industry-implemented problem solving (Swann 49). Together, Kapinua, Callaghan Innovation and Massey University all serve as key stakeholders in this project, forming a working relationship depicted in Figure 1. My design practice encompassed the management of these stakeholder relations and critically responded to individual and shared interests.

Due to the unique nature of this project, the appropriate candidate had to have experience with both traditional pattern-making, grading, and fashion CAD software - as well as experience with a wider breadth of three-dimensional (3D) rendering software. As it happened, 2017 had been my fourth and final year completing a Bachelor of Design (Honours) Majoring in Fashion Design. My honours year project had explored ideas around Posthumanism and the intersection of the natural and technological worlds. The direction this project took had required preliminary experimentation with laser cutting, 3D printing, Vuforia Augmented-Reality (AR) software, as well as programs commonly used for game development and modelling like Unity 3D, Maya, and Blender. These additional skills, though in most cases only developed to a precursory capacity, proved invaluable in learning and mastering the many digital aspects of this project.

The core proposed goals of this project (explained in further detail on *Process I*) were gaining an understanding of Kapinua’s business, customers and needs; conducting relevant research into sizing and body shape parameters; evaluating Kapinua’s current process; identifying ways to incorporate modularity; creating a comprehensive pattern library and replicating and contributing to their 3D virtual prototyping. Looking for ways to simplify and streamline their process to increase efficiency, as well as beginning to establish resources for future Kapinua development projects and employees, were additional personal objectives.

Other personal aims included the refinement and



development of my technical patternmaking and digital design skills, and to further understand the application and effect of technology and automation within the fashion industry. Experience working concurrently between academic design theory and industry-based design practice is something I hope to apply to future endeavours.

(Above) Figure 2.
Stakeholder Relationship,
personal image by author and Ben
Reyburn, 5 Dec 2018.

CONTEXT

- i. Designer/User/Maker
- ii. Customisation & Product Architecture
- iii. Fit & Sizing

i.

Designer/User/Maker

The 21st Century has witnessed technological advancements and changes in consumer culture at unprecedented rates (Abnett, *Business of Fashion*, “Fashion’s Fourth Industrial Revolution” par. 1-2). Some fashion journalists believe we could be witnessing the overture of ‘Fashion’s Fourth Industrial Revolution’ as machinery, materials, information sharing, and the way we approach clothing continues to evolve (Abnett, *Business of Fashion*, “Fashion’s Fourth Industrial Revolution” par. 1-2). These developments have caused a “paradigm shift” in the relationship between the ‘designers’, ‘makers’ and ‘users’ of fashion (Sun and Zhao 362). Unlike past models that almost exclusively saw designers setting the tone, Lushan Sun and Li Zhao believe the future consumer will call for continued deviation from traditional production models in favour of more efficient, user-focused and symbiotic approaches (362).

Automation, mass data processing capabilities, and the easy exchange of information digitally is to this era of manufacturing, what the harnessing of water, steam, and electricity were to 18th and 19th Century garment production (Abnett, *Business of Fashion*, “Fashion’s Fourth Industrial Revolution” par. 1). That is to say, that these technologies caused an irrevocable change not only to how clothing is made but to the culture of wearing and owning clothes (Abnett, *Business of Fashion*, “Fashion’s Fourth Industrial Revolution” par. 1). As production becomes easier and faster, clothing continues to become increasingly accessible - usually to the detriment of garment longevity (Eckert et al. 785). While prior to the industrial revolution most just had a few garments in their wardrobe, a 2012 report estimated that in the UK alone £30 Billion worth of purchased clothing had not been worn in the last year (Smithers par. 1). The report cites ill-fitting clothing as being one of the leading reasons for garments going unworn (Smithers par. 2), an issue discussed in more detail in the next chapter. Despite unparalleled access to clothing globally, consumers remain categorically dissatisfied with clothing options (Eckert 785). An oversaturated market of fast-fashion retailers continues to compromise on fabric caliber, in-depth fit testing, and construction quality - in what industry experts describe as a “race to the bottom line” (Parry par. 1). Shortened garment life-expectancy,

paired with consumers ability to replace and replenish their wardrobe more frequently (Yang and Huiying 590), has lead towards a culture of viewing clothing as dispensable (Eckert et al. 785).

All the while, these technological advancements and the ever-increasing access to knowledge, is allowing the customer to be more selective, informed and involved in the clothing production process (Sun and Zhao 373). This is causing many retailers to rethink the way they approach production and retailing strategies (Sun and Zhao 362) and placing pressure on brands to incorporate more ethical and sustainable practices - commonly known as Corporate Social Responsibility (CSR) (James 287). James and Montgomery’s 2016 study on consumer engagement with transparent business models in relation to CSR, concluded that consumers were more inclined to purchase from brands that were willing to share information regarding supply chains and manufacturing practices (295). Citing media coverage and social media-lead campaigns as a driving force for consumer engagement with these issues (288), James and Montgomery emphasised that there were still sizable gaps in consumer knowledge - particularly when it comes to understanding industry-specific lingo and processes (296). Allowing for the varied pre-existing consumer knowledge and facilitating the increased inclusion of the user’s in the garment development process, has the potential to entice consumers, contribute positively to sales, and ensure products on offer align more accurately with user demand (Shin 358-359).

One increasingly prevalent method of facilitating a movement towards a more informed and included user is the shift away from ‘made-to-stock’ (MTS) manufacturing models (Kaminski et al. 1). The default model of producing garments, MTS involves creating an inventory and making sales once this stock is available (Kaminski et al. 1). This method requires hefty start-up costs like materials, labour and shipping costs must be expended before any revenue can be created (Kaminski et al. 1). With MTS, depending on manufacturing lead-times, it may be many months between the time an order is placed, when manufacturing is completed, shipping and customs time, and when it is available in-store or online for purchase and distribution (Kaminski et al. 1). This model is best suited for mass manufacturing businesses



that require a rapid, high turnover of stock (Kaminski et al-2). The alternative to MTS is ‘made-to-order’ (MTO) which allows the manufacturer to create the product once the order has been placed (Kaminski et al. 1). This production model provides a number of benefits to both the manufacturer and customer (Kaminski et al. 1). The overheads of MTO are limited to prototyping and establishment costs, and all additional costs are only incurred as required when an order has been placed (Kaminski et al. 1-2).

With the long lead times required for offshore MTS manufacturing, retailers must predict the number of units required of each style and size (Kaminski et al. 1). As a result, it is common for retailers to be left with a surplus of stock that did not sell as anticipated, and be understocked on the more popular styles and sizes (Kaminski et al. 1). While often surplus garments will be sold at a discounted price through either in-store promotions, outlet stores, or discount retailers like TJ Maxx, many will inevitably wind up as pre-consumer waste (The Economist par 2). Conversely, as MTO garments are made as required, the margin of discarded

items is limited to faulty or returned items (Das 74). There is, however, often more textiles waste per garment produced during the manufacturing process with MTO models (Das 74). Large clothing runs can often be configured on pattern markers more efficiently to create a higher fabric yield (Das 74). In the case of Kapinua, garments are often produced as one-off orders, meaning that a high proportion of the fabric ends up on the cutting room floor. Nevertheless, when considering both the overall production of pre-consumer textile waste and post-consumer textiles waste caused by customer dissatisfaction in the product, MTO manufacturing models appear to be far superior in terms of efficiency and sustainability (Kaminski et al. 1-2).

Seeing the potential and relevance to the changing fashion market, increased divergence from traditional manufacturing has greatly affected the parameters of roles within the industry (Sun et al. 362). Sun and Zhao cite Sandra Keiser et al’s model of ‘makers’, ‘designers’ and ‘users’, which more broadly groups the breadth of people involved in the clothing creation process (Keiser qtd. in Lush Sun et al. 363). Here, ‘maker’ refers to

(Above - in descending order)
Figure 3. *Maker/Designer/User*, personal image by author and Ben Reyburn, 10 Jan 2019. Modified from the Maker/Designer/User Model (Sun & Zhao 2018).

Figure 4. *Designer/Maker/User*, personal image by author and Ben Reyburn, 10 Jan 2019. Modified from the Maker/Designer/User Model (Sun & Zhao 2018)

those involved with the material production - working in fibre, yarn and fabric creation. Meanwhile, the 'designer' refers to those involved in the conceptualising and manufacturing of the product itself. The designer dictates the aesthetic and functional decisions, influencing the kind of garment being created, how it will be worn, and the details it will feature (Keiser qtd. In Lushan Sun et al. 363). The products are then acquired by the user - the customer by way of those involved in marketing and retailing (Keiser qtd. In Lushan Sun et al. 363). While Keiser et al.'s categorisations (Figure 2) are a great framework when discussing the apparel industry as a whole, this case study focuses solely on product design, production, and use, not the process of sourcing and creating the materials. For this reason, the terms 'designer', 'maker' and 'user' better serve to describe those conceptualising, manufacturing the product, and consuming, respectively. This regrouping is illustrated in Figure 3, with Sun and Zhao, and Keiser et al's commentary relating to product manufacturing, as opposed to material production, just as pertinently.

Sun and Zhao elude to the linear and sequential format of conventional manufacturing strategies like MTS (Sun et al. 362). Designers, makers, and users have traditionally operated independently of each other with all interactions being transitional in nature (Sun et al. 362). These clear-cut, boundaries were only reinforced with the movement towards offshore manufacturing in the second half of the 20th century, which created an additional geographical separation between roles (Sun et al. 364). But as Sun and Zhao discuss, recent technological advancements have seen an increasing number of businesses deviate from this linear model (Sun et al. 362-364). For one thing, the speed of online communication allows businesses to close the gap created by offshore manufacturing as information can now be instantaneously exchanged between consumers, retailers, and manufacturers (Sun et al. 363-364). The accessibility of e-commerce has also seen many makers and manufacturers begin to market directly to consumers (Sun et al. 364). Companies like Alibaba provide an online platform for customers to buy directly from vendors. Vendors are given the chance to save on the cost of dealing with intermediary parties (Alibaba par. 1). Similarly, websites like Etsy allow small-scale

businesses, often specialising in handcrafted items, the chance to sell directly to users (Etsy par. 2). Etsy provides the e-commerce platform, technological and logistical support, and virtual 'foot traffic' in exchange for a percent of the profits (Etsy par. 2). Both easier and more affordable than creating an independent online retailing system, Etsy particularly serves artists and designers who would need to drastically increase price points or production volumes to compete - likely at the cost of product integrity and handmade techniques (Etsy par. 2-5). This direct contact between involved parties means that feedback no longer has to be retrospective (Sun et al. 364). Many Etsy vendors, for example, offer personalised and customised products (Etsy par. 2). Users can be more direct about their needs, and many companies are adopting vertical integration supply chains as designing, making and using becomes more of a mutually informed, hybrid system (Sun et al. 364).

It is suggested in Sun and Zhao's work that these hybrid systems will become increasingly prevalent within the mainstream fashion industry, at the benefit of all parties involved (364). The advantages of MTO manufacturing, outlined in the previous paragraphs, affirms Kapinua's business model which is marketed heavily as offering their consumers the kind of influence and empowerment the Designer/User/Maker model condones. By utilising this model, along with the notions of MTO and CSR within this research, progress can be made towards the kind of human-centred, inclusive design thinking desired by the stakeholders of this project.

COST/LABOUR

COMPLEX VARIATIONS

Bespoke x Couture Products. Labour intensive redesign.	Produced based on one-off client needs.
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MEDIUM VARIATIONS

Alterations to simple garments. Standardised fit variations.	Offering similar design variations of one garment.
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SIMPLE VARIATIONS

Change of color or non-structural features such as embroidery, pockets, etc.	Printing onto a Kapinua product.
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ii.

Customisation & Product Architecture

In response to customer dissatisfaction with readily available products and the emerging role of more empowered and involved consumers, many businesses are beginning to explore the production and retailing of customisable products in a range of market positions (Eckert et al. 785). While high-end bespoke production models reiterate the long-standing tradition of couture, new technologies and design approaches are providing opportunities for personalisation to be implemented at a more widely-accessible level (Eckert et al. 785). Due to a lack of precedence and commentary on this newly surfacing market, a number of comparisons to the engineering and industrial design sector have been included. Eckert, Clarkson, and Black, examine the parallels between new garment design and production practices, and existing engineering design principles (786). They suggest the “cross-fertilization” of knowledge could lead to economically viable mass customisation (786) - and perhaps provide the solution to prevalent user discontentment and fashion’s prolific resource wastage (785).

Product personalisation techniques can be classified in terms of a spectrum, ranging from basic level customisation through to the aforementioned level of one-off redesign seen in bespoke and couture, with all manner of intermediary levels in between (Eckert et al. 787). This spectrum is traditionally applied to engineered products like machinery or technology (Eckert et al. 785). Most new automobiles offer a more standardised method of customising, similar to a simple fashion product like jeans or a shirt (Eckert et al. 787). Meanwhile, products such as military helicopters are not produced in great enough volume to justify the labour required to develop the required systems of modularity and are best designed or adapted on a case-by-case basis - much like one-off pieces designed for celebrity red carpet events, such as Lady Gaga’s custom Valentino gown for the 2019 Golden Globes, pictured in Figure 6 (Eckert et al. 787; McCall par. 2)). Basic customisation can include changes of colour and material, like Apple offering customers purchasing an iPhone model a choice of metal colour and storage configuration, or a “decorative but non-structural feature” like Tiffany & Co’s in-store monogramming services (Eckert et al. 787; Tiffany & Co. par. 1). While offering users basic personalisation services

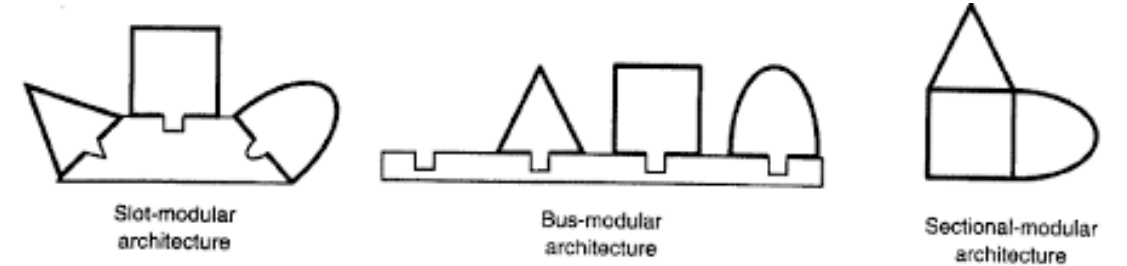
(Opposite) Figure 5.
Levels of Customisation,
personal image by author and
Ben Reyburn, 20 Jan 2019.
Modified from the Spectrum of
Garment Customisation model
(Eckert et al. 2008)



can contribute to an enjoyable purchasing experience and drive business positively, within the context of fashion it does little to address customer issues with finding well-fitted and well-liked pieces (Eckert et al. 787). Conversely, while luxury retailers like Burberry are incorporating new technologies to aid with customisation, their strategic positioning within the market means that high-end redesign developments also does little to help with these largely mass-market concerns (Luxury Insider par 1.; Eckert et al. 787). Rather, accessible fashion must look to ideas of modularity to ensure personalisation extends beyond novelty - and offers options that practically and meaningfully serve its' users.

The challenge with offering more comprehensive mass customisation is achieving this in a way that is “economically viable” (Eckert et al. 785). Consideration must be made for each individual business as to the level of customisation that can be offered, how much this customisation will cost, and the level of benefit the business stands to gain (Eckert et al. 788). From there, the existing design process must be analysed to identify opportunities for streamlining through simulation or elimination. This is a task that can be assisted through visual documentation using models like Wynn, Eckert and Clarkson’s Applied Signposting Model (ASM) (Eckert et al. 788; Wynn 1). “Obtaining accurate estimates for task durations” and examining the workflow can help highlight steps that “contribute little to the design process”, from being repeated unnecessarily, or can be simplified through the use of templates or automated digital processes (Eckert et al. 789). Ideally, a more simplified and efficient process can accommodate additional tasks that provide the desired individualised outcome without altering the product’s price point drastically or compromising product profit margins (Eckert et al. 787-788).

Additionally, garment design can utilize industrial design approaches to maximise the number of products being developed at one time. Product architecture is a term used in product engineering to refer to the way components of a product are organised and assembled (Ulrich, “The role of product architecture in the manufacturing firm.” 419). It is synonymous with the idea of modularity, as product architecture examines the sub-functions of a product’s parts, as



(Above) Figure 7.
Ulrich, Karl. Types of
Modularity, 2003, diagram.

well as interrelationships between each (Ulrich, “The role of product architecture in the manufacturing firm” 419). While typically used in the context of objects like automobiles and printers the core concepts can be applied to garments, particularly within mass manufacturing (Eckert et al. 785). Modularity can be broken down into three types of architectures: bus, sectional and slot, illustrated in Figure 7 (Ulrich qtd. in Techcoil par. 4). A bus-modular architecture provides a common base in which different components (or ‘chunks’ as they are often termed) can be attached interchangeably - similar to the way all manner of different technological items can be plugged into an electrical board (Ulrich qtd. in Techcoil par. 6). Sectional-modular architecture shares the interchangeable interfaces of bus-modularity but isn’t constrained to attaching at one base (Ulrich qtd. in Techcoil par. 7). Instead, it can be reconfigured in a wide variety of ways, like piping and pre-made sectional kitchen cabinets and appliances (Ulrich qtd. in Techcoil par. 8). But slot-modular architecture is the most comparable with clothing as each interface between components is specific and unique. While a scye

(Above) Figure 6. Kopaloff, Jon.
[Lady Gaga wearing Valentino at
the 2019 Golden Globes], 2019,
photograph. Fashionista, www.
fashionista.com/2019/01/2019-
golden-globes-awards-lady-gaga-
valentino-couture

(armhole) can accommodate a bell, bishop, or straight sleeve, a standard tailored collar could not seamlessly be inserted instead. By identifying clothing 'slots' and their functions, and reframing the configuration of a garment in terms of product architecture and identifying the function of each 'slot', the opportunities for modular customisation can be recognised and explored.

One business that is already applying this approach is Brooks Brothers who offer their clients custom dress shirts (Brooks Brother's par. 3). By taking a structurally simple garment like a dress shirt, they have broken-down the product architecture of this product and identified the different modules that can be altered to create a variety of combinations and therefore options for their customers. In the case of Brook Brothers' shirts, this is the collar, cuffs and fit, with the last likely accomplished through the use of a range of slightly different base patterns or alterations to the side seams and darts (Brooks Brother's par. 3). Then, in addition to medium-level customisations, they offer basic and non-structural customisation in the form of a range of fabric options, patch pockets, and monogramming (Brooks Brothers par 3.). While the labour and time required to establish this customisable product was no doubt significantly greater than a single-option product, a mass manufacturing company like Brook Brothers have no doubt sold the volume over time to make back these expenses (Eckert et al. 787).

The principles of product architecture hold a great deal of promise in their application to fashion design. By working from base patterns and viewing design decisions in terms of interchangeable 'slots', groups of garment variations - like Brook Brothers' custom dress shirts - can be developed to be accessible to makers, and marketed to users. Fashion CAD patternmaking practices that are informed by principles of modularity already commonly used in product engineering and industrial design, can make 'medium variations' an economically-viable reality for businesses like Kapinua.



iii.

Fit & Sizing

“Nothing needs to undergo more change than the way we address garment fit. Fit underlies comfort, and the apparel industry has a long way to go in order to actualize satisfactory fit for a range of bodies. Bodies are not standard, and standard sizing is a myth... Comfortable clothing gets worn more often and is kept longer. Future possibilities in design efforts towards developing comfortable environments will require a strong understanding of both textile properties as well as the anatomy and physiology of the body.”

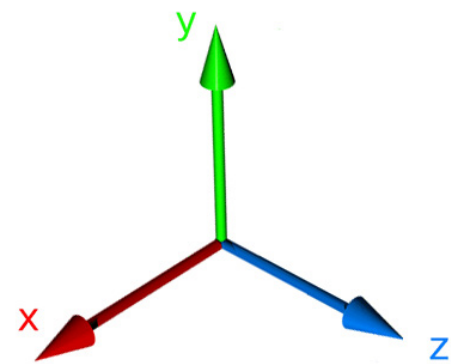
Janet Hethorn,
Sustainable fashion practitioner.

A 2004 study concluded that 49% percent, just shy of half of the women studied, have difficulty finding clothing that fits well (Kurt Salmon Associates qtd. in Bye et al. 79). While once all clothing was fitted individually to the wearer or designed in such a way that allowed them to be adjusted easily to be worn by a range of sizes, the industrial revolution saw the advent of commercialised patterns and ready-to-wear fashion (Bye et al. 80). By offering a range of standardised sizes, garments no longer had to be draped on the wearer and algorithms could predict and average the parameters of an array of forms (Bye et al. 80). This new approach to garment production, lead largely by the emergence of 19th Century English tailoring and the need for a large volume of military uniforms in the 19th and 20th centuries, meant clothing was made dramatically more affordable and accessible (Bye et al. 80). This process of algorithm-based standardised sizing, known as grading, streamlined the garment creation process and allowed for mass manufacturing, meaning consumers had more choice than ever (Bye et al. 80). But not without drawbacks. Grading has largely been criticised as not accurately serving a range of body types (Bye et al. 79). Studies like Kurt Salmon Associates confirm, the misnomer of finding the ‘average’ set of body parametric measurements for each size, is leaving large proportions of the populous dissatisfied with clothing options. Though technology has evolved greatly since the emergence of English tailoring, the grading system has evolved minimally. Although grading rules can now be applied to patterns digitally, allowing for them to be created, copied and adjusted quickly, technology has yet to be applied to the grading process in a way that advances or supersedes the system itself. Additional problems with current sizing systems ironically include a lack of standardisation between grading systems - especially internationally (Han par 7.). Different countries, as well as different brands, often operate under different sizing systems to cater for different body ideals and target markets (Han par. 7). This creates wild inconsistencies for the consumer while shopping and contributes to the large margins of dissatisfaction, returned items and ultimately, discarded clothing (Shin 352). Accessibility to sizing information has become increasingly important with the rise of online

shopping (Lee et al. 59). Many retailers — like Kapinua — are selling products primarily or exclusively through e-commerce channels. With so much merchandise being sold remotely, it is important that brands like Kapinua offer excellent sizing options, as well as concise sizing information and resources (Lee et al. 59).

Grading methods operate in nature, based on a series of broad assumptions (Bye et al. 81). It is assumed that the human form grows proportionately as one’s size increases, and that chest-waist-hip ratio and body mass distribution all the while remains more or less the same (O’Brien and Shelton qtd in Elizabeth Bye et al. 79). In order to create a sizing standard, the height and proportions of the average wearer must be assumed, with very few retailers offering additional sizing options for customers whose dimensions are described in apparel terms as ‘tall’, ‘petite’ or ‘plus-sized’ (Bye et al. 80). There have been a number of studies conducted in order to gauge the success of standardised sizing, including Bye et al.’s 2007 investigation. This study compared garments created using an ASTM sizing standard table (ASTM D5585-95) with garments custom fit to a range of models whose measurements matched those specified in the table (Bye et al. 82). While the investigation only studied five models and called for further research, they were able to provide a strong case against the effectiveness of current grading practices (Bye et al. 86). Despite each model matching the exact measurements of ASTM standard sizes, the study found that each dress needed an average of 3.4 alterations to successfully fulfil Armstrong’s framework of fit criteria (Bye et al. 85). If these models — who possess the measurements and proportions of the supposed median wearer — are still experiencing fit issues, it begs the question: how successfully is the current grading process meeting the needs of the mass market? Or perhaps more importantly, how successfully is mass market manufacturing meeting the needs of the individual?

The shortcomings of existing grading practices are particularly apparent when applied to digital pattern-making software. Programmes such as the Optitex Pattern Making Suite allow the patternmaker to work concurrently between digitised 2D flat pattern-making and 3D drape simulation. While this 2D-3D relationship very much exists in manual pattern-making, computer-

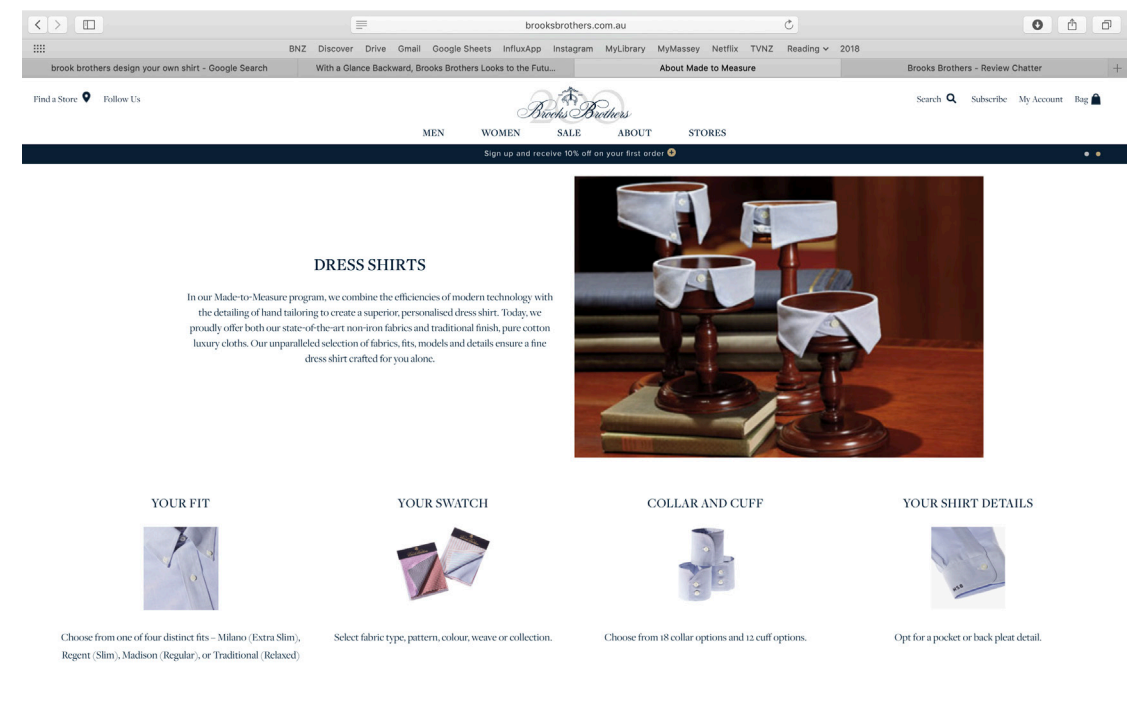


aided design (CAD) allows for the patterns and drape to be altered rapidly and simultaneously. Real-time 2D-3D synchronising only further emphasises the breakdown in the translation of data between these two modes. 3D digital simulations use the Cartesian Coordinate System, operating in terms of an x, y, and z-axis (Maths First par.1). This accounts for the width and height of objects, as well as their depth. Digital assets can be manipulated across each of these axes, allowing them to represent the parameters of physical, three-dimensional objects — like the human form — with great accuracy and detail. Meanwhile, existing grading methodologies focuses almost entirely on changes to the bust, waist and hip measurements (Bye et al. 80). Circumferential dimensions would be sufficient if the human form was perfectly cylindrical. However, due to the irregular shape of the human torso and the endless variations of each individual, expecting a set of parameters to account for all the specifics of a person's frame seems fruitless (Bye et al. 80). Accounting for individual differences in height (or the y-axis) and varying relationships between width and depth (x and z-axes) would be a great first step towards creating a grading system that is both more comprehensive and more inclusive.

The sizing options available in women's lingerie offers a framework for what this more comprehensive grading system could look like. Bras and bustiers are typically all offered in a range of sizes that gives the wearer options in terms of 'cup size' as well as under-bust circumference. By giving more attention to variations in the distribution of mass, as well as the standard numerical incremental grading, the chances of the individual finding a bra that fits their body are notably higher. For example, a mass-market daywear retailer like Glassons offers most of their styles in six sizing grades (Glassons par. 1). Meanwhile, lingerie retailers like Honey Birdette offer some styles in as many as 48 different size variations — ranging from 6-18 numerically and A-G in cup size (Honey Birdette par 1).

Of course, logistically there are limitations to the application of more comprehensive sizing systems within the commonly implemented MTS manufacturing models. The majority of fashion retailers source their apparel offshore, requiring a large amount of estimation in terms of units ordered, and long lead times to allow for

(Above) Figure 9.
[X, Y, Z Axis Diagram], n.d.,
JPEG image. Adobe, www.adobe.com/support/freehand/basics/3d_animations/



(Above) Figure 10.
[Screenshot of Brook Brothers
Website], n.d. JPEG image. Brook
Brothers, www.brooksbrothers.com.au/mtm-mtm.html

manufacturing and shipping (Sun et al. 374). Drastically increasing the number of size variations available would further complicate the buying process for retailers and wholesalers, likely contributing to even more pre-consumer waste. Made-to-order business models like Kapinua however, could greatly benefit from the development of such a sizing system. As garments are not being produced until an order is confirmed, having a larger range of size variations to choose from would not require more stock and would likely increase customer satisfaction dramatically.

It is important to note of course, that not all garment styles would require this level of in-depth fit options. In the case of Kapinua, who work exclusively with knit apparel, the stretch of the fabric accounts for some deviations in the wearer's physique from the standardised size. However, Kapinua reported a number of complaints with garment fit particularly when it comes to hem length, sleeve length, neck circumference, and waist-hip proportions. Preliminary steps were taken in order to remedy these issues through the inclusion of two fit styles and two length options, however, developing a more

complex and encompassing approach to grading requires extensive research that lies outside of the scope and focus of this project.

Literary research into fit and sizing has only underscored the need for significant research to be conducted into the sizing and fit component of fashion design academia (Shin et al. 352). Offering 'tall', 'petite' or 'plus-size' ranges can serve as an intermediary response to customer fit dissatisfaction, but ultimately a heavily tested, comprehensive sizing system would better serve the needs of our current market. Building on the kind of multidimensional sizing ranges used with lingerie, would be an excellent starting off point for creating sizes informed by more parameters than just bust/chest, waist, and hip circumference as it is now. It is likely that MTO manufacturers and businesses proficient with CAD patternmaking practices, like Kapinua, will lead the way in providing fit and length options to consumers desperately in need of better fitting clothing.

(Opposite) Figure 11. *Kapinua Manufacturing 002*, personal photograph by author. 5 Feb 2019.



PROCESS

- i. Breakdown of Brief & Understanding Client Needs
- ii. Establishing Sizing Parameters
- iii. Pattern Development
- iv. Familiarisation with the Existing Digital System
- v. Developing & Refining the Digital System

1. CUSTOMER ORDER

2. PRINT FILE IS CREATED

3. PRINTED

4. TRANSFERRED ONTO FABRIC

5. LAZER CUT

6. SEWN

7. SENT TO CUSTOMERS

i.

Breakdown of Brief & Understanding Client Needs

Unlike many retailers whose goods are obtained solely through the purchase of wholesale products from international suppliers, or are designed in-house but manufactured off-shore, Kapinua is one of a shrinking number of New Zealand clothing companies who use vertical integration. A management term, vertical integration is when a company serves not only as a goods retailer but also owns and operates the majority, if not all, of the production process (Sun et al. 364). In the case of Kapinua, not only does the company handle the design, manufacturing, distribution, and retailing of their products, but this is all conducted from a single premise in Levin. Uncommon in this largely globalised economy, this localised supply chain allows Kapinua complete control over their product development (Sun et al. 364). It presents a unique set of possibilities for the company to explore newer models of production like modular design. Ability to provide input into not only how these products are made, but also how they are designed and marketed, allowing for more synergised and contemporary approaches to be applied to garment creation. But this first involved gaining a comprehensive understanding of Kapinua's processes, clients, distinct opportunities and challenges.

Sublimation Printing & Garment Manufacturing Overview

Kapinua owns multiple wide-format sublimation printers which print dye onto transfer paper (Kapinua, "Sublimated Shirts" par. 8-9). This dye can then be heat pressed onto a range of fabrics effectively by using specialised machinery (Kapinua, "Sublimated Shirts" par. 8-9). A camera is mounted above a digital laser cutter, which has been programmed to identify the outline of printed shapes and - upon confirmation by the operator - can quickly cut out a great number of garment pattern pieces (Kapinua, "Sublimated Shirts" par. 4). These pattern pieces are then sewn by Kapinua's in-house machinists, and shipped directly to their customers (Kapinua, "Sublimated Shirts" par. 6-7). The use of automation practices and the elimination of intermediary transport which is facilitated by localised vertical integration makes for drastically shortened lead times. Kapinua can if necessary, provide their customers with

(Opposite) Figure 12. *Kapinua Vertical-Integration Process*, personal image by author and Ben Reyburn, 1 Feb 2019.

personalised MTO garments on demand in a matter of days, giving them an incredibly competitive edge within the market (Kapinua, “Sublimated Shirts” par. 1).

Market

At this stage, Kapinua focuses primarily on stretch apparel like t-shirts, hoodies, and sportswear (Kapinua, “Sublimated Shirts” par. 1). From the information provided by Kapinua’s owner, the brand’s clients include men and women, of varying age-groups and ethnicities (Schleuss, “Personal communication. 6 Jan. 2018”). It should be noted that collecting information and statistics around demographic and psychographic specifics was not an objective of this project. Through e-commerce, they are able to reach a global audience and have been known to send orders to Germany, Australia and Canada (Schleuss “Personal communication, 7 Jul. 2018”). A lot of the company’s business does, however, still comes from local individuals and community groups, or New Zealand sporting teams who contact Kapinua directly (Schleuss, “Personal communication, 7 Jul. 2018”) By working individually with clients, the brand can deliver solutions that extend beyond what is currently on offer on their online platform. Long term, expanding the available product range, and minimising the needs for such involved and individualised customisation, would allow the business not only to deliver faster results but would allow employees to devote more time into furthering product and system development.

Brief

At the project’s inception, information was provided by the key stakeholders - Kapinua, Callaghan Innovation and Massey University - in the form of an industry brief, outlining the desired outcomes of this project. The project aims had been broken into four technical objectives. It had been proposed these be completed consecutively, however, it was understood that in practice these were likely to be approached concurrently. Key information from this document has been summarised in the table on the following page, but a copy of the full document has been included in the appendix.



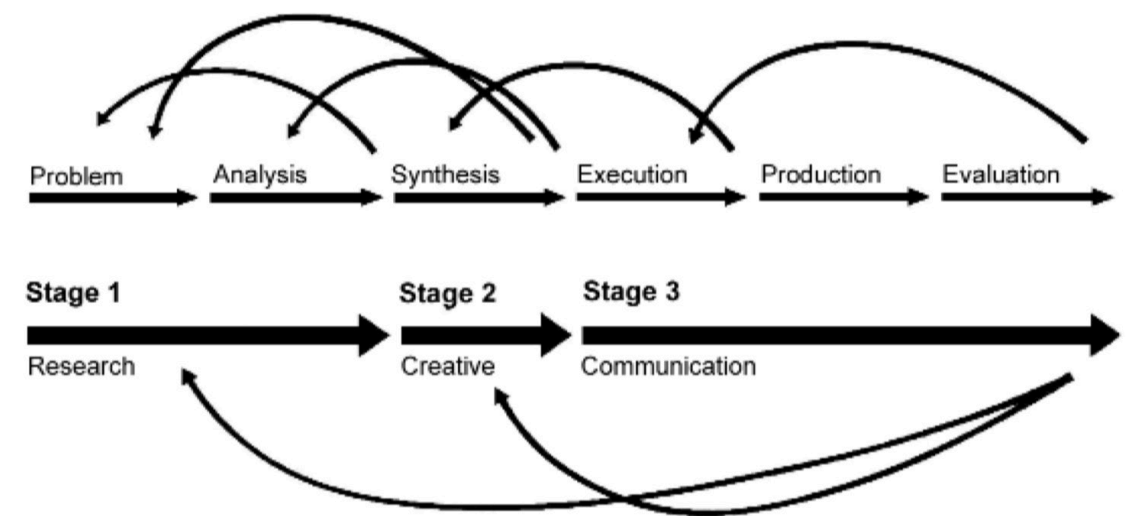
(Opposite) Figure 13. Kapinua. *Sublimated Custom Shirts Gallery*, 16 Oct 2012, JPEG image. Facebook, www.facebook.com/kapinua/photos/?tab=album&album_id=179344755441400.

Technical Objective	Work Plan	Deliverable
Research diverse parameters and assess different software options.	<ul style="list-style-type: none"> - Define and capture a set of diverse parameters for body shapes, sizes and weight. - Access CorelDRAW, Optitex 3D software, and alternative software options eg. CLO3D, Accumark, Photoshop, Illustrator. - Appraise a range of existing garment customisation and digital design response systems, including FullGear. - Develop a platform for Modular apparel design and manufacture to cater a diverse and inclusive audience. 	<ul style="list-style-type: none"> - An in-depth understanding of the project processes and parameters as shown through the design and development of a prototypical workflow system. - The context will be assessed on the sustainability of the proposed design systems and their suitability for purpose and NZ based market
A modular system for customisation.	<ul style="list-style-type: none"> - To extend and optimise a parametric apparel digital system to produce a customised single or multiple garment pattern outcome/s. - To explore pattern design development for customised garment design units to optimise efficient production using OptiTex or alternative 3D apparel technology. - To produce prototype modular garment system for online presentation. 	<ul style="list-style-type: none"> - A library of modular styles appropriate for the identified Kapinua price point, read for 3D virtual prototyping for a wide range of body measurement. - A system for presenting and browsing the modular style in a web format.

3D virtual prototyping 1st stage.	<ul style="list-style-type: none"> - The aim of this stage is to master 3D virtual prototyping to drape a garment on a 3D figure. - Consider fabric stretch, weight and opacity or transparency to produce product images. - Prepare the product mesh for web upload and usability. - Reduce mesh count and delete shaders and faces. - Create the placeholders for the various shaders. - Create customized avatars to create lookbook images for the website. 	<ul style="list-style-type: none"> - Cleaning up and formatting the models from the parametric pattern making stage into a web format so they can be browsed by customers
3D virtual prototyping 2nd stage including testing and finalising.	<ul style="list-style-type: none"> - Explore and design experimental design applications. - Create test and finalise customised avatars to create look book images for the website. - 3D mesh development and conversion. - Create test and finalise shader placeholders. - Finalise set up of automatic print template for automated laser pattern cutting and dye sublimation printing. - Final testing. - Make recommendations for future customisation processes in apparel systems based on experience from existing prototype development. 	<ul style="list-style-type: none"> - A set of design prototypes of diverse body shapes with and without an avatar. - Provide recommendations for future customisation 3D virtual prototyping from capture to design to production process in apparel systems. - A roadmap of the next new integrations with the design systems that have been developed in this project.

Methodologies

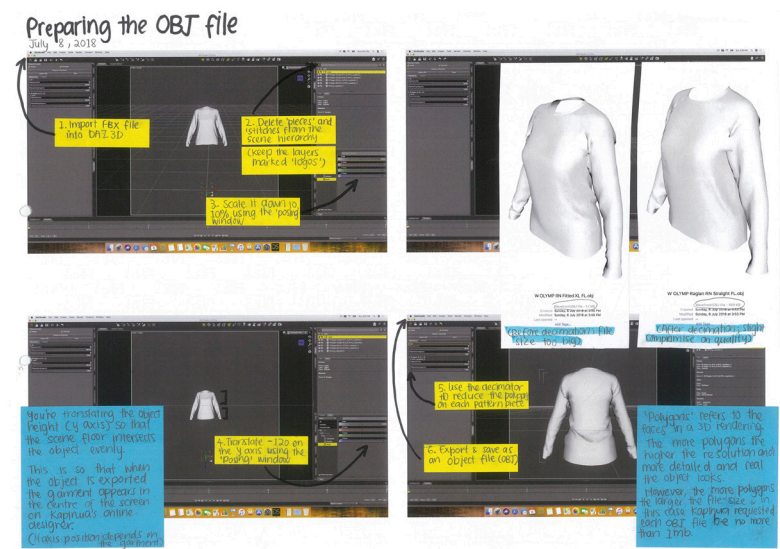
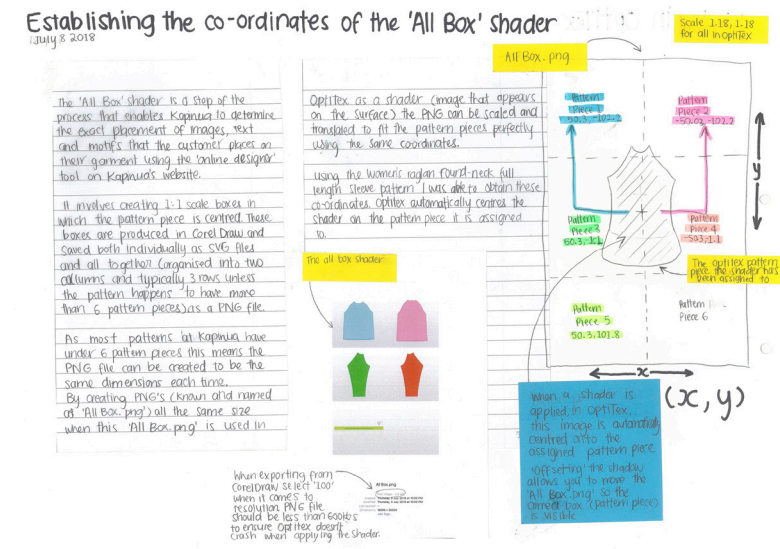
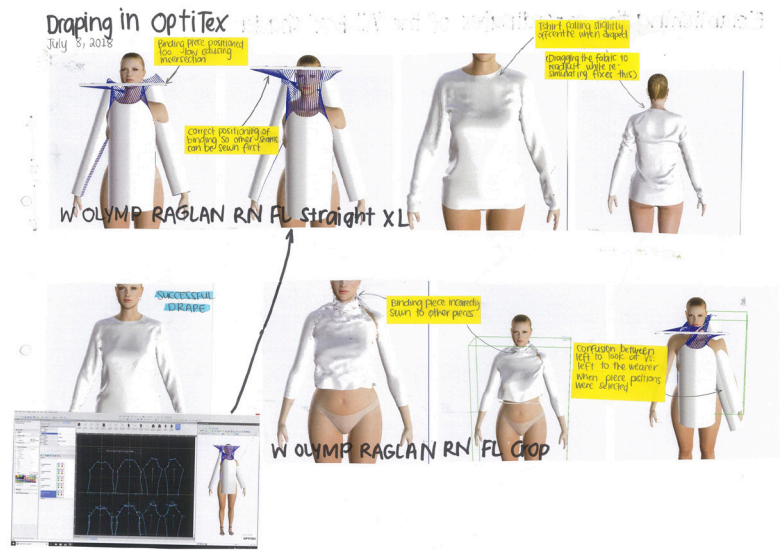
The methodologies of this project align with design professor Richard Buchanan's postulation that "education and industry can become partners, and education might challenge and even lead industry" (Buchanan 64). Cited in Cal Swann's text *Action Research and the Practice of Design*, Swann goes on to argue that the design process is in itself a research process - sharing elements of the objectivity of science and engineering research methodologies, while allowing for the personal interpretation and intuition tied to creative practice (Swann 51, 55). This was very much the case for this project, which followed a synthesized approach to design practice, described as a "spiral of cycles of planning, acting, observing, and reflecting in a systematic and documented study" (Figure 14) (Swann 55). Permission for information and imagery from the documentation to be included in this exegesis has been obtained from the stakeholders and participants. Details on each cycle in their application to this project can be found in the accompanying table and have been categorised according to this model. Additional terms used in Swann's research have been included in parenthesis to provide an alternate way of framing these stages.



(Above) Figure 14. Cross, Nigel. *Engineering Design Methods*, 1989, diagram.

<p>Planning (problem/research).</p>	<ul style="list-style-type: none"> - Foundational information provided by stakeholders in the form of an industry brief. - Project management through the creation of physical and digital timeline projections, and task self-assignment in an A5 daily planner. - Regular direct communication with Kapinua through email, telephone and personal communication. - Indirect public input through Kapinua's communication with customers. - Literary research, primarily on the topics of the applications of technology and automation in design manufacturing, consumer behaviour, industry observation and trends, and fit testing and sizing information. - Online research into program support resources, online forums, third-party tutorial videos, instructional blog posts, and business competitors.
<p>Acting (execution/production).</p>	<ul style="list-style-type: none"> - Fit testing of a sample group to obtain parametric information. - Iterative design experimentation using relevant design software. - Sampling and fit testing conducted either personally or by Kapinua and communicated via email. - Creation of digital content. - Amendments to digital content based on feedback from Kapinua through either email or personal communication.
<p>Observing (analysis).</p>	<ul style="list-style-type: none"> - Documentation of information and process in the form a physical A3 workbook. - Progressional image documentation, usually in the form of digital 'screengrabs'. - Short reports provided to Callaghan Innovation quarterly.

<p>Reflective (evaluation)</p>	<ul style="list-style-type: none"> - Ongoing workbook annotation as a form of self-evaluation and reflective writing. - Regular direct feedback from Kapinua through email, telephone and personal communication. - Compilation of troubleshooting and reference information, compiled in list or chart format. - Development of charts and diagrams to translate observations into an accessible format and determine data trends and workflow patterns.
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(Right) Figure 17. Scans of Workbook Pages 003, personal image by author, 7 Feb 2019.

(Opposite) Figure 18. Kapinua Manufacturing 003, personal photograph by author, 5 Feb 2019.



NZ/AU	BUST (CM)	WAIST (CM)	LOW HIP (CM)
6 (XS)	78/79	60/61	88/89
8 (S)	83/84	65/66	93/94
10 (M)	88/89	70/71	98/99
12 (L)	94/95	75/76	103/104
14 (XL)	99/100	80/81	108/109
16	104/105	85/86	113/114

	XXS	XS	S	M	L	XL	XXL	XXXL
CHEST (CM)	82-88	88-92	92-96	96-100	100-104	104-108	108-112	112-116
CHEST (INCHES)	31-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48

Measurement (CM)	AU 6	AU 8	AU 10	AU 12	AU 14	AU 16
	XS	S	M	L	XL	XXL
	(24 denim)	(26 denim)	(28 denim)	(30 denim)	(32 denim)	(34 denim)
Bust Circumference	78	83	88	93	98	103
Under Bust Circumference	62.5	67.5	72.5	77.5	82.5	87.5
True Waist Circumference	61	66	71	76	81	86
Hip Circumference at widest point	88	93	98	103	108	113
Thigh Circumference at widest point	51	54	57	60	63	66
In-Leg Length	82	82.25	82.5	82.75	83	83.25
Height	169	172	175	178	181	184
Bust Circumference D/DD Cup	80	85	90	95	100	105

Smart Shirts				
Topman Size (To Fit Chest)	Inches	CM	Inches (To Fit Collar)	CM (To Fit Collar)
XXXS	30-32	76-81	13.5	34
XXS	32-34	81-86	14	35.5
XS	34-36	86-91	14.5	37
S	36-38	91-96	15	38
M	38-40	96-101	16	41
L	40-42	101-106	17	43
XL	42-44	106-111	17.5	44
XXL	44-46	111-116	18	46
XXXL	46-48	116-121	18.5	47

ii.

Establishing Sizing Parameters

In order to provide consistency for customers ordering garments with Kapinua, research was conducted into a range of body shape parameters and different standardised sizing systems. It had come to the company's attention that, as they had obtained their patterns from multiple sources, there were some irregularities with the sizing and fit of their existing products (Schleuss, "Personal communication. 21 Nov. 2017") Investigation into the appropriate sizing parameters for the brand was required before any product development could start.

Comparing & Selecting a Size Chart

As discussed in Context III, sizing charts, target body shapes and fit styles can vary greatly between countries and brands. As a globally-reaching company, Kapinua is faced with the challenge of providing a clear and reliable range of sizing options to a breadth of customers - each with different expectations and perceptions of sizing. In order to determine the most appropriate sizing options for Kapinua's clients, research was conducted by sourcing a range of exemplary sizing charts. Sizing charts act as a framework for consumers to find the size that closest resembles their own measurements (Bye et al. 79). It lists the body parameters for each size offered, indicating the measurements which that company has developed its patterns and garments to fit. Cross-comparisons were made between popular domestic and international brands to determine similarities and patterns. This research included New Zealand women's retailer Glassons, men's fashion retailer Hallenstein Brothers, Australian surfwear brand Billabong, and the United Kingdom-based, international retailer TopShop and their menswear label Topman. Sizing chart exemplars were selected based on company prevalence and popularity, so as to get a good indication of common consumer sizing ranges.

As well as offering MTO digitally printed garments, Kapinua work with a supplier to provide ready-made garments which can be embroidered and personalised using Kapinua's machinery (Kapinua, "About" par. 8). On analysing the data of the previously listed range of popular brands, along with the sizing chart of the company Kapinua source their ready-made garments

(Opposite - in descending order)
Figure 19. Glassons. *Dress Sizing Guide Measurement Chart*, 2019, photograph. Glassons, www.glassons.com/size-guide/dresses.

Figure 20. Hallenstein Brothers. *Men's Shirt Sizing Chart*, 2019, photograph. Hallenstein Brothers, www.hallensteins.com/size-guide.

Figure 21. Billabong. *Men's Size Guide*, n.d., photograph. Billabong, au.billabong.com/page/help/size-chart

Figure 22. Topshop. *Size Guide: Dresses*, photograph. Topshop, www.topshop.com/en/tsuk/category/size-guide-6849801/home?geoip=noredirect.

from, it became apparent that the latter offered a suitably median range of parametric measurements. As Kapinua are already offering garments created to these measurements, it was logical to align Kapinua's MTO garments with this sizing chart, further improving fit consistency across Kapinua's range of product. Once these sets of sizing parametric measurements had been determined, this information was later used to create 3D avatars with adjusted properties that replicated the measurements of each size interval.

Assessing Appropriate Base Patterns

As well as working from the same sizing chart, all variations of the same garment needed to be created from one base pattern to ensure patterns had the level of interchangeability required to create structurally customisable products. While Kapinua offers their clients a range of products, t-shirts make up a considerable portion of their orders. Despite having a number of different t-shirt patterns in their library, Ingo reported that they had the most success with their 'Olymp' pattern (Schleuss, Ingo. "Personal communication. 6 Jan. 2018"). Despite reports that the Olymp tee ran 1-2 sizes too small, customers recounted that once the correct size had been selected they were pleased with how the garment looked and felt (Schleuss, Ingo. "Personal communication. 6 Jan. 2018"). This feedback inferred that relabelling the sizes would be an easy resolution, with very little additional fit alterations needed. By developing all t-shirt variations from the men's and women's Olymp t-shirt pattern, Kapinua could ensure fit consistency and work towards creating interchangeable, modular pattern variations. Similarly, the 'Jalie' style of the hoodie was selected due to its popularity, to act as the base pattern for all future hoodie and jersey pattern developments.



(Opposite) Figure 23. *Olymp Tee Shirt Diagram Featuring Polo Render and Photograph of Tom Ashley wearing the Kapinua produced Olympic uniform*, personal image by author and Ben Reyburn, 20 Jan 2019. Modified from: Mu, Sandra. "Tom Ashley Portrait Session", 16 Oct 2008, JPEG image. Getty Images, <https://www.gettyimages.co.nz/detail/news-photo/tom-ashley-poses-with-the-gold-medal-he-won-in-the-news-photo/83289098>

Fit Testing Pre-existing Samples

Once the sizing standards and base patterns had been determined, it was a matter of fit testing a range of sample sizes from each base pattern to highlight any fit issues. Measurements were obtained from a small range of fit models. These measurements were then compared with the chosen sizing chart to classify each model's size according to Kapinua standards. Each model tried on samples in a range of sizes in order to determine the correct fit. The fit was determined through both visual information (pulling, fabric strain and restriction of movement) and verbal feedback from the participants regarding comfort, ease of movement, and personal like or dislike of how each garment looked on their form. Insight into individual sizing expectations and perceptions was also collected, by asking models which size they would normally select when shopping. Models were also asked to provide any additional feedback regarding specific fit concerns, like necklines being too tight or sleeves too long. First conducted with the Men's Olymp tee and singlets, this process was then replicated with the women's sizing samples and Men's Jalie hoodie. This feedback informed how sizes were relabelled and any notable alterations that needed to be made to the base patterns. As a result, minor alterations were made to the Women's Olymp tee, while the Men's Olymp tee and Jalie hoodie were scaled up two sizes.

Due to the scope of this project, participant numbers were limited, with 9 men and 5 women taking part in this process. Further research with a larger number of participants, and more attention to ensuring a wide range of ethnicities, ages, and demographics are represented, would be beneficial to gaining more extensive results. For the purpose of this study, however, positive Kapinua customer feedback suggests that this research while limited was sufficient and successful in addressing the company's primary fit concerns (Schleuss, "Personal communication. 30 Nov. 2018.").

(Opposite) Figure 24. *Parametric Research - Mens 'Olymp'*, personal photographs by author, photographs, 17 May 2018.

(Continued on following page/s)
Figure 25. *Parametric Research - Women's 'Olymp'*, personal photographs by author, photographs, 17 May 2018.

Figure 26. *Parametric Research - Mens 'Jalie'*, personal photographs by author, photographs, 17 May 2018.





iii.

Pattern Development Refining Base Patterns

At the onset of this project, the men's and women's Olymp tee, and Men's Jalie hoodie were only available with a set-in sleeve, and the need for a raglan sleeve had been identified (Scleuss, "Personal communication. 6 Jan. 2018") Developing this pattern was the first step in creating base patterns, as it was decided that creating raglan style tees and hoodies would be the primary focus of the products developed for this project. Using fit testing practices these patterns were created and sampled, requiring a number of iterations before a satisfactory fit was achieved (Armstrong 23-28).

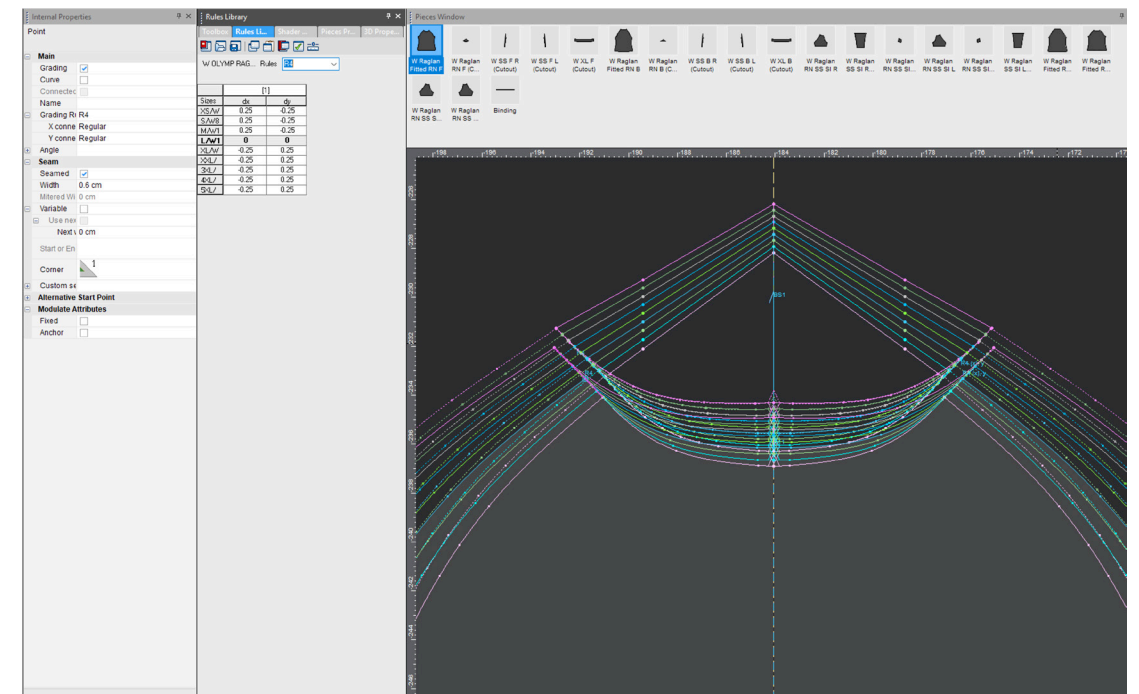
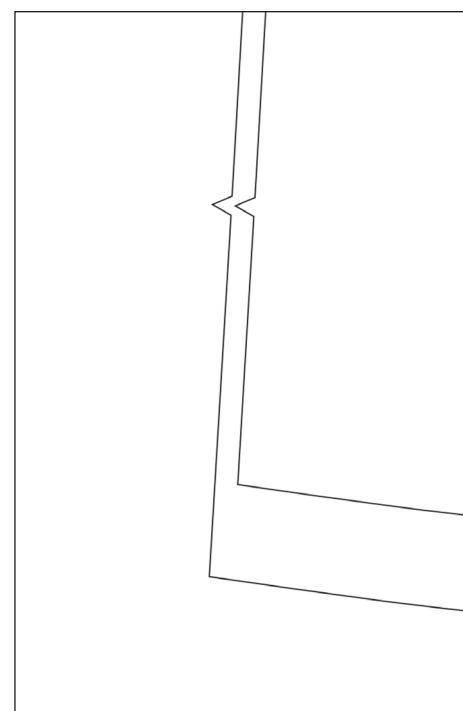
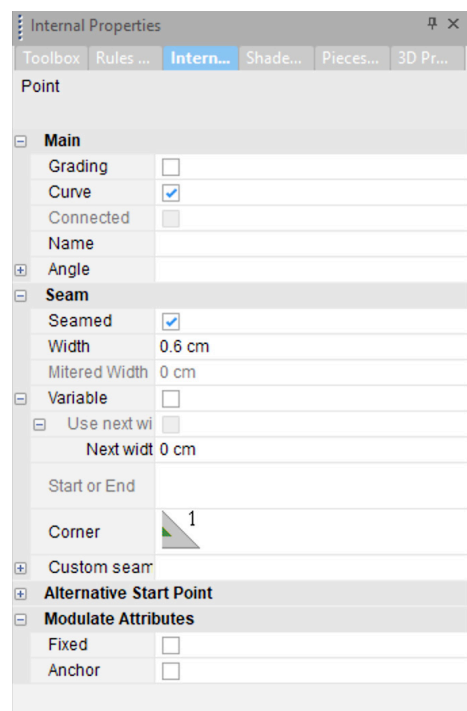
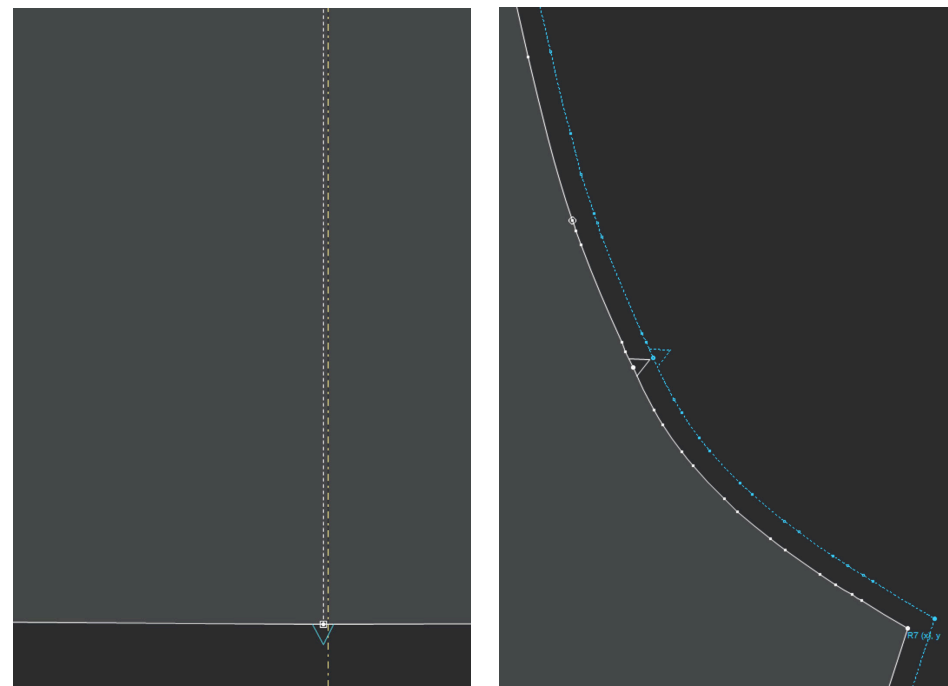
Once the raglan base patterns had been developed, a pattern template was made for each. Because of Kapinua's specialised, digitally integrated system, the required pattern-making practice deviated somewhat from industry standards. While products would typically be developed individually, Kapinua utilizes product variation ranges which allow for the print design application to be automated using a programmed CorelDraw plugin. Because of this, it was important all style variations be developed from the same base pattern, and instead of simply developing standard pattern pieces, negative-space shaped 'cut-outs' was created. The base pattern templates comprise of the longest hemline options available in that style, and necklines are not included. Instead, shoulder seams continue until meeting at the centre-front line or centre-back line, creating a point. This arrow shape, acts as the upper parameters of neckline cut-out pieces, with the bottom of the piece serving as the outline of that neckline. Similarly, shortened sleeve lengths, body lengths, and side seam contouring informed the creation of additional cut-out pieces. These cutouts were always aligned with the perimeter points of the pattern template to ensure easy and accurate placement. In effect, when these cutouts are coloured with a white fill, they act as a mask over the pattern template. Using a combination of these modular masks, multiple customised versions of a single print design can quickly and efficiently be produced. This function is particularly useful with groups or teams wanting multiple styles of the same print design, like the local Roller Derby team who wanted their uniforms to showcase variety and personality and an example of this



patternmaking practice can be seen in Figure 27.

Special attention also needed to be paid to the symmetry of the pattern pieces as many of the mirror lines of existing patterns were ever so slightly angled, causing later inconsistencies and misalignment. Additionally, the number of pattern points were reduced where possible, point properties standardised, and grading points were examined for consistency. Notches also had to be formatted so that they protruded far enough from the perimeter to be registered by the laser cutter, 5mm proving to be the minimum notch width and depth. Process images of these pattern amendments can be found in Figure 28. In many cases alterations were also needed to address minor fit issues, and sizing was adjusted and regulated according to the fit testing conducted in Process II.

(Above) Figure 27. *Olymp Base Pattern template and 'RN SS Fitted' style variation*, personal image by author, JPEG image, 10 Dec 2018.



(Opposite) Figure 28. *Pattern Refinement Screenshots*, personal photograph by author, JPEG image, 4 Feb 2019.

(Above) Figure 29. *Rule table and grading nest of round-neck style [Screengrab]*, personal photograph by author, JPEG image, 4 Feb 2019.

Many of Kapinua's patterns had been purchased with grading or had been graded using the automated, if somewhat rudimentary, digital grading function of the Optitex Pattern Making Suite. With the software automatically applying grading information, this had eliminated Kapinua's need to create standardised rule tables. Rule tables are a chart of values that determine the distance a point moves to create the next size interval and can be applied to both manual and computer-aided patternmaking. While enabling employees without formal grading experience to work with these patterns, having no specific rule tables meant new patterns needed to be created by copying and adjusting pre-graded pieces, hindering the process of developing new styles. It also meant creating new necklines or sleeve lengths was challenging, as this similarly required working with pre-graded pieces to ensure pattern cut-outs shared the same grading properties.

In order to create rule tables, rules were reverse-engineered by naming the points on the automatically or pre-graded pattern pieces, estimating their value, applying this estimation to that point, and looking for changes to

the grade. When the grade was changed, meaning the value estimated had been inaccurate, the 'undo' function was utilized and a new more accurate value was estimated. These steps were often repeated a number of times per rule, and though a time-intensive exercise, once completed, these rule tables provided consistency to the grading of all new and existing patterns. Having a documented rule table for each base pattern allowed any alterations to the grade to be applied to all pattern variations, ensuring the consistency required for modular patterns.

Sampling

Samples were required as new styles were developed, or changes were made to existing patterns. It became apparent that developing a process that utilized Kapinua's short manufacturing lead times would be advantageous, and it became standard practice that patterns would be developed remotely, and emailed to Kapinua where they were printed, laser cut and constructed. Typically, samples of patterns that were in the early stages of development were posted to me or else collected when in Levin, so I could personally identify and resolve any issues. However, as the project progressed and alterations became more iterative and minor, fit testing was often conducted by the team at Kapinua, who would then email any feedback. The advantage of this was it allowed Kapinua to express their opinion on the style and employed the machinists' industry experience and expertise to identify any problems that may have been missed. As the base patterns had been thoroughly tested and refined, samples were not created for every configuration of modular features. Instead, garments were only sampled when featuring a whole new neckline or sleeve option, preventing the unnecessary use of labour and resources.



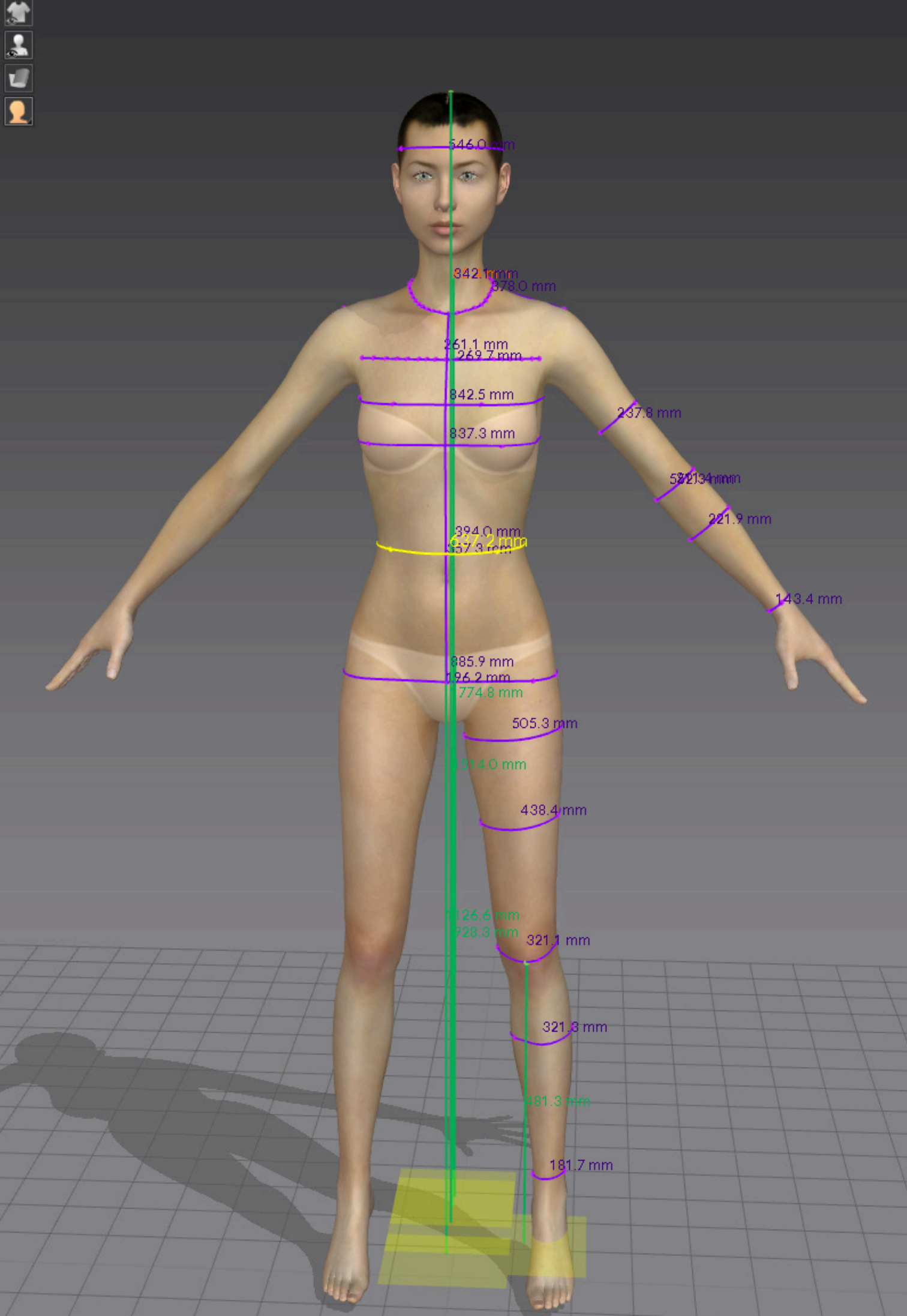
(Opposite) Figure 30.
*Early sample of the Women's
Raglan Tee*, personal photograph
by author, photograph,
17 May 2018.



Production Planning

As it became apparent that developing new modular variations and their corresponding cut-out pieces was one of the more time-intensive aspects of developing Kapinua products, it made sense to make a number of varying configurations from each neckline and sleeve style that was developed. While the combinations of components felt somewhat limitless, it was important to prioritise which variations were valuable for the company. This was ascertained through discussion with Ingo who was able to speak to which style combinations had been requested or suggested by customers. The Men's Polo style variations were a priority for the brand, however, they required more advanced knowledge of digital drape simulation and software functions. Instead, these tee configurations were created towards the conclusion of the project, and the simpler round neck and v-neck style variations were completed first. Of the round neck and v-neck garments (both Men's and Women's), the full-length and short-sleeve variations were completed first. Later, crop sleeves, extra-short-sleeves, and a Women's cap-sleeve were created. For each neckline and sleeve-length combination, four variations were created; a fitted regular-length; fitted extra-long; unfitted or 'straight' regular-length; and straight extra-long. The four variations of each neckline and sleeve combination were always created sequentially as they required little alteration beyond inclusion or exclusion of side seam contouring and hemline cutouts. All pattern variations of a single neckline style were consolidated into a master file for quick accessibility, and later duplications of each pattern were included in these master files with 3D properties applied where possible. Lists and later checklists were numbered in order of priority to create a loose production plan, however, this list was updated and revised as the project progressed.

(Opposite) Figure 31. *Kapinua Manufacturing 004*, personal photograph by author, photograph, 5 Feb 2019.



iv.
**Familiarisation
 with the Existing
 Digital System**

6 Weeks Training

One of the earlier stages of this project was six weeks of intensive, hands-on training with Ingo. This involved receiving instructions and tips for completing each task of the existing digital content creation process, as well as a chance to interact and learn from employees responsible for other manufacturing stages. During this time, a children's towel was developed as a method of learning and applying this knowledge. The structurally simple pattern served as an exemplar to test software functions and drape simulation properties.

Assessing Different Software Options

Preparing products for Kapinua's online platform requires an assortment of files serving a variety of functions. To produce these files a pattern must be created and graded using 2D pattern making software, processed with a vector image editing program, draped using 3D pattern functions, and adjusted and rendered using 3D modeling software. Kapinua's system had been creating using the programs Optitex, CorelDraw and Daz3D for each of these functions. One of the objectives outlined in the brief was to conduct research into software alternatives to ensure these were the best suited and most effective programs for the job. This research was carried out by assessing the functions and User-Interface of each program based on the criteria outlined in the tables on the following pages. As a way of testing this, a simple Women's poncho or Children's towel was created using each of the software options. The information obtained through this testing, and a further description detailing the function of each type of software, has been included.

(Opposite) Figure 32. *Marvelous Designer Screenshot*, personal photograph by author, photograph, 17 Dec 2017.



PATTERNMAKING CAD SOFTWARE

Used to digitally prepare patterns, apply grading and drape garments onto a 3D avatar.

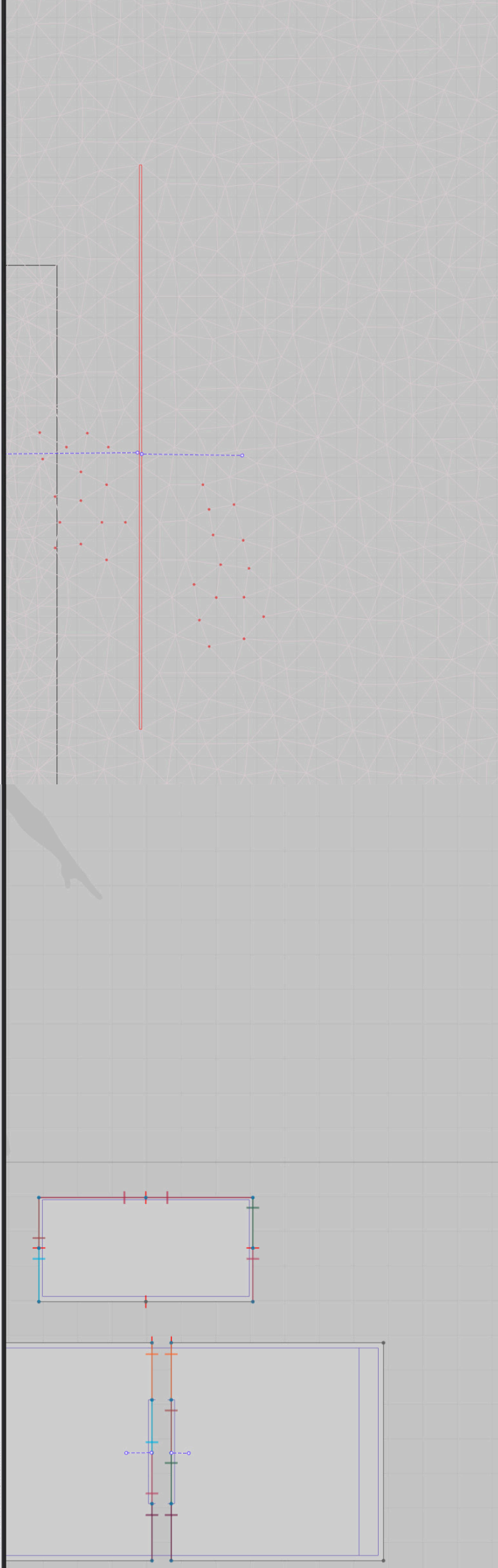
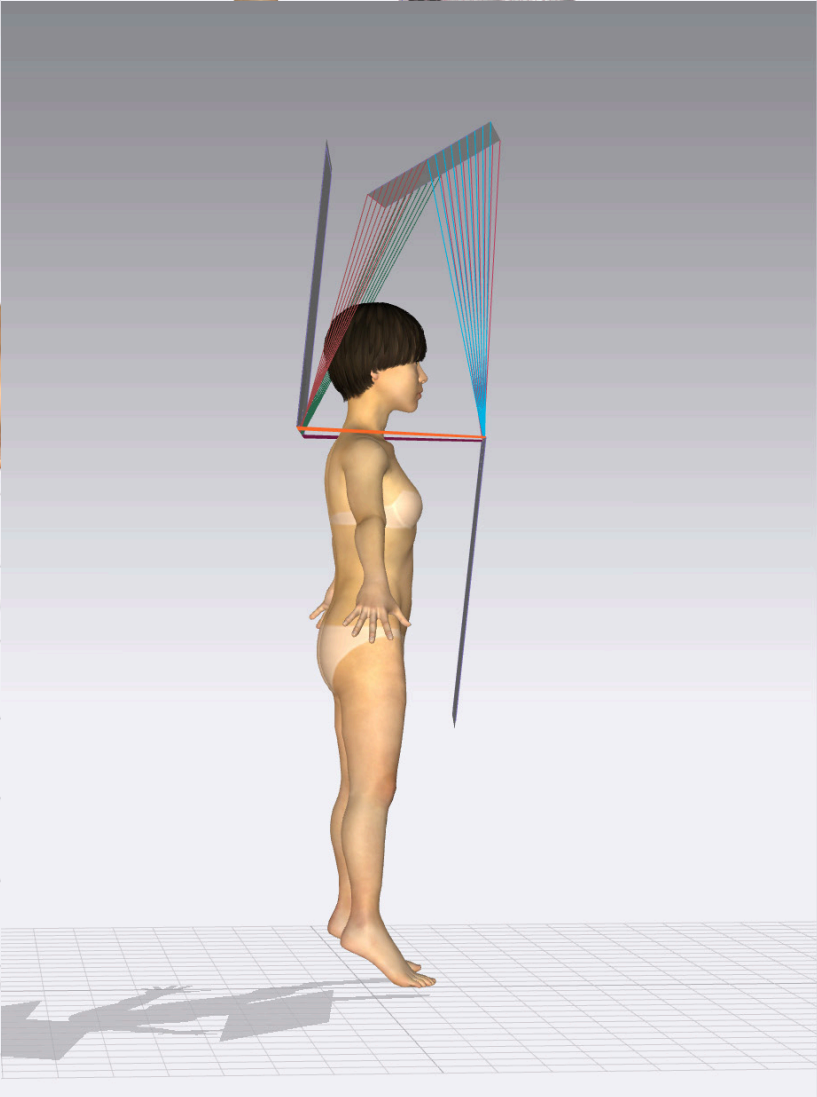
	OptiTex	Clo3D	Marvelous Designer	Gerber AccuMark
Affordable software licensing	X	Yes	Yes	X
Cloud-based licensing	X	Yes	Yes	X
Suitable import/export function	Yes	Yes	X	Yes
2D and 3D function integration	Yes	Yes	Yes	X*
Intuitive User-Interface (UI)	X	Yes	Yes	X
Comprehensive 2D patternmaking tools	Yes	X	X	Yes
Satisfactory 2D pattern accuracy	Yes	X	X	Yes

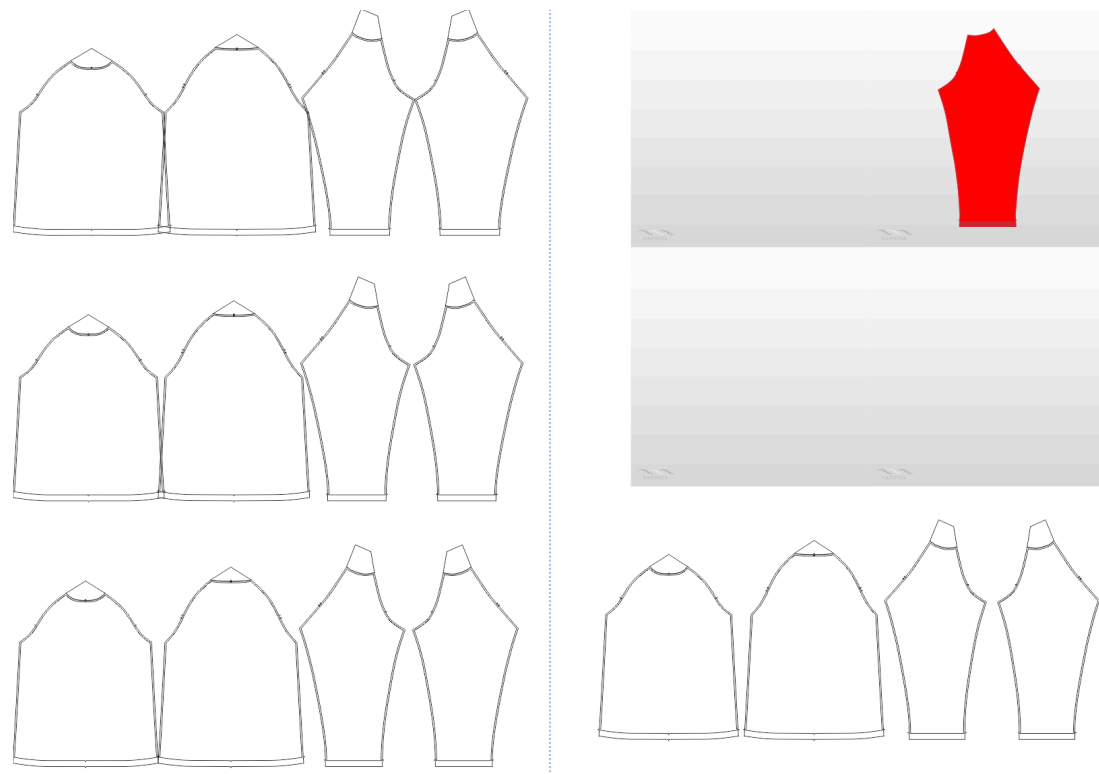
*At the time of research, Gerber had not yet released their AccuMark 3D software

Though both CLO3D and Marvelous Designer had notably superior 3D drape functions, cheaper and more accessible licensing options, and far more intuitive and easy-to-master user-interfaces (UI), neither offered the 2D patternmaking accuracy necessary for Kapinua’s manufacturing process. As Gerber AccuMark had not yet released their 3D patternmaking software, this left Optitex as the obvious choice, despite its inferior UI and expensive licensing. It would be beneficial to replicate this research process in a few years as new versions of each program emerge, and new software options enter the market.

(Opposite) Figure 33. *CLO3D Drape Trial Screenshot 001*, personal photograph by author, photograph, 15 Dec 2017.

(Continued on following page/s) Figure 34. *CLO3D Drape Trial Screenshot 002*, personal photograph by author, photograph, 15 Dec 2017.





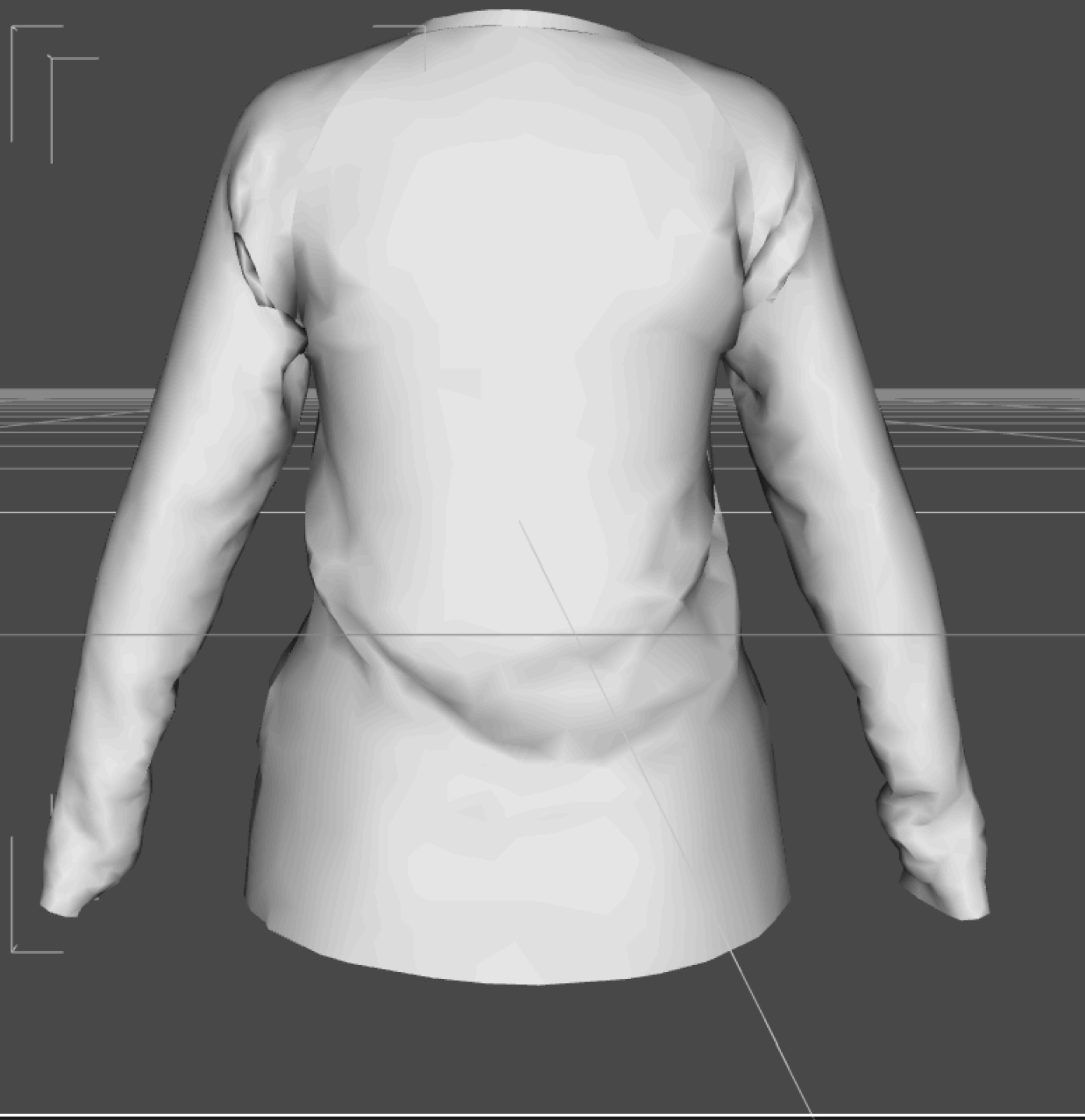
VECTOR IMAGE EDITING SOFTWARE

This software is used to prepare exported PLT (plotting) files of finalised patterns for garment printing and establishing templates.

	CorelDraw	Adobe Illustrator
Affordable software licensing	Yes	Yes
Cloud-based licensing	X	Yes
Suitable import/export function	Yes	Yes
Intuitive User-Interface (UI)	X	Yes
Satisfactory line accuracy	Yes	Yes
No limitations on size of digital canvas	Yes	X
Custom programmed tools	Yes	X

Similarly to CLO3D and Marvelous Designer, Adobe Illustrator offers superior licensing and UI but fails to meet key criteria for Kapinua’s manufacturing. Due to the unique requirements of Kapinua’s digital system, the vector images of the company’s patterns must be presented as a 1:1 ratio. This equates to many metres of digital canvas or ‘artboard’ space, a function Adobe Illustrator does not accommodate. Additionally, Kapinua has worked with a programmer to create a number of CorelDraw plug-in tools specific to their processes. Replicating this in Adobe Illustrator would be a costly and labor-intensive task.

(Opposite) Figure 35. *CorelDraw file Screenshot*, personal photograph by author, photograph, 5 Jul 2018.



3D MODELLING SOFTWARE

Produces OBJ (object) files of 3D drape meshes and is used to render high-quality images of garments, including images where the product is draped and styled on an avatar and within a scene.

	DAZ3D	Unity	Unreal Engine	Blender	Maya
Affordable software licensing	Yes	Yes	Yes	Yes	Yes
Cloud-based licensing	Yes	Yes	Yes	Yes	Yes
Suitable import/export function	Yes	Yes	Yes	Yes	Yes
Intuitive User-Interface (UI)	Yes	Yes	Yes	Yes	Yes
High-Quality Image Rendering Function	Yes	X	X	Yes	Yes
Scene Preparation	Yes	Yes	Yes	X	Yes
Purchased 3D avatars & assets	Yes	X	X	X	X

Unity and Unreal Engine did not provide the high-quality image rendering functions required for Kapinua’s process, and Blender is more geared towards creating new assets rather than importing and preparing scenes.

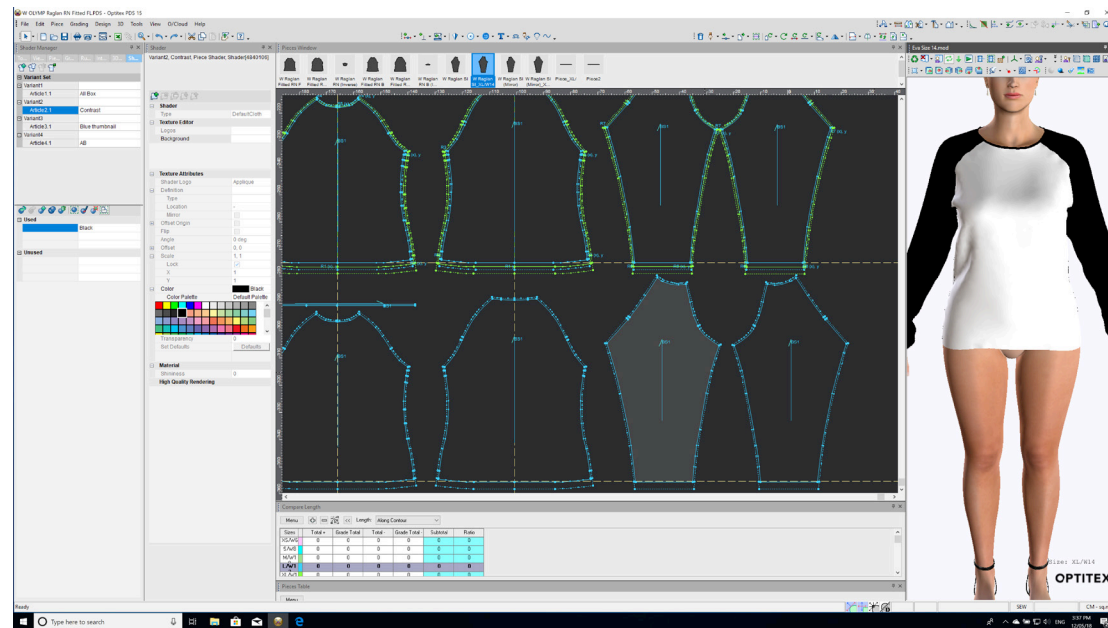
Maya was the most comparable to DAZ3D in the context of Kapinua’s purposes, but it made little sense to move away from DAZ3D when Kapinua had already invested in purchasing a range of 3D avatars and assets compatible with that program.

(Opposite) Figure 36. *DAZ3D Product Mesh Screenshot*, personal photograph by author, photograph, 8 Jul 2018.



After an extensive amount of experimentation with relevant software alternatives, it was concluded that none of the other software options offered any functions warranting the time and resources required to deviate from the already implemented programs. A need was identified, however, to develop informational resources to assist with some of the unaddressed glitches with the existing software, difficult-to-learn UI, and limited software support services, particularly in the case of the Optitex Patternmaking Suite. Drafting preliminary iterations of such resources, which might later be developed by a visual communication designer if the company wished, was included as an additional objective of the project.

(Opposite) Figure 37.
Kapinua Manufacturing 005,
personal photograph by author,
photograph, 5 Feb 2019.



v. Developing & Refining the Digital System

Making the Pattern Library

With sizing and base patterns prepared, Kapinua training completed, and suitable software determined, work started on building the 3D integrated pattern library. Following the production plan that had been created, development commenced on the women's round neck and v-neck styles. The time frame it took to complete each product shortened exponentially as the project progressed, and insight into specificities on each task, and workflow patterns observed, informed how the process was refined over time.

Technical Challenges

Despite the 6 weeks of training, further clarity was still needed on some tasks, and replicating the system proved more difficult than anticipated. Installing Optitex, CorelDraw and DAZ3D involved obtaining licenses from Kapinua, downloading the necessary programs, and locating and copying files and assets specific to Kapinua's process onto my personal computer to enable remote working. As I work primarily from a Mac, a program was required to accommodate the Windows-compatible Optitex software and CorelDraw which Kapinua had purchased with a Windows license. Though the disk-partitioning software Bootcamp was first trialed, this was later replaced by the program Parallel. Unlike its predecessor, Parallel allowed for the simultaneous running of both Mac and Windows operating systems (OS), allowing for the kind of multitasking that was later implemented. All programs had specific characteristics and properties that needed to be learned to create Kapinua's content successfully, and Optitex, in particular, had a number of bugs that had not yet been resolved by the software distributor. All of these technical challenges were resolved, and notes were taken both for the documentation of this project, and for the benefit of future employees. These challenges along with their solutions, including any issues with digital drape simulation of garments, can be found in the table on the following page. While not exhaustive, this list exemplifies the kind of ongoing learning that informed the refinement of the process. In the future, Kapinua would benefit from translating this information into troubleshooting resources for future employees to learn from and add to.

(Opposite) Figure 38. *Women's Round-Neck Raglan Optitex Screengrab*, personal photograph by author, photograph, 12 May 2018.

Technical Challenge	Type of Challenge	Resolution
OptiTex cannot be installed and operated on a Mac OS.	Software installation.	Install program that allows Mac to run Windows OS.
Boot Camp software does not allow Mac and Windows OS to run simultaneously.	Software installation.	Remove Boot Camp software and install Parallel.
Pattern piece not symmetrical despite mirror line appearing vertically straight.	2D pattern.	<ul style="list-style-type: none"> - In OptiTex create a guideline by dragging from the edge of the ruler (ctrl + r if ruler is not visible) and place directly over the mirror line. - Starting with one of the points of the mirror line, use max zoom to enlarge point as much as possible, and reposition guideline if necessary so directly over mirror line. - Move viewfinder to the other point of the middle line and use max zoom, move point if even slightly off centre from the guideline.
Pattern piece has no mirror line in OptiTex.	2D pattern.	<ul style="list-style-type: none"> - Create a top and bottom point on pattern piece along the centre front or centre back line if not created already. - Select 'Set Mirror Line' in <i>Toolbox</i> under the 'Half Symmetry' submenu and click the appropriate points on pattern piece. - Check mirror line is completely vertically straight by creating a guideline.

Incorrectly shaped curve on pattern piece.	2D pattern.	<ul style="list-style-type: none"> - In OptiTex check the correct grading rules have been applied to relevant grading points on that line. - Select a non-graded point on the curve, then select and deselect the grading option in <i>Internal Properties</i>. This will adjust the shape of the curve according to the properties of the other graded points along that line.
Seam allowance is not the correct angle when applied in OptiTex.	2D pattern.	Re-apply seam allowance and select option I for both the beginning and end of the seam line.
Grade rules not loading when OptiTex file is opened.	2D pattern.	Reopen rule table file in <i>Rules Library</i> window.
Unable to create internal lines on pattern pieces in OptiTex.	2D pattern.	Instead of using the 'Draft' tool to create a line, select the 'Create Parallel' tool from the toolbar, then select the line you are wanting to offset, inputting the correct distance from the perimeter line of the pattern.
Internal lines not visible when OptiTex file is reopened.	2D pattern.	<ul style="list-style-type: none"> - Create an additional internal line using the 'Draft' or 'Create Parallel' functions on the applicable pattern pieces - doing so will cause the existing internal lines to appear, then delete the newly created internal line. - This process may need to be repeated on reopening of OptiTex file as this is an unresolved error with the program.

Technical Challenge	Type of Challenge	Resolution
Program lagging when garment draping is simulated in OptiTex.	Digital draping.	<ul style="list-style-type: none"> - Shut down computer and program, allow time for hardware to cool before rebooting. - If problems persist, reduce mesh resolution by selecting 'Simplify Cloth' in <i>Model window</i>.
Stitching is reversed causing bunching of pattern pieces when draped in OptiTex.	Digital draping.	Select the affected stitch and select the 'Flipped' setting in <i>3D Properties</i> .
Front and back pieces intersecting sleeve pieces when draped on 3D avatar in OptiTex causing bunch at underarms when draped.	Digital draping.	<ul style="list-style-type: none"> - Increase the percentage of the cylinder shape of each affected pattern piece in <i>3D properties</i> under 'Positioning' - change sleeves to 100% and front and back pieces to 60%. - Move the position of the front and back pieces further away from the 3D avatar's body to allow the sleeve seams to be stitched before colliding with the front and back pieces.
Binding on round-neck tee gapes when digitally draped in OptiTex.	Digital draping.	<ul style="list-style-type: none"> - Change shrinkage of binding piece in 3D properties under 'Fabric Parameters' to '25%, 0%'. - Adjust thickness settings of binding piece in <i>3D properties</i> to 3-4mm.

Polo collar not folding correctly; part of polo collar disappearing into the front piece when draped.	Digital draping.	<ul style="list-style-type: none"> - Select cylinder as the positioning shape of collar in <i>3D properties</i> instead of folded or flat. - Apply fold 'Left/Right' and 'Out' to position settings of the collar in <i>3D properties</i>. - Alternatively, use the polo collar that has already been successfully draped and alter the points if necessary to same time troubleshooting drape properties.
Armhole of digitally draped singlet gaping at front despite fitting correctly when sampled.	Digital draping.	In OptiTex change shrinkage of front piece in <i>3D properties</i> under 'Fabric Parameters' to '25%, 0%'.
Collar or binding snagging on the hair of the 3D avatar in OptiTex.	3D drape mesh.	<ul style="list-style-type: none"> - Remove ponytail by selecting 'Model Properties' in the <i>Model window</i>. - Alternatively, reposition and reangle the placement of the affected pattern piece in the <i>Model window</i> using the '3D Move Piece' and '3D Rotate Piece' functions or corresponding shortcuts.
Unable to select stitch options in OptiTex.	3D drape mesh.	Ensure that the <i>Model window</i> is open and ensure 'Show Stitch Mode' has been selected before selecting the stitch line - adjustments can then be made once the stitch has been successfully selected using the <i>3D properties window</i> .
Topstitching not appearing on 3D drape in OptiTex.	3D drape mesh.	<ul style="list-style-type: none"> - Check the internal line has been stitched using the 'Stitch' tool in the <i>Model window</i>. - Select the stitch and change the resolution in <i>3D properties</i> 0.5cm.

Technical Challenge	Type of Challenge	Resolution
OptiTex program lagging when adding or adjusting stitch properties.	3D drape mesh.	Remove pieces from 3D avatar so program does not have to continually update 3D view, improving computer processing time.
OptiTex program crashing when 'All Box.png' shader is applied.	3D drape mesh.	<ul style="list-style-type: none"> - Decrease file size by reducing image resolution to 72 dpi when exporting 'All Box.png'. - Close <i>Model</i> window whenever possible so that program does not have to continually update 3D view, improving computer processing time. - Adjust shader placement using numerical coordinates rather than manually adjusting on 3D avatar.
OptiTex program crashing when exporting FBX file.	File import/export.	<ul style="list-style-type: none"> - Close all other applications. - Ensure device is plugged into power-source if working off laptop. - Once 'Save' option has been selected, do not interact with device until image exporting complete. - If problem persists, select 'Simplify Cloth' option from <i>Model</i> window.
Carrara program not opening on Mac OS.	Software installation.	Glitch in Mac version of software - install and use Windows version through Parallel instead.
Purchased DAZ3D assets not appearing in <i>Smart Content</i> window of DAZ3D.	Software installation.	<ul style="list-style-type: none"> - Check sign-in settings of DAZ3D to ensure the correct account has been accessed and that there has not been a sign-in error. - Open the Installation Manager application and reimport assets if necessary.

Unable to import CLT files into DAZ3D.	Software installation.	Ensure the correct Dynamic Clothing plugin has been installed - CLT importation feature is only available with this plugin.
Unable to export MOD files successfully into DAZ3D.	Software installation.	Ensure the correct Dynamic Clothing plugin has been installed.
Unable to import DAZ3D presets into program.	Software installation.	<ul style="list-style-type: none"> - In the <i>Content Library</i> window of DAZ3D locate the 'Presets' subfolder of 'My Library'. - Select the 'Presets' folder and then click 'Browse to Folder Location...' from the right click menu, a file explorer or finder will open. - Copy preset files into this folder location, creating subfolders to organise presets if necessary. - Reboot DAZ3D program - preset should now appear in appropriate subfolders in the <i>Content Library</i> window.
DAZ3D Dynamic Clothing function not working.	Software installation.	Reinstall plugin using Install Manager application, ensure licence key has been activated by opening 'About Installed Plugins' window from 'Help' drop-down menu.
Additional clothing pieces, footwear and hairstyles not applying to the selected model correctly.	3D drape mesh.	<ul style="list-style-type: none"> - If minor, re-angle camera lens to hide drape issue if possible, alternatively smooth appearance of fabric in post-production using photoshop - If major, select a different model as not all assets are compatible with all avatar models.

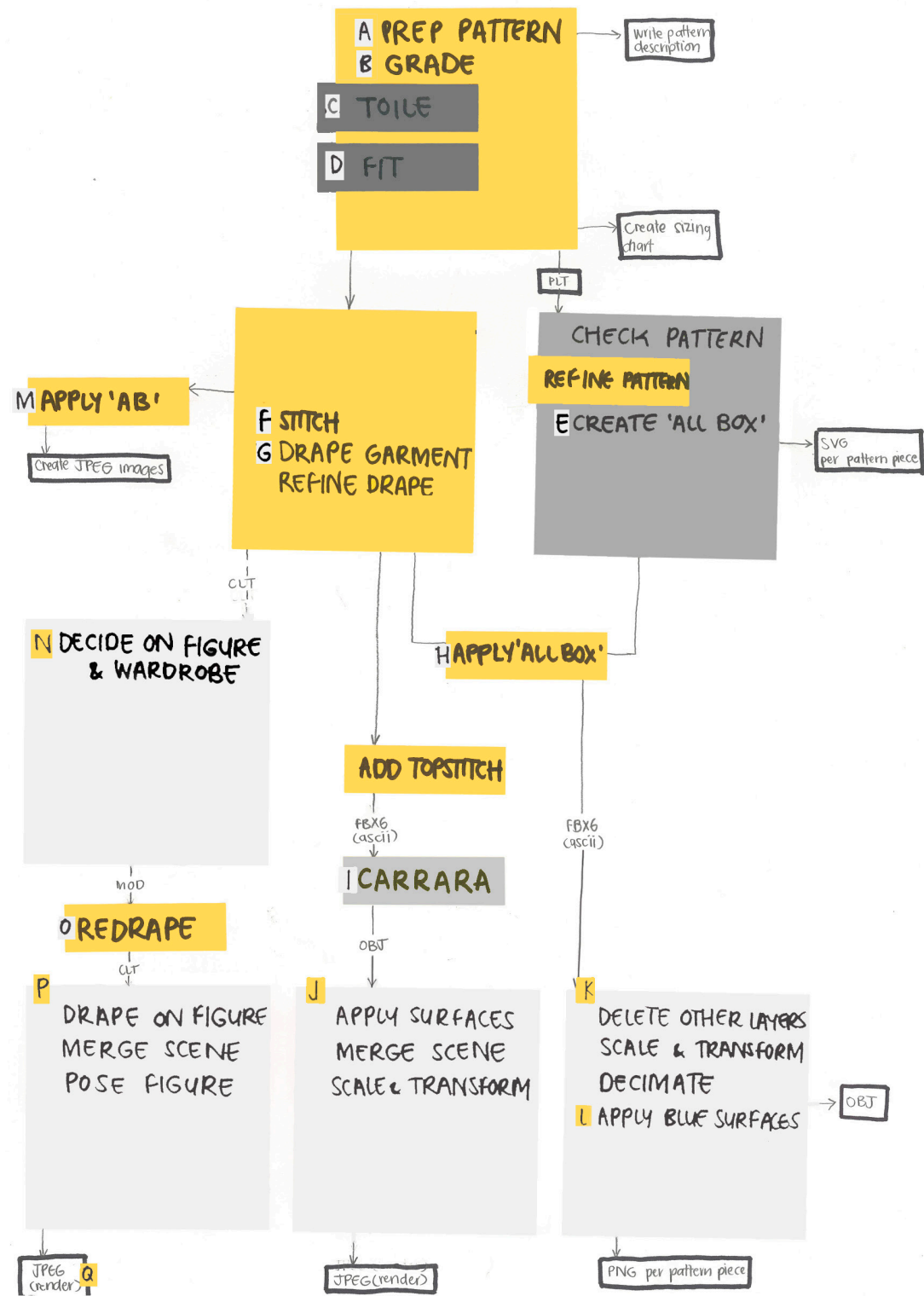
Technical Challenge	Type of Challenge	Resolution
Cloth mesh bunching or pulling when draped on avatar in DAZ3D.	3D drape mesh.	<ul style="list-style-type: none"> - If minor, re-angle camera lens to hide drape issue if possible, alternatively smooth appearance of fabric in post-production using photoshop. - If major, select a different pose for the avatar with less body contortion and re-import and redrape the CLT file. - Note: select poses with minimal arm movement for long-sleeve garments, poses with arms lifted can be used for trousers, short sleeve tees and sleeveless dresses or tee shirts.
Parts of avatar or additional clothing appearing through cloth when draped on avatar in DAZ3D.	3D drape mesh.	<ul style="list-style-type: none"> - If minor, re-angle camera lens to hide drape issue if possible, alternatively smooth appearance of fabric in post-production using photoshop. - If major, create a 3D primary shape in DAZ3D, scale and translate over part of avatar causing drape issues (for example create a sphere slightly larger than avatar head if ears are causing poke-through) - export object and avatar as MOD or OBJ file and redrape garment in OptiTex on this model.
Avatar hairstyle causing issues with clothing drape in DAZ3D.	3D drape mesh.	<ul style="list-style-type: none"> - Remove 'ponytail' or other protruding hair options from avatar for the seconds of the scene timeline when the cloth is still draping, re-apply hair functions once.

OBJ file exported from DAZ3D too large to be uploaded to Kapinua's digital platform.	File import/export.	<ul style="list-style-type: none"> - Apply 'Decimator' function to each pattern piece by selecting the appropriate component of the FBX file from the hierarchy in the Scene window. - exported OBJ file should be no larger than 1mb (recommended decimator settings for front and back pieces is 30-60%; sleeves 40-80%; binding 80-100%).
3D mesh displaying obvious polygons when rendered.	Rendering.	<ul style="list-style-type: none"> - Ensure only one surface shader is applied to garment object in DAZ3D - re-import object if necessary. - Use a different surface shader if problem persists ('PDISK Cotton' is recommended). - Apply the SubD function which subdivides the mesh polygons, refining the appearance of the mesh. - Keep in mind the more polygon subdivision applied to the object the slower render processing time will be (Render level 2 is recommended). - Select the 'Smooth surfaces and corners' function from the SubD settings.
Inconsistent lighting when rendering 4-view product images in DAZ3D.	Rendering.	Utilising the scene timeline feature, apply staggered rotation to the object instead of the camera, this will ensure consistent lighting for all images.

Technical Challenge	Type of Challenge	Resolution
Images taking hours to render in DAZ3D.	Rendering.	<ul style="list-style-type: none"> - Delete any hidden or unnecessary objects from the scene. - Change the 'Max time (secs)' setting to a lower number (7200 recommended) in the <i>Render Settings</i> window. - Leave computer to render over night - when creating product images multiple garments can be left to render in the one session by utilising the scene timeline and moving the appropriate object into view of the camera at different intervals of the timeline. - Alternatively, use the Kapinua computer if it has a higher power graphics card.
Ground visible when product images are being rendered in DAZ3D.	Rendering.	Select 'Off' option on 'Draw Ground' setting in <i>Render Settings</i> .
Background appearing black when product images are being rendered in DAZ3D.	Rendering.	Select 'Backdrop' from the drop down menu in the <i>Environment</i> window - then select the background colour once options have appeared.
Program starting to lag after rendering multiple images.	Rendering.	<ul style="list-style-type: none"> - Close all other applications. - Restart program. - Reboot computer if problem persists.



(Above) Figure 39. *Experimentation with Drape Simulation Properties of Round-Neck Binding Piece [Screengrabs]*, personal photographs by author, photographs, 26 May 2018.



Flow Chart

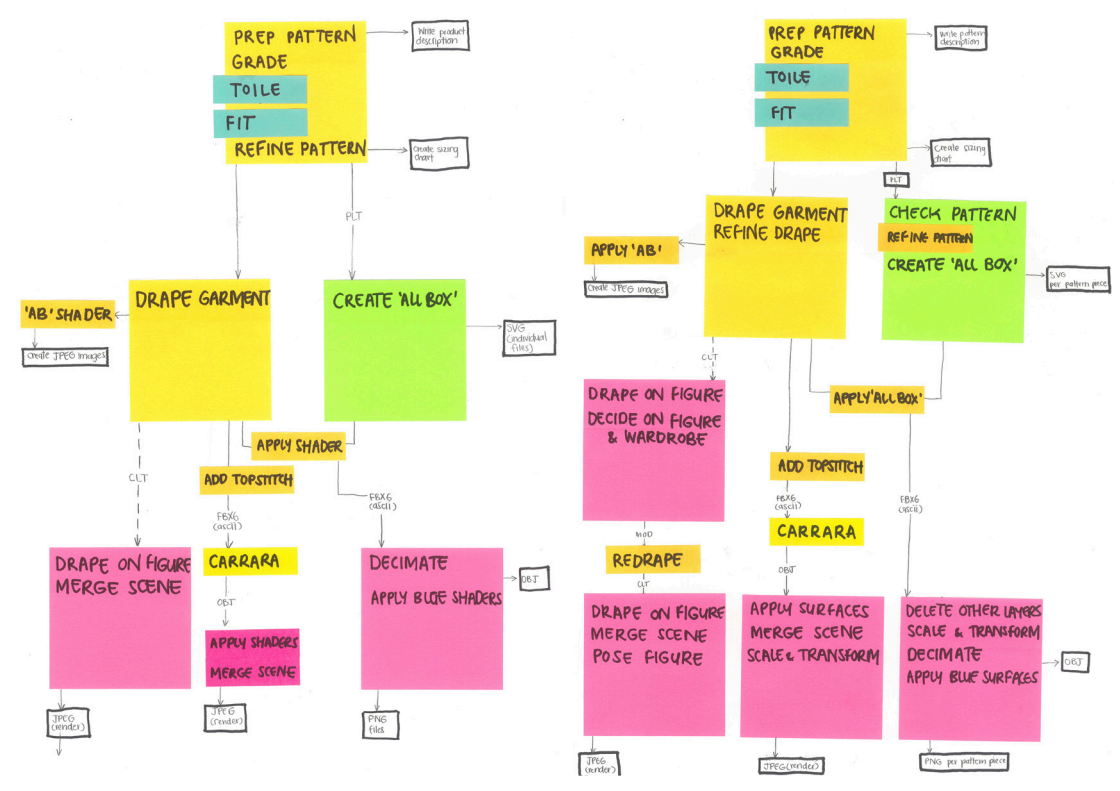
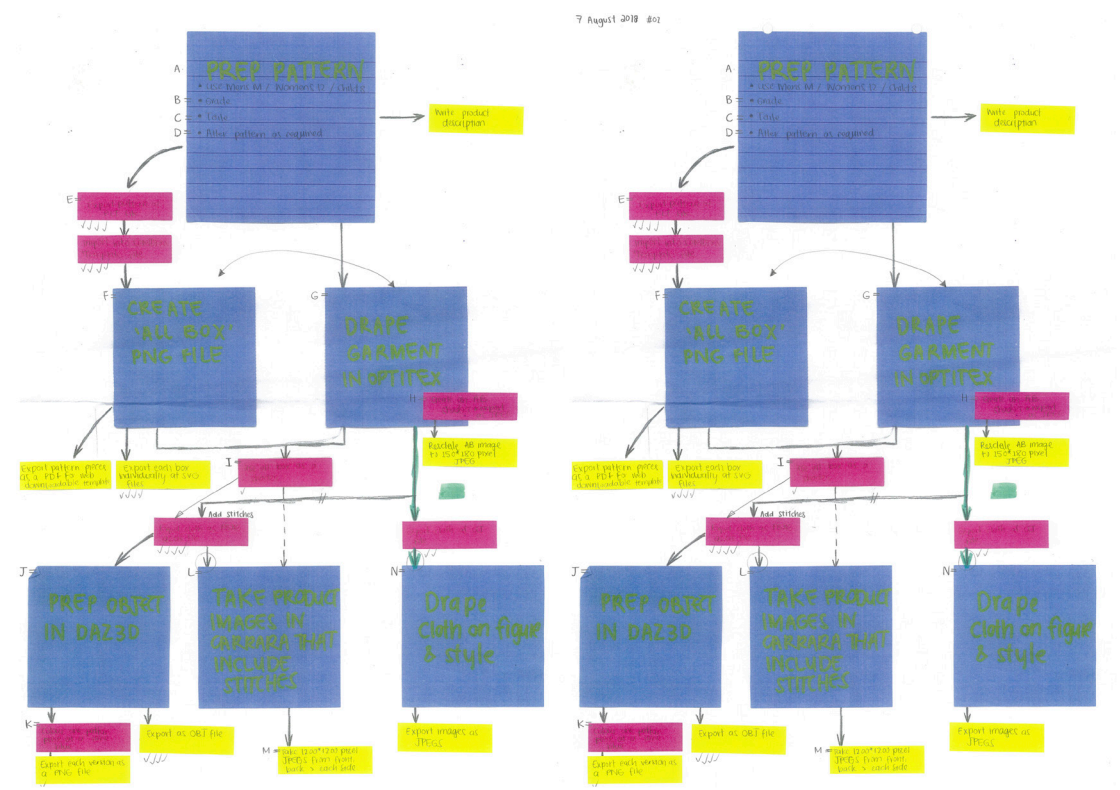
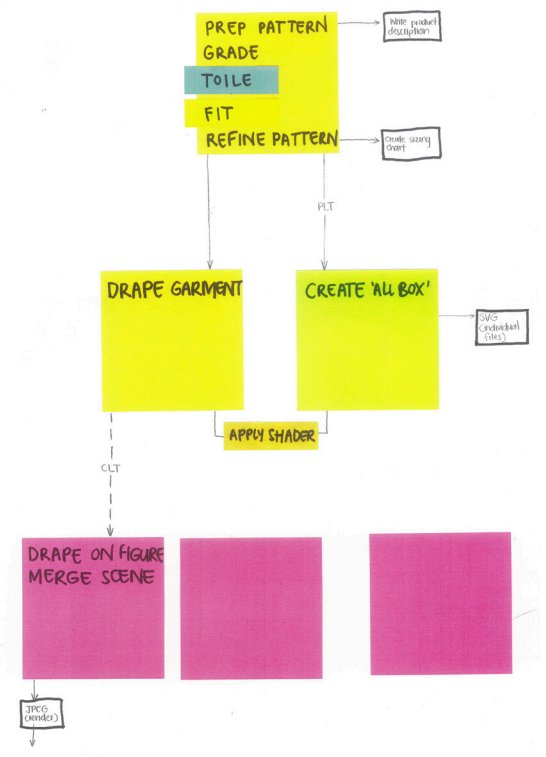
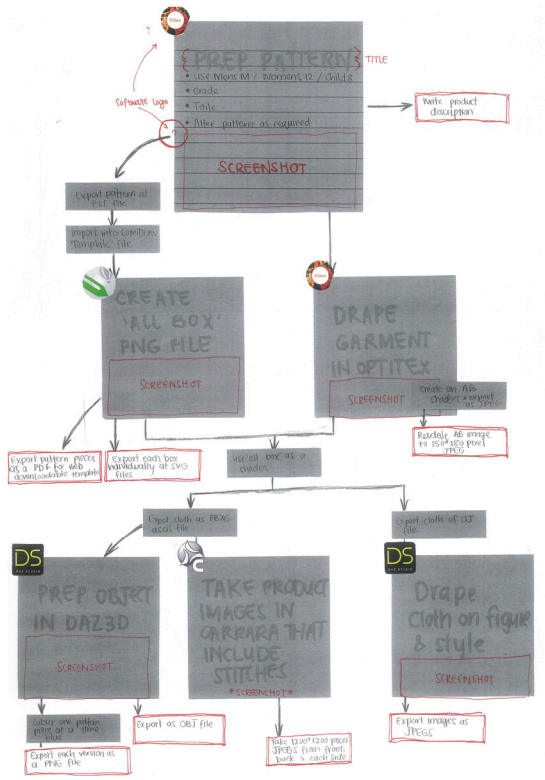
Prior to this project, instructional resources on Kapinua’s digital content creation process were limited to an excel spreadsheet. The spreadsheet, an itemised list of steps presented in sequential order, contained some general information regarding which program was to be used and which file type was involved with each step. While helpful, this resource required the foundational knowledge acquired through hands-on training at Kapinua. Though this kind of one-on-one learning is ideal, it puts a strain on the company’s productivity who cannot be expected to delay fulfilling orders in lieu of addressing these informational needs. A more comprehensive breakdown of tasks was needed, one that also reflected the flexibility in the sequence that the process afforded.

A series of flow chart iterations were developed over time as my comprehension of the system improved. This resource was developed simultaneously to making the pattern library, informed by observations that came from repeating the process to develop each style variation. Representing the process as a flow chart, turned out to offer additional benefits beyond remembering the sequence of steps. As the technical challenges outlined in Process I were identified, this resource enabled the quick identification of other tasks that could be completed while working through these roadblocks. It also helped to clarify the purpose of different file types and tasks, and their relation to the process as a whole. While the final version of the flowchart would benefit from future revision by a visual communication designer, it contains all the structural and informational components required to inform future users, and successfully improved efficiency within this project.

(Opposite) Figure 40. *Final Flowchart Iteration*, personal image by author, JPEG image, 9 Feb 2019.

(Continued on following page/s) Figure 41. *Development of Flowchart 001*, personal image by author, JPEG image, 9 Feb 2019.

Figure 42. *Development of Flow Chart 002*, personal image by author, JPEG image, 9 Feb 2019.



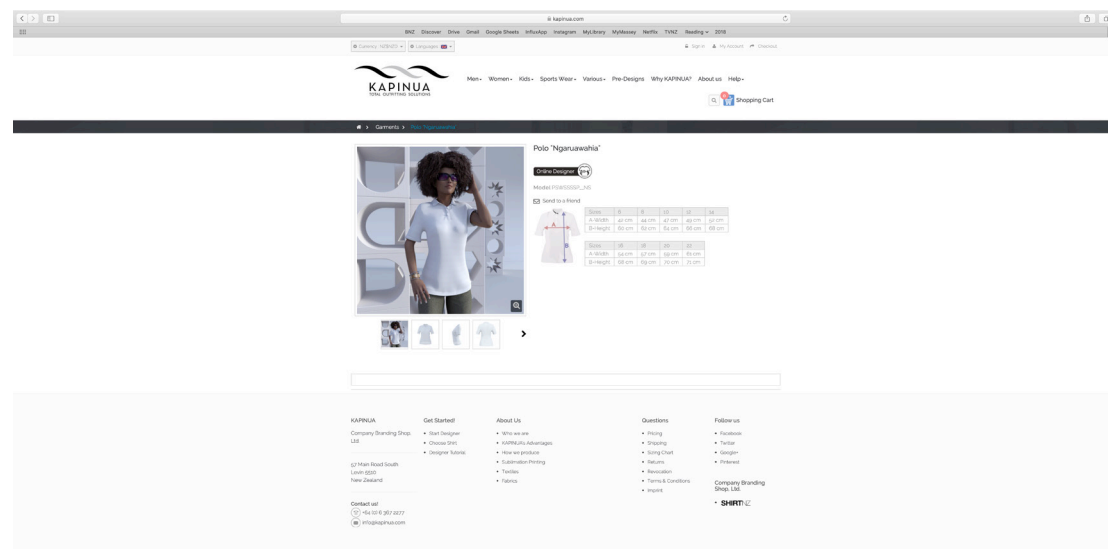
	Prep Pattern	Grade	Toile	Fit	'All Box' (Corel)	Stitch	Drape garment	'All Box' shader	Carrara	Product images	Prep object	Apply blue surfaces	AB images	Prep DAZ figure	Redrape in Optitex	Prep scene & render	Photoshop
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
W Raglan RN FL Fitted	1																
W Raglan RN FL Fitted XL	2																
W Raglan RN FL Straight	3																
W Raglan RN FL Straight XL	4																
W Raglan RN SS Fitted	5																
W Raglan RN SS Fitted XL	6																
W Raglan RN SS Straight	7																
W Raglan RN SS Straight XL	8																
W Raglan RN XSL Fitted	45																
W Raglan RN XSL Fitted XL	46																
W Raglan RN XSL Straight	47																
W Raglan RN XSL Straight XL	48																
W Raglan RN C Fitted	49																
W Raglan RN C Fitted XL	50																
W Raglan RN C Straight	51																
W Raglan RN C Straight XL	52																
W Raglan RN Cr Fitted	53																
W Raglan RN Cr Fitted XL	54																
W Raglan RN Cr Straight	55																
W Raglan RN Cr Straight XL	56																
W Raglan RN Singlet Fitted	65																
W Raglan RN Singlet Fitted XL	66																
W Raglan RN Singlet Straight	67																
W Raglan RN Singlet Straight XL	68																

Checklist

As the flow chart enabled a less linear approach to completing the product development process, the need for a way of effectively tracking which tasks had been completed became apparent. This became increasingly important as I began to work on multiple garment variations simultaneously, identifying improved productivity when batch-completing tasks. Repeating the same task multiple times in a row, enhanced my proficiency with each task and eliminated the need to run multiple programs simultaneously and reduce computer processing speed, or else inefficiently reopening programs frequently as required.

Each task was assigned a signifier, a letter of the alphabet in lieu of a number which I felt implied a strict sequential order. These reference letters were added to the flowchart, as well as making up the column headers for the checklist. The fill colour of each column header was changed to reflect the most prominent colour in the logo or interface of the program that task required, thus providing the user quick visual association. While each column represents a different task, each row represents a different garment variation. Strategic indentations were used in the titling of these rows so that variations could be grouped by their shared modular characteristics. Each different neckline for each base pattern receives its own checklist page, and the fit and length variations for each sleeve style are grouped together. This resource not only facilitates working concurrently on multiple garment variations but in future applications at Kapinua would allow multiple employees to work on garments simultaneously with ease, should Kapinua's production team increase. Like the flowchart, the resource would benefit from further refinement from a visual communication designer but was utilized successfully throughout the duration of this project.

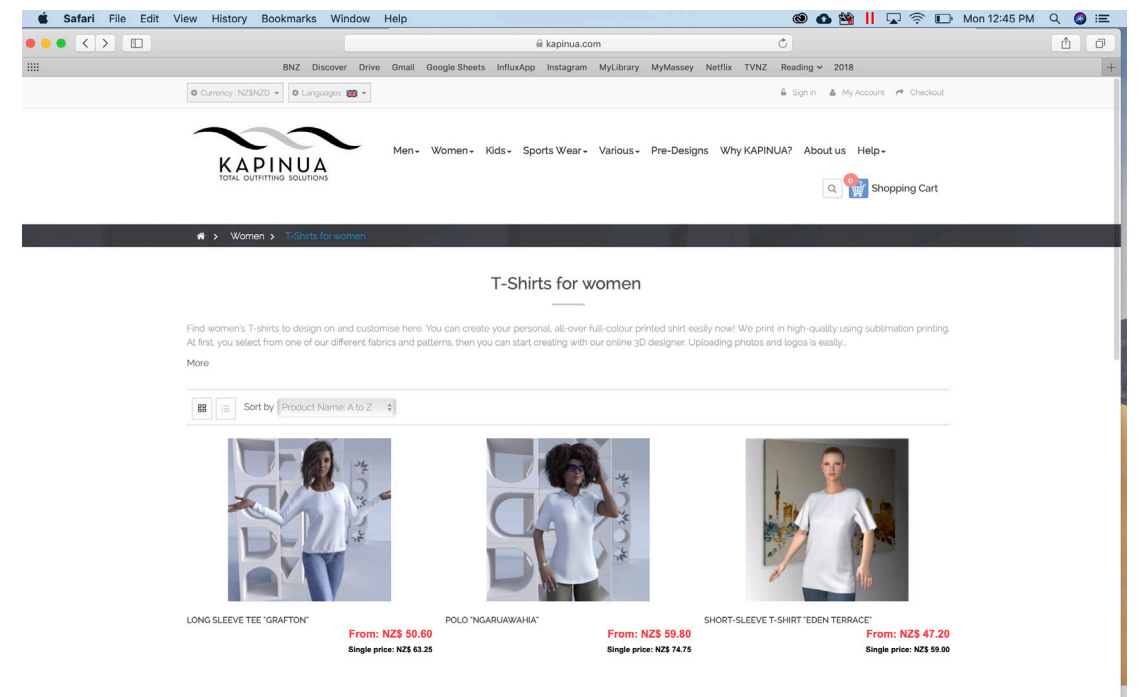
(Opposite) Figure 43. *Example of Checklist Resource in use*, personal image by author, JPEG image, 12 Dec 2019.



(Above) Figure 44. *Screengrab of the individual product page as it is on Kapinua's ecommerce platform,* personal photograph by author, JPEG image, 2 Feb 2019.

Grouped products

With the checklist tracking system in place, it became easier to observe patterns within the process workflow. When working on the fit and length variations of a women's round neck raglan tee, it became apparent that these variations (fitted, fitted extra-long, straight fit, straight fit extra-long) while crucial to accommodating customer preferences, could not easily be distinguished from one another without side-by-side comparison when presented as still images as they are in the online platform. Kapinua's e-commerce store, offering only a limited range of 3D-integrated products at this stage, had been formatted to present each style variation as a separate product, each with its own product page. It came to my attention that as the number of products on offer grew, presenting each subtle variation with its own product page would likely overwhelm the customer. While neckline and sleeve length decisions are obvious differentiators, presenting four fit and length variations of each neckline and sleeve combination would just add confusion, and took away from the idea of customisation.



(Above) Figure 45. *Screengrab of the featured products page as it is on Kapinua's ecommerce platform,* personal photograph by author, JPEG image, 2 Feb 2019.

Instead, it was proposed that these variations would be grouped. Instead of being presented with an overwhelming number of products, the customer, after selecting what type of garment they were searching for in the website's drop-down menus, would be given a choice of sleeve and neckline combinations. Then, once selecting this product, they choose from fit and length options presented in the form of drop-down menus within that product's page.

Grouping garment variations reduced the number of digital components needed for those styles to be uploaded to the website. Most notably, images created by draping the garment onto a 3D avatar and styling into a digital scene served as cover images for each different product page. By grouping style variations and reducing the number of individual product pages, the number of styled cover images required was quartered. This was a particularly notable improvement to productivity as this task was by far one of the most time-consuming stages of the process. Other unnecessarily repeated tasks were identified, like the creation of thumbnails. These thumbnails, appearing no larger than a square

centimetre on most monitors, could be reused. One set up thumbnails, depicting, for example, a Men's round neck raglan tee with full-length sleeves could be used for all Men's tees that featured those sleeves as it was near impossible to ascertain the fit, length or neckline from such small images. As the need to repeat certain tasks was eliminated, this was reflected in the checklist resource, with the blocked out task squares serving as a visual representation of improved production times. Enabled by the batch-completion of tasks and development of supportive resources, grouping products and eradicating the repetition of tasks that brought little or no value, contributed greatly to the exponential reduction of lead times as the project progressed.

(Opposite) Figure 46.
Kapinua Manufacturing 006,
personal photograph by author,
photograph, 5 Feb 2019.



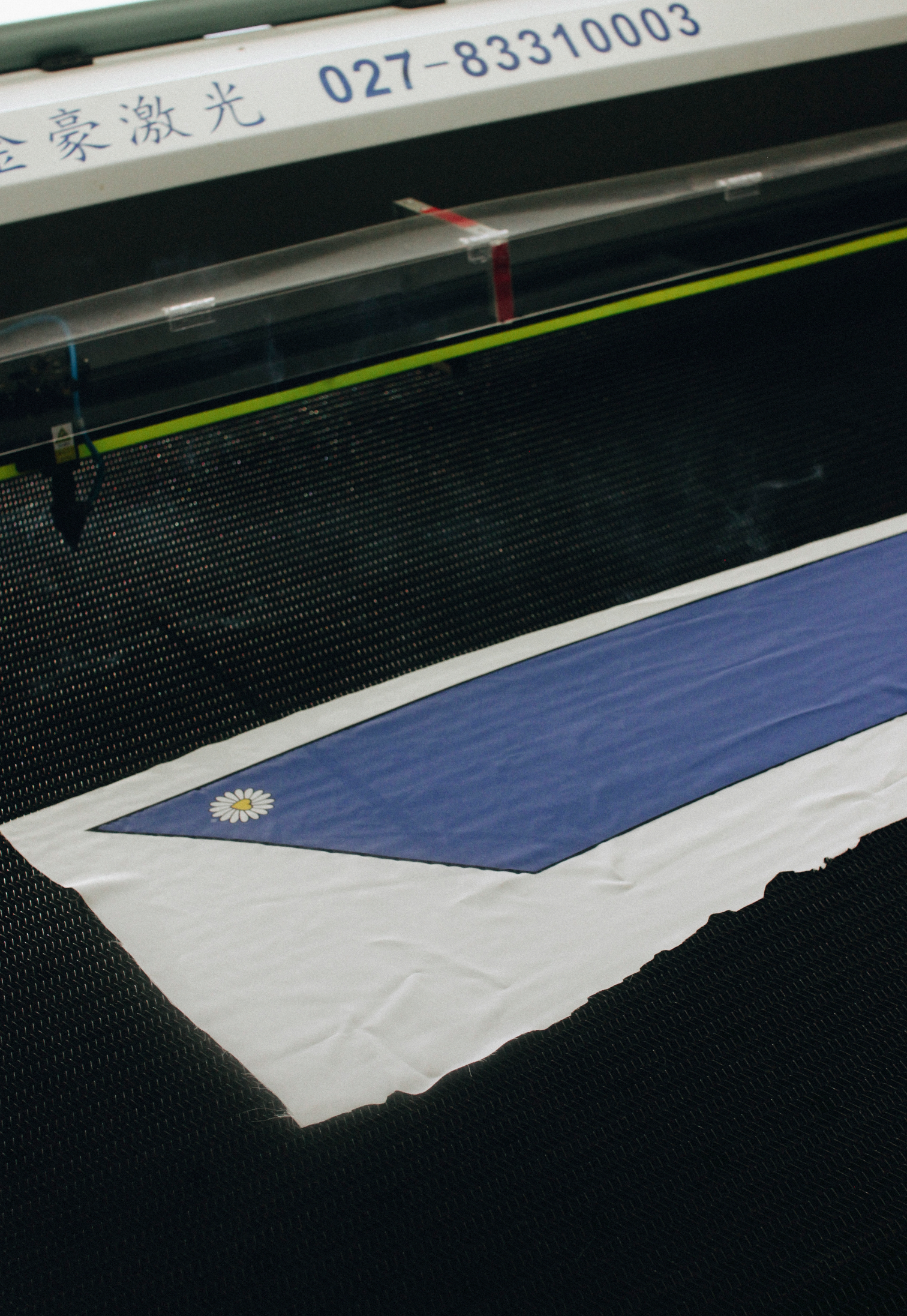
OUTCOMES

- i. Sizing Charts
- ii. Rule Tables
- iii. Product Images: Men's
- iv. Product Images: Women's
- v. Cover Images
- vi. Product Architecture
- vii. Product Package

i.

SIZING CHARTS

Two sets of parametric measurements - men's and women's - informed by the sizing and fit research outlined in Process II. This information informs how sizing ranges and brackets are structured and is used when determining garment fit. Kapinua develop products within the sizing ranges of extra-small and 5XL in their men's clothing range, and sizes 6 to 22 in their women's clothing range.



WOMENS

	6	8	10	12	14	16	18	20	22
Bust	79	84	89	94	99	104	111	116	121
Waist	61	66	71	76	81	86	93	98	103
Hip	89	94	99	104	109	114	121	126	131

MENS

	XS	S	M	L	XL	2XL	3XL	4XL	5XL
Chest	92	97	102	107	112	117	122	127	132
Neck	36	38	40	42	44	46	48	50	52
Waist	77	82	87	92	97	102	107	112	117

(Opposite) Figure 47.
Kapinua Manufacturing 007,
 personal photograph by author,
 photograph, 5 Feb 2019.

ii.

RULE TABLES

Sets of data informed by parametric research that informs the distance each grading point must be translated to produce the corresponding sizing increment. Three rule tables were created - a Men's and a Women's 'Olymp' tee grading rule table and a Men's 'Jalie' hoodie grading rule table. Though the project time-frame did not allow for the Jalie style to be developed to the point of finalised modular products, the patternmaking and grading was completed for use by Kapinua in the future.

WOMEN'S 'OLYMP' RULE TABLE

	R0		RI		R2		R3		R4		R4B	
6	0	0	0	1.5	1.25	1.5	1.25	0.25	0.25	-0.25	0.9	0.1
8	0	0	0	1.5	1.25	1.5	1.25	0.25	0.25	-0.25	0.9	0.1
10	0	0	0	1.5	1.25	1.5	1.25	0.25	0.25	-0.25	0.9	0.1
12*	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	-1.5	-1.25	-1.5	-1.25	-0.25	-0.25	0.25	-0.9	-0.1
16	0	0	0	0	-1.25	0	-1.25	-0.25	-0.25	0.25	-0.9	-0.1
18	0	0	0	0	-1.25	0	-1.25	-0.25	-0.25	0.25	-0.9	-0.1
20	0	0	0	0	-1.25	0	-1.25	-0.25	-0.25	0.25	-0.9	-0.1
22	0	0	0	0	-1.25	0	-1.25	-0.25	-0.25	0.25	-0.9	-0.1

	R4C		R4D		R4E		R5		R6		R7	
6	0.65	-0.1	0.59	-0.12	0.54	-0.14	0.31	-0.63	0.3	1.5	0.8	0
8	0.65	-0.1	0.59	-0.12	0.54	-0.14	0.31	-0.63	0.3	1.5	0.8	0.2
10	0.65	-0.1	0.59	-0.12	0.54	-0.14	0.31	-0.63	0.3	1.5	0.8	0.2
12*	0	0	0	0	0	0	0	0	0	0	0	0
14	-0.65	0.1	-0.59	0.12	-0.54	0.14	-0.31	0.63	-0.3	-1.5	-0.8	-0.2
16	-0.65	0.1	-0.59	0.12	-0.54	0.14	-0.31	0.63	-0.3	-1.5	-0.8	-0.2
18	-0.65	0.1	-0.59	0.12	-0.54	0.14	-0.31	0.63	-0.3	0	-0.8	-0.2
20	-0.65	0.1	-0.59	0.12	-0.54	0.14	-0.31	0.63	-0.3	0	-0.8	-0.2
22	-0.65	0.1	-0.59	0.12	-0.54	0.14	-0.31	0.63	-0.3	0	-0.8	-0.2

	R8		R9		R10		R11		R11B			
6	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.3	0	-0.3		
8	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.3	0	-0.3		
10	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.3	0	-0.3		
12*	0	0	0	0	0	0	0	0	0	0		
14	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25		
16	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25		
18	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25		
20	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25		
22	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25		

MEN'S 'OLYMP' RULE TABLE

	R0		RI		R2		R3		R4B		R4C	
XS	0	0	0	1.5	1.25	1.5	1.25	0.25	0.29	-0.18	0.26	-0.23
S	0	0	0	1.5	1.25	1.5	1.25	0.25	0.29	-0.18	0.26	-0.23
M	0	0	0	1.5	1.25	1.5	1.25	0.25	0.28	-0.19	0.26	-0.23
L	0	0	0	0	0	0	0	0	0	0	0	0
XL	0	0	0	-1.5	-1.25	-1.5	-1.25	-0.25	-0.28	0.2	-0.26	0.23
2XL	0	0	0	0	-1.25	-1.5	-1.25	-0.25	-0.27	0.2	-0.25	0.23
3XL	0	0	0	0	-1.25	-1.5	-1.25	-0.25	-0.28	0.21	-0.25	0.23
4XL	0	0	0	0	-1.25	0	-1.25	-0.25	-0.27	0.21	-0.25	0.23
5XL	0	0	0	0	-1.25	0	-1.25	-0.25	-0.27	0.22	-0.25	0.23

	R4D		R4E		R4F		R5		R6		R7	
XS	0.25	-0.18	0.25	-0.23	0.23	-0.23	0.31	-0.63	0.3	1.5	0.8	0.2
S	0.25	-0.19	0.25	-0.24	0.23	-0.23	0.31	-0.63	0.3	1.5	0.8	0.2
M	0.25	-0.21	0.24	-0.24	0.23	-0.23	0.31	-0.63	0.3	1.5	0.8	0.2
L	0	0	0	0	0	0	0	0	0	0	0	0
XL	-0.25	0.21	-0.25	0.24	-0.23	0.23	-0.31	0.63	-0.3	-1.5	-0.8	-0.2
2XL	-0.25	0.21	-0.24	0.24	-0.23	0.23	-0.31	0.63	-0.3	0	-0.8	-0.2
3XL	-0.25	0.21	-0.25	0.24	-0.23	0.23	-0.31	0.63	-0.3	0	-0.8	-0.2
4XL	-0.25	0.22	-0.24	0.24	-0.23	0.23	-0.31	0.63	-0.3	0	-0.8	-0.2
5XL	-0.25	0.22	-0.25	0.25	-0.23	0.23	-0.31	0.63	-0.3	0	-0.8	-0.2

	R8		R9		R10		R11		RIIB		RIIC	
XS	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.25	0	-0.3	0.15	-0.25
S	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.25	0	-0.3	0.15	-0.25
M	0.1	-0.6	-0.3	-0.6	0	-0.65	0	-0.25	0	-0.3	0.15	-0.25
L	0	0	0	0	0	0	0	0	0	0	0	0
XL	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25	-0.15	0.25
2XL	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25	-0.15	0.25
3XL	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25	-0.15	0.25
4XL	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25	-0.15	0.25
5XL	-0.1	0.6	0.3	0.6	0	0.65	0	0.25	0	0.25	-0.15	0.25

iii.

PRODUCT IMAGES: MEN'S

As a part of the product packages containing all of the necessary files for ecommerce compatibility, four product images were rendered of each finalised product. The front-view image of all completed products are featured in Outcomes to illustrate the finished product range. A copy of all product images produced and delivered has been included in the Appendix. All images were delivered to Kapinua as JPEG images in the product package of the appropriate garment variation.

(Figures on following page/s)

Figure 48. *Finished Men's Round Neck Olymp Products*, personal photograph by author, photograph, 6 Feb 2019.

Figure 49. *Finished Men's V-Neck Olymp Products*, personal photograph by author, photograph, 6 Feb 2019.

Figure 50. *Finished Men's Polo Products*, personal photograph by author, photograph, 6 Feb 2019.

Figure 51. *Finished Men's Stand Collar Products*, personal photograph by author, photograph, 6 Feb 2019.

ROUND NECK



FULL LENGTH SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

SHORT SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

CROPPED SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

V NECK



FULL LENGTH SLEEVE



SHORT SLEEVE



CROPPED SLEEVE



POLO



POLO WITH ZIPPER



STAND COLLAR**STAND COLLAR WITH ZIPPER**

iv.

PRODUCT IMAGES: WOMEN'S

As a part of the product packages containing all of the necessary files for ecommerce compatibility, four product images were rendered of each finalised product. The front-view image of all completed products are featured in Outcomes to illustrate the finished product range. A copy of all product images produced and delivered has been included in the Appendix. All images were delivered to Kapinua as JPEG images in the product package of the appropriate garment variation.

(Figures on following page/s)

Figure 52. *Finished Women's Round Neck Olymp Products 001*, personal photograph by author, photograph, 6 Feb 2019.

Figure 53. *Finished Women's Round Neck Olymp Products 002*, personal photograph by author, photograph, 6 Feb 2019.

Figure 54. *Finished Women's V-Neck Olymp Products 001*, personal photograph by author, photograph, 6 Feb 2019.

Figure 55. *Finished Women's V-Neck Olymp Products 002*, personal photograph by author, photograph, 6 Feb 2019.

ROUND NECK



FULL LENGTH SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

SHORT SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

CROPPED SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

CAPPED SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

EXTRA SHORT SLEEVE



Fitted | Straight Extra-Long

SINGLET



V NECK



FULL LENGTH SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

SHORT SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

CROPPED SLEEVE



Fitted | Fitted Extra-Long | Straight | Straight Extra-Long

CAPPED SLEEVE

Fitted



Fitted Extra-Long



Straight



Straight Extra-Long



v.

COVER IMAGES

Rendered using DAZ3D, cover images serve as the representative image of each product or group of products listed in the featured product ranges of Kapinua's online platform. These are created to give additional context and fit information to the customers about that product or group of products, and are delivered as a JPEG file in the product packages.



(Left) Figure 57. *Men's round-neck cropped sleeve cover image 001*, personal photograph by author, photograph, 12 Nov 2018.

(Below) Figure 58. *Men's round-neck cropped sleeve cover image 002*, personal photograph by author, photograph, 12 Nov 2018.



(Below) Figure 59. *Men's round-neck full length sleeve cover image 001*, personal photograph by author, photograph, 12 Nov 2018.

(Right) Figure 60. *Men's round-neck full length sleeve cover image 002*, personal photograph by author, photograph, 12 Nov 2018.





(Left) Figure 61. *Men's round-neck short sleeve cover image 001*, personal photograph by author, photograph, 10 Nov 2018.

(Below) Figure 62. *Men's round-neck short sleeve cover image 002*, personal photograph by author, photograph, 10 Nov 2018.



(Below) Figure 63. *Men's v-neck cropped sleeve cover image 001*, personal photograph by author, photograph, 10 Nov 2018.

(Right) Figure 64. *Men's v-neck cropped sleeve cover image 002*, personal photograph by author, photograph, 10 Nov 2018.





(Left) Figure 65. *Men's v-neck full length sleeve cover image 001*, personal photograph by author, photograph, 10 Nov 2018.

(Below) Figure 66. *Men's v-neck full length sleeve cover image 002*, personal photograph by author, photograph, 10 Nov 2018.



(Below) Figure 67. *Men's v-neck short sleeve cover image 001*, personal photograph by author, photograph, 10 Nov 2018.

(Right) Figure 68. *Men's v-neck short sleeve cover image 002*, personal photograph by author, photograph, 10 Nov 2018.





(Left) Figure 69. *Women's round-neck full length sleeve cover image 001*, personal photograph by author, photograph, 3 Jan 2019.

(Below) Figure 70. *Women's round-neck full length sleeve cover image 002*, personal photograph by author, photograph, 3 Jan 2019.



(Right) Figure 71. *Women's v-neck short sleeve cover image*, personal photograph by author, photograph, 3 Jan 2019.





(Left) Figure 72. *Women's v-neck capped sleeve cover image 001*, personal photograph by author, photograph, 12 Nov 2018.

(Below) Figure 73. *Women's v-neck capped sleeve cover image 002*, personal photograph by author, photograph, 12 Nov 2018.



(Below) Figure 74. *Women's v-neck full length sleeve cover image 001*, personal photograph by author, photograph, 3 Nov 2018.

(Right) Figure 75. *Women's v-neck full length sleeve cover image 002*, personal photograph by author, photograph, 3 Nov 2018.





(Left) Figure 76. *Women's v-neck short sleeve cover image 001*, personal photograph by author, photograph, 12 Nov 2018.

(Below) Figure 77. *Women's v-neck short sleeve cover image 002*, personal photograph by author, photograph, 12 Nov 2018.



vi.

PRODUCT ARCHITECTURE

Informational diagrams have been created to display the garment pattern customisation system, Influenced by product engineering modularity models, this diagram has been configured in a way that frames each point of variation as a 'slot' module. Images of cut out pattern pieces which are applied to the base pattern template to create product variations, have been presented on the page on the right-hand side of the following pages. These diagrams can serve the company and customers in an informational capacity.

(Figures on following page/s)
Figure 78. *Product Architecture*
- *Men's 'Olymp' Raglan Tee*,
personal image by author and
Ben Reyburn, JPEG image,
7 Dec 2019.

Figure 79. *Product Architecture*
- *Women's 'Olymp Raglan Tee*,
personal image by author and
Ben Reyburn, JPEG image,
7 Dec 2019.

MEN'S 'OLYMP' RAGLAN TEE

COLLARS



SLEEVES



FIT

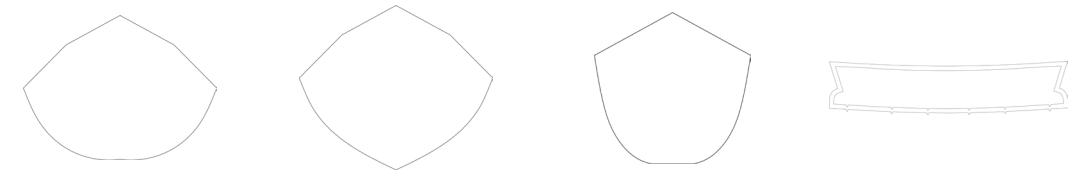
- Fitted
- Straight

LENGTH

- Regular
- Extra-Long



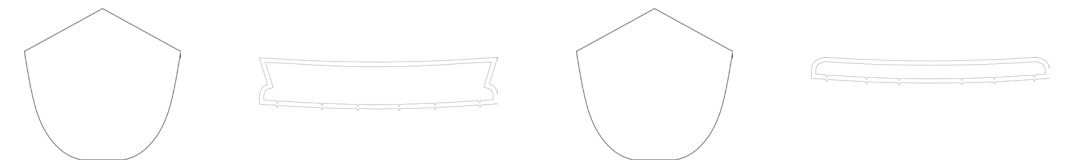
NECKLINE



Round Neck

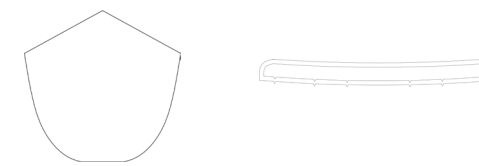
V Neck

Polo



Polo with Zip

Stand Collar



Stand Collar with Zip

SLEEVES



Full Length

Short

Cropped

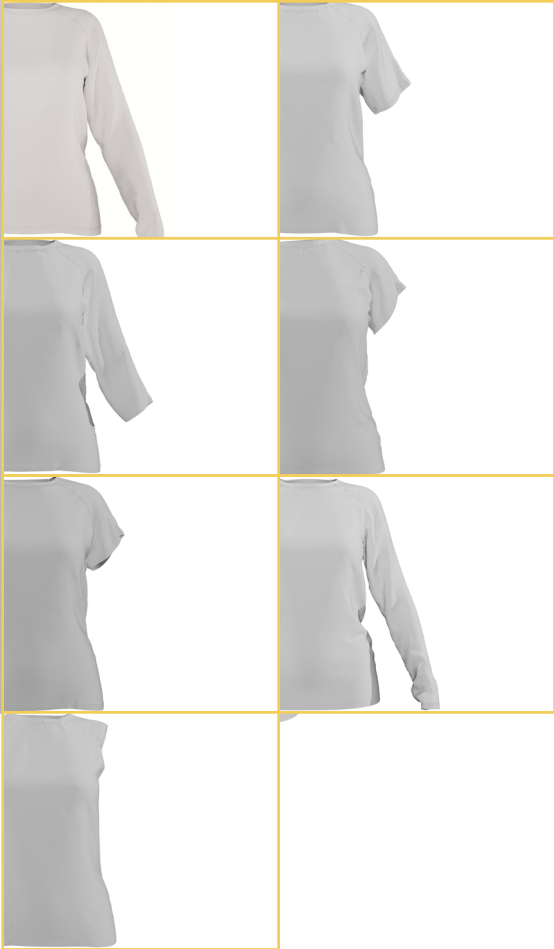
Extra Long

WOMEN'S 'OLYMP' RAGLAN TEE

COLLARS



SLEEVES



FIT

- Fitted
- Straight

LENGTH

- Regular
- Extra-Long

NECKLINE



Round Neck | Round Neck Binding | V Neck

SLEEVES



Full Length | Short | Cropped | Capped



Extra Short | Extra Long | Singlet

vii.

PRODUCT PACKAGE

Following the file naming system created during this project, product packages were delivered to Kapinua through file transfer. Each product package has the digital components for that garment to be uploaded to Kapinua's online platform. Information outlining the structuring of the file naming system and a chart describing each file has been included in the following pages.

[FILE NAMING SYSTEM]

[Gender] [Name of Base Pattern] [Sleeve Style]

[Neckline] [Sleeve Length] [Fit/Length]

Category	File text or abbreviation	Description
Gender.	M / W.	Men's / Women's.
Base Pattern Name.	- Jalie. - Olymp.	- Jalie. - Olymp.
Sleeve Style.	- Raglan. - Set-In.	- Raglan Sleeve. - Set-In Sleeve.
Neckline.	- Po. - PZ. - RN. - SC. - SZ. - VN.	- Polo. - Polo with zipper. - Round-neck. - Stand collar. - Stand collar with zipper. - Neck.
Sleeve Length.	- C. - Cr. - FL. - Si. - SS. - XSL.	- Capped sleeve. - Cropped sleeve. - Full-length sleeve. - Singlet. - Short sleeve. - Extra-short sleeve.
Fit/Length.	- Fitted. - Fitted XL. - Straight. - Straight XL.	- Fitted style. - Extra-long fitted style. - Straight fit. - Extra-long straight fit.

PRODUCT PACKAGE

Optitex File
 PLT File
 CorelDraw File
 'All Box.png' (Shader Image)
 Pattern Piece SVG Images
 CLT File
 FBX File
 OBJ File
 Product Images
 Sizing Images
 Thumbnails
 Cover Images

File Type	Description
Optitex File	Contains the 2D pattern pieces, 3D draping information, simulation properties, stitch properties, shaders and settings of that product within Optitex.
PLT File	Contains a vector image of patterns for that product, organised by size - this file is then imported into CorelDraw, but is included in the product package for use directly with Kapinua's laser cutting and sublimation printing machinery, or a digital plotter if need be.
CorelDraw File	Opens a CorelDraw document containing the PLT patterns and vectoral information processed to create the 'All Box.png' for that product.
'All Box.png' (Shader Image)	Created in CorelDraw, the 'All Box.png' serves as a shader/surface on the 3D fabric mesh in Optitex. The image includes all of the pattern pieces for that product, formatted specifically to convey information between the finalised online 3D garment mesh and the proportionally scaled 2D patterns.
Pattern Piece SVG Images	1:1 scaled vector images of each pattern piece of that product, configured to communicate design information with the finalised online 3D garment mesh, facilitated by the strategic placement of the 'All Box.png' as shaders on the Optitex.
CLT File	Saved 3D information that can be used in DAZ3D and assigned draping properties using the 'Dynamic Clothing' plugin. This file is used to create rendered cover images.
FBX File	Saved 3D information of that product which is used to create 3D garment mesh OBJ files and can be altered and rendered in DAZ3D.
OBJ File	Two files are included in each product package, one has the 3D stitch information obtained by importing an FBX file into Carrara and used to create product images, the other is the finalised 3D garment mesh which is uploaded to the website.

Product Images	Front, back, left and right views of that product, rendered in DAZ3D and modelled to emulate the surface and shadow properties of a physical garment as realistically as possible. These images are featured on the website to show the customer the specific formal properties of that product.
Sizing Images	Front and back images featuring a render of the product along with a horizontal arrow labelled 'A' and a vertical arrow labelled 'B'. These images are used to show how the measurements of the product specification chart translates to the garment's form.
Thumbnails	A set of small images of the product used as thumbnail tabs to direct the customer to the corresponding pattern piece in Kapinua's 'Online Designer' function.
Cover Images	Rendered image(s) of the product, presented draped on a 3D avatar and posed and positioned within a digital scene. These serve as the featured image when customers are scrolling through Kapinua's featured product pages.



(Opposite) Figure 80.
 Kapinua Manufacturing 008,
 personal photograph by author,
 photograph, 5 Feb 2019.

Conclusion

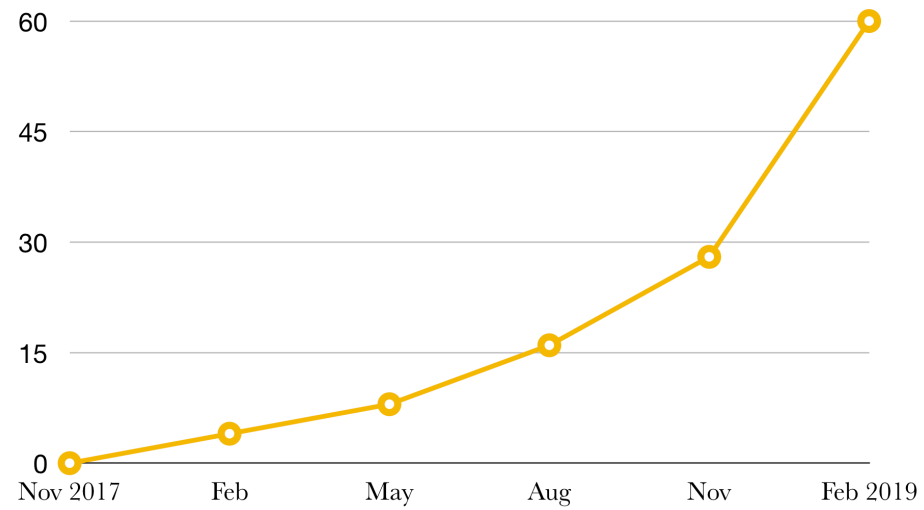
Bridging academic and industry methodologies, this project sought to investigate the application of modularity within apparel production.

Through gaining a comprehensive understanding of the needs of the stakeholders, the wider contextual influences and implications, and the many nuances of Kapinua's processes, I believe significant contribution has been made towards the realisation of economically-viable, structurally customisable product manufacturing practices.

Digitally informed MTO manufacturing, comes as a response to the current hegemonic modus operandi of the industry that is in many ways failing consumers, businesses and our environment. Kapinua's core aims - improved processing efficiency, shorter lead times, greater digital integration, enhanced accessibility and involvement for their users, and the emphasis of choice, fit and individualism in clothing retailing - should be the collective goals of our industry. Literary research, outlined in Context I, II and III, supports the encouraging notion that this is, in fact, becoming a commonly shared vision.

At its essence, customisation is the driving force of Kapinua's brand. By developing a 3D-integrated interchangeable modular library, Kapinua's online platform now offers the kind of structural interchangeability - or 'medium variation' as it is termed Ecker et al.'s framework - previously only offered via direct communication with the company. This will speed up the process of placing orders, facilitate a faster design-approval process for the company, and provide customers with more choice and control - all desired outcomes emphasised in the industry brief. Applying the model of product architecture, usually limited to the engineering and industrial design sectors, enables the kind of transformation of designer/user/maker roles that Sun and Zhao believe will lead to greater customer satisfaction (Eckert 785; Sun et al. 372-373). This work also began to explore the notions of developing a more comprehensive fit and sizing options by offering each style in two fit types and two lengths. I hope to see this explored to a greater depth within future academic research, where larger participant sample sizes can be accessed, and focus can be placed solely on developing the kind of advanced grading system that is long overdue.

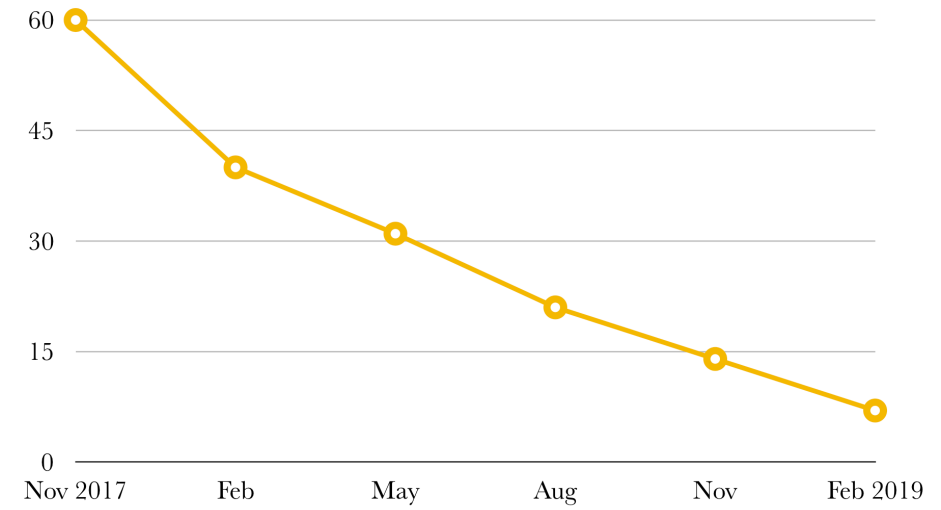
A number of other potential future developments have been identified that extend beyond the scope of



Number of products developed

this project. In terms of modularity, the possibilities of applying the practices and resources developed during this project are expansive. Kapinua has expressed interest for the same 3D-integrated, interchangeable product development practices to be applied to a great number of other garments. Figures 81 and 82 present information showing how ongoing learning, effective task management tools, instructional and troubleshooting information, and the grouping of products, improved my own execution of the product development process. The success in shortening the time required to develop these products, shows promise that this can be achieved within similarly, exponentially improving timeframes. It would be worthwhile for the company to continue developing these resources, particularly in terms of clarifying the visual presentation of information. Working with a designer who specialises in visual-communication would allow the resources conceptualised and wire-framed within this work to be fully realised. The use of video to educate both employees and customers also merits further investigation. Incorporation of reflection and documentation methodologies within Kapinua's workplace - perhaps to

(Above) Figure 81. *Product Development statistic chart showing exponential efficiency - Number of Products Developed*, personal image by author, JPEG image, 21 Jan 2019.



Estimated days to create a product

a lesser extent than is exemplified - would stand to ensure that the company as a whole can benefit from the ongoing learning of individuals who continue working with this process.

Customers could also be further informed and included in Kapinua's processes. Though the development of an interchangeable modular pattern library was developed primarily for the benefit of the company, this serves the customers too. Rather than just presenting these garment variations as individual or even grouped products as they are currently, an interactive selection tool on Kapinua's online platform could be created to showcase the outcomes of this project in a way that the user cares about. Presenting a 'Build Your Own Tee Shirt' function on the website's home page, could be as simple as a series of images where the user selects first the gender, then the sleeve style, neckline, and sleeve length, before being lead to the individual product page of the appropriate style variation for their needs. This would further reinforce Sun and Zhao's model of synergetic designer/user/maker relationships, as would allowing customers to upload feedback and images of their finished garments to the

(Above) Figure 82. *Product Development statistic chart showing exponential efficiency - Estimated Days to Create a Product*, personal image by author, JPEG image, 21 Jan 2019.

product page of the style variation they chose. Video, blogging and additional informational pages on their website would also achieve the kind of brand transparency that benefits both Kapinua and their clients.

Along the same lines, creating a formal Corporate Social Responsibilities (CSR) procedure and communicating these on Kapinua's website and social media platforms would be mutually beneficial. Currently, Kapinua's MTO manufacturing is marketed to its users purely from a customisation and creative input standpoint. But as literary research emphasised, MTO manufacturing - especially in a localised, vertically-integrated supply chain - eliminates the need to make the kind of stock estimations that result in large quantities of surplus garments. Translating this information into a way customers can easily access and comprehend, would educate users on pre-consumer waste and how Kapinua is working to reduce this. It may be, that Kapinua can implement additional textiles waste-reduction strategies in the future like finding the use for fabric offcuts, developing zero-waste patterns, or offering customers a way of repurposing or recycling their Kapinua garments when no longer needed.

It is important to note that due to rapid technological advancements, there is limited academic research currently available on many of the topics and programs discussed within this project. The need for more in-depth academic research on these emerging concepts and technologies was evident, as well as a progression towards building a more comprehensive sizing system - informed by parametric research on a much grander scale than is conducted within this project.

At the conclusion of this project, Kapinua has now been equipped with sizing charts and rule tables informed by parametric research, a file naming and organisational system, 63 completed 3D-integrated products, and the formative components of a range of additional styles like the Jalie hoodie. Included in these product file packages are: sizing guide images; thumbnails; individual pattern piece SVG images; OBJ, CLT and FBX files; product images taken of the front, back and side views; and styled lookbook image renders featuring the garments presented on 3D avatars. Additionally, a number of Optitex, CorelDraw, and DAZ3D templates have been presented, alongside the foundations of informational

resources created to improve workflow efficiency. At the time of publication, Kapinua is currently in the process of uploading the finalised products onto their e-commerce platform. It is my belief that Callaghan Innovation was right when they described Kapinua as internationally leading online manufacturing and retailing specialists. I look forward to seeing how Kapinua and the apparel production industry continue to be transformed by the ever-evolving capabilities of digitally-integrated modular clothing production, and it has been a pleasure contributing to these practices.

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- Alibaba Group. "About Us." *Alibaba Group*. Alibaba Group, n.d. www.alibabagroup.com/en/about/overview. Accessed 28 Nov 2018.
- Brooks Brothers. "About Made to Measure." *Brooks Brothers*. Brooks Brothers Group, 2018. www.brooksbrothers.com.au/mtm-mtm.html. Accessed 8 Feb 2019.
- Buchanan, Richard. "Education and Professional Practice in Design." *Design Issues*, vol.14, no.2, 1998, pp. 63–66. JSTOR, www.jstor.org/stable/1511851. Accessed 7 Feb 2019.
- Callaghan Innovation. "About Us." *Callaghan Innovation*. Callaghan Innovation, 30 Nov. 2018. www.callaghaninnovation.govt.nz/about-us. Accessed 5 Dec 2018.
- Das, Rajib. "Meticulous Overview on Apparel Marker Construction and Appliance: A Milieu of Apparel Industry in Bangladesh." *European Journal of Business and Management*, vol.8, no.13, 2016, pp. 74–79. *International Knowledge Sharing Platform*, www.iiste.org/Journals/index.php/EJBM/article/viewFile/30324/31162.
- Eckert, Claudia M. et al. "Process simulation to make personalisation economically viable." *8th International Symposium on Tools and Methods of Competitive Engineering (TMCE 2008)*, Izmir, Turkey, 21–25 Apr 2018, edited by I. Horváth and Z. Rusaák, 2018, pp. 785–795. www.citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.559.1516&rep=rep1&type=pdf. Accessed 12 Jan 2018.
- The Economist. "To the Maxx." *The Economist*. The Economist Newspaper, 9 Jan. 2016. www.economist.com/business/2016/01/09/to-the-maxx. Accessed 3 Dec 2018.
- Etsy. "About Etsy." *Etsy*. Etsy, 2019. www.etsy.com/about. Accessed 9 Feb 2019.
- Glassons. "Dress Size Guide." *Glassons*. Glassons, 2019. www.glassons.com/size-guide/dresses. Accessed 10 Feb 2019.
- Han, Esther. "Shoppers in a twist over inconsistent clothing sizes." *They Sydney Morning Herald*. The Sydney Morning Herald, 24 Nov. 2014. www.smh.com.au/national/shoppers-in-a-twist-over-inconsistent-clothing-sizes-20141126-11ua1x.html. Accessed 1 Feb 2019.
- Honey Birdette. "Size Guide - Honey Birdette." *Honey Birdette*. Honey Birdette, 2018. www.honeybirdette.com/pages/size-guide?geo=NZ. Accessed 10 Dec 2018.
- James, A. M. and B. Montgomery. "Engaging the fashion consumer in a transparent business model." *International Journal of Fashion Design, Technology and Education*, vol.10, no.3, 2017, pp. 287–299. *Taylor & Francis Online*. www.doi.org/10.1080/17543266.2017.1378730. Accessed 4 Apr 2018.
- Kaminski, Philip M. and Onur Kaya. "MTO-MTS Production Systems in Supply Chains." *2006 NSF Design, Service and Manufacturing Grantees and Research Conference*, St. Louis, United States, 24–27 Jul 2006, pp. 1–36. *Semantics Scholar*, www.pdf.semanticscholar.org/cc99/2c667710b267bc418cc0e63897e413a79799.pdf. Accessed 8 Aug 2018.
- Kapinua (Company Branding Shop) R&D Project*. Wellington: Callaghan Innovation, 2017. Print.
- Kapinua. 'About.' *Kapinua*. Kapinua, 2015. www.kapinua.com/en/content/15-who-we-are. Accessed 4 Jun 2018.
- Kapinua. 'Sublimated Shirts.' *Kapinua*. Kapinua, 2015. www.kapinua.com/en/content/28-production-process#sublimation. Accessed 10 Feb 2019.
- Lee, Eunyong and Huiju Park. "3D Virtual fit simulation technology: strengths and areas of improvement for increased industry adoption." *International Journal of Fashion Design, Technology and Education*, vol.10, no.1, 2017, pp. 59–70. *Taylor & Francis Online*. www.doi.org/10.1080/17543266.2016.1194483. Accessed 21 Apr 2018.
- Luxury Insider. "It's Personal: Burberry Monogramming Services." *Luxury Insider*, SPH Magazines Luxury Network. <https://www.luxury-insider.com/luxury-news/2015/04/burberry-monogramming-service>. Accessed 9 Feb 2019.
- McCall, Tyler. "Lady Gaga's 2019 Golden Globes look pays tribute to Judy Garland." *Fashionista*, Breaking Media, 6 Jan. 2019. www.fashionista.com/2019/01/2019-golden-globes-awards-lady-gaga-valentino-couture. Accessed 8 Feb 2019.
- Maths First. "Cartesian Coordinates in 3D." *Maths First*. Massey University, n.d. www.mathsfirst.massey.ac.nz/Algebra/CoordSystems/Coordinates3D.htm. Accessed 10 Feb 2019.
- Parry, Martine. "The true cost of fast fashion." *Fairtrade Foundation*. Fairtrade foundation, 25 Apr. 2018. www.fairtrade.org.uk/Media-Centre/Blog/2018/April/The-true-cost-of-fast-fashion. Accessed 5 Dec 2019.
- Schleuss, Ingo. Personal communication. 21 Nov. 2017.
- Schleuss, Ingo. Personal communication. 6 Jan. 2018.
- Schleuss, Ingo. Personal communication. 7 Jul. 2018.
- Schleuss, Ingo. Personal communication. 30 Nov. 2018.
- Shin, Eonyou and Mary Lynn Damhorst. "How young consumers think about clothing fit?" *International Journal of Fashion Design, Technology and Education*, vol.11, no.3, 2017, pp. 352–361. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2018.1448461. Accessed 12 Jan 2019.
- Smithers, Rebecca. "Unused clothing worth £30bn, report finds." *The Guardian*. Guardian News and Media, 11 Jul. 2012. www.theguardian.com/environment/2012/jul/11/unused-clothing-wardrobe. Accessed 12 Oct 2018.
- Sun, Lushan and Li Zhao. "Technology disruptions: exploring the changing roles of designers, makers, and users in the fashion industry." *International Journal of Fashion Design, Technology and Education*, vol.11, no.3, 2018, pp. 362–374. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2018.1448462. Accessed 12 Apr 2018.
- Swann, Cal. "Action Research and the Practice of Design." *Design Issues*, vol. 18, no.1, 2002, pp. 49–61. JSTOR, www.jstor.org/stable/1512029. Accessed 5 Feb 2019.
- Tiffany & Co. "Personalisation." *Tiffany & Co*, T&Co., 2019. www.tiffany.com.au/personalize. Accessed 9 Feb 2019.
- Typecoil. "Types of modular interface design." *Techcoil*. Techcoil.com, 8 Dec. 2017. www.techcoil.com/blog/types-of-modular-interface-design/. Accessed 9 Dec 2018.
- Ulrich, Karl. "The role of product architecture in the manufacturing firm." *Research Policy*, no.24, 1995, pp. 419–550. KT Ulrich, <http://www.ktulrich.com/uploads/6/1/7/1/6171812/ulrich-architecture.pdf>. Accessed 10 Feb 2019.
- Ulrich, Karl. and Stephen E. Eppinger. *Product Design and Development*. 5th ed. McGraw-Hill Education, 2011.
- Yang, Fan and Huiying Zhanf. "The impact of customer orientation on new product development performance: The role of top management support." *International Journal of Productivity and Performance Management*, vol.67, no.3, 2018, pp. 590–607. *Emerald Insight*, www.doi.org/10.1108/IJPPM-08-2016-0166. Accessed 11 Jan 2019.

ii. Bibliography

- Abnett, Kate. "The Robot Opportunity." *Business of Fashion*. The Business of Fashion, 18 May. 2016. www.businessoffashion.com/articles/fashion-tech/the-robotics-opportunity-manufacturing-efficiencies. Accessed 22 Apr 2018.
- Blender Foundation. "Features - blender.org." *Blender*. Blender Foundation, n.d. www.blender.org/features/. Accessed 1 Dec 2018.
- Blender Foundation. "Simulation - blender.org." *Blender*. Blender Foundation, n.d. www.blender.org/features/simulation/. Accessed 1 Dec 2018.
- Bye, Elizabeth et al. "Optimized Pattern Grading." *International Journal of Clothing Science and Technology*, vol.20, no.2, pp. 79-92. Emerald Insight, www.doi.org/10.1108/09556220810850469. Accessed 1 Nov 2018.
- DAZ3D. "3D Models and Assets." *DAZ3D*. DAZ Productions, 2018. www.daz3d.com/shop/. Accessed 31 Oct 2018.
- Demott, Rick. "OptiTex's Dynamic Clothing Engine for DAZ3D comes to Mac OS." *AWN*. Animation World Network, 20 Sep. 2011. www.awn.com/news/optitexs-dynamic-clothing-engine-daz-3d-comes-mac-os. Accessed 8 Oct 2018.
- De Silva, R. K. J. et al. "A collaborative apparel new product development process model using virtual reality and augmented reality technologies as enablers." *International Journal of Fashion Design, Technology and Education*, vol.12, no.1, 2019, pp. 1-11. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2018.1462858. Accessed 12 Jan 2019.
- Francis, Ryan. "Offshoring's victims: Two stories." *Network World*. IDG Communications, 5 Jul. 2004. www.networkworld.com/article/2323793/software/offshoring-s-victims--two-stories.html. Accessed 7 Jul 2018.
- Freeth, Michelle. *Maintaining Design Aesthetics: Case studies investigating grading for body shape variation; the translation of garment designs to fit fuller figured women*. 2011. Massey U, Masters thesis. Massey Research Online. <https://mro.massey.ac.nz/handle/10179/2256>. Accessed 4 May 2018.
- Hanburry, Mary. "TJ Maxx is proving it's the business model of the future as the retail apocalypse hammers the industry." *Business Insider*. Business Insider Australia, 5 Jun. 2018. www.businessinsider.com.au/tj-maxx-taking-department-store-suppliers-2018-6?r=US&IR=T. Accessed 12 Aug 2018.
- Hethorn, Janet. "User-Centered Innovation: Design Thinking and Sustainability." *Sustainable Fashion: What's Next? A Conversation about Issues, Practices and Possibilities*, 2nd ed, edited by Janet Hethorn and Connie Ulasewicz, Fairchild Books, 2015, pp. 50-75.
- Kapinua. 'Why KAPINUA?.' *Kapinua*. Kapinua, 2015. www.kapinua.com/en/content/25-advantages. Accessed 4 Jun 2018.
- Kim, Hye-Young et al. "Consumer adoption of smart in-store technology: assessing the predictive value of attitude versus beliefs in the technology acceptance model." *International Journal of Fashion Design, Technology and Education*, vol.10, no.1, 2017, pp. 26-36. *Taylor & Francis*. www.doi.org/10.1080/17543266.1177737. Accessed 19 May 2018.
- Kirschner, Jack. *Lingerie Patternmaking and Grading Simplified: A Manual for the student and the worker*. Fairchild Publications, 1950.
- Lewis, Tasha L. "Closing the loop: a scalable zero-waste model for apparel reuse and recycling." *International Journal of Fashion Design, Technology and Education*, vol.10, no.3, 2017, pp.353-362. *Taylor & Francis Online*. www.doi.org/10.1080/17543266.2016.1263364. Accessed 4 Apr 2018.
- Mau, Dhani. "How a Few Brands Are Making Made-to-Measure Fashion Accessible." *Fashionista*. Breaking Media, 23 May. 2018. www.fashionista.com/2018/05/accessible-made-to-measure-clothing-brands. Accessed 8 Oct 2018.
- Perry, Anna. "Factors that influence consumers' purchase intention of smart closets." *International Journal of Fashion Design, Technology and Education*, vol.10, no.1, 2017, 91-100. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.016.1202332. Accessed 21 Apr 2018.
- Raj, Deepika et al. "Implementation of lean production and environmental sustainability in the Indian apparel manufacturing industry: a way to reach the triple bottom line." *International Journal of Fashion Design, Technology and Education*, vol.10, no.3, 2017, pp. 254-265. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2017.1280091. Accessed 12 Apr 2018.
- Sayet, Abu Sadat Muhammad. "Objective analysis of the drape behaviour of virtual shirt, part 1: avatar morphing and virtual stitching." *International Journal of Fashion Design, Technology and Education*, vol.10, no.2, 2017, pp. 158-169. *Taylor & Francis Online*. www.doi.org/10.1080/17543266.2016.1223354. Accessed 2 Apr 2018.
- Sherman, Lauren. "How Automation Is Reshaping Fashion." *Business of Fashion. The Business of Fashion*, 23 Jan. 2017. www.businessoffashion.com/articles/fashion-tech/how-automation-will-reshape-fashion. Accessed 22 Apr 2018.
- Tselepis, Thea Judith. "When clothing designers become business people: a design centred training methodology for empowerment incubation." *International Journal of Fashion Design, Technology and Education*, vol.11, no.3, 2018, pp. 299-309. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2018.1431809. Accessed 12 Jan 2019.
- Unity Technologies. "Unity." *Unity*. Unity Technologies, 2018. www.unity3d.com. Accessed 19 Dec 2018.
- Wang, Baolu and Jung E. Ha-Brookshire. "Exploration of Digital Competency Requirements within the Fashion Supply Chain with an Anticipation of Industry 4.0." *International Journal of Fashion Design, Technology and Education*, vol.1, no.3, 2018, pp. 333-342. *Taylor & Francis Online*, www.doi.org/10.1080/17543266.2018.1448459. Accessed 12 Jan 2019.

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iv. Glossary of Terms

A compilation of terms and their meanings within the context of this project - as informed by my design practice and the research listed in the Reference List and Bibliography.

Applied Signposting Method (ASM) - a framework used to streamline process workflow
ASTM (American Society for Testing and Materials) - an organisation which has produced a number of sizing standards based on parametric research.

Avatars - 3D characters who can be incorporated into 3D scenes and simulations
Base pattern - the originally sized pattern a garment was developed from before grading is applied to make additional sizing breaks.

Boot Camp - a software available for use on Mac computers which allows both the Mac and Windows operating systems to be run concurrently.

CLT (cloth) file - a file used to export digital clothing mesh from Optitex into 3D modelling software like DAZ3D.

Carrara - a software created by DAZ3D which allows the stitch and 3D detail properties of garment meshes to be captured from FBX files and exported as OBJ files.

Complex variations - completely personalised customisation that is conducted in small numbers and typically does not rely on developing standardised modularity systems.

Computer-aided design (CAD) - a type of software that facilitates digital design and manufacturing.

Corporate Social Responsibility (CSR) - a framework for implementing ethical practices into a business, these are usually accessible to both company staff and customers.

Customisation - the act of altering or adapting a product based on personal needs and preference - modularity is one way of achieving this.

DAZ3D - a 3D modelling and digital scene creation software.

Designer - those involved with with the conceptualising and early development stages of products.

Digital printing - application of colours and designs onto fabric through large-formatting printing technology.

Draping - used to describe either manual or digital fabric manipulation in a three-dimensional setting, typically on a dress form, person or avatar
Ecommerce - the online retailing of merchandise through a website or application.

Economic-viability - whether production costs and desired or required profit margins will be covered by the retail price of a product - in the context of this project economic-viability was used to describe the validity of incorporating a customisation option or practice.

Fast fashion - affordable, cheaply produced clothing that is designed to be frequently updated, superseded or discarded.

Fit - how a garment engages with the human form when worn, used to either describe garment behaviour characteristics like pulling or gaping, or the style of intended proximity to the body like slim fit or straight fit.

Fit testing - see 'sampling'.

Garment life cycle - a series of stages or states a garment will undergo from the time of first production, through to disposal or repurposing
Garment life expectancy - the anticipated duration from a product being produced through to its final disposal or repurposing.

Gerber AccuMark - a patternmaking software that operated as a 2D patternmaking program at the time of research, since this research stage was completed Gerber have since released a 3D patternmaking program.

Grade - the method of creating different sizes by moving key pattern points incrementally according to an assigned algorithm.

Grading rule - a set of data informing how a point is to be moved incrementally to produce additional sizes.

Import/export - a program function that allows files to be opened and saved in a range of varying file types depending on the individual software's capabilities.

In-house patternmaker - often seen in businesses who operate under vertical integration, this is somebody who works within the company to produce patterns rather than outsourcing the task to a third-party.

Internal line - pattern markings away from the perimeter of a pattern piece that do not affect the external shape of the pattern pieces, used to indicate functions like pleating or darts.

Lag - slowed or delayed computer response usually caused by computer processing capabilities.

Licensing - the way the ownership of a software is structured, this will typically be a one time purchase where the user owns the product outright, or regular payments which allow the user to use the software - this is often monthly or annually .

Maker - those involved in the physical production of the materials and/or final products.

Manufacturing - the act or process of physically producing a garment.

Medium variations - mid-level customisation options that offer structural changes to simple products, often using modular principles.

Mirror line - the line of symmetry used in patternmaking practices.

Modularity - a form of product design that allows for easy alteration or adaption through development of interchangeable 'modules' or 'slots'.

MTO (Made-to-Order) - a manufacturing strategy where product prototypes are produced and marketed and stock is only manufactured once customers have purchased the product.

MTS (Made-to-Stock) - a manufacturing strategy where estimated numbers of products are produced prior to retailing.

Notches - patternmaking notations that are typically used to inform placement and positioning.

Online platform - a website or application that is used to connect or communicate with users.

Operating system (OS) - the software system that facilitates a computer's basic functions.

Optitex - a 2D and 3D patternmaking CAD software.

Participant - a fit model who participated in the sizing parametric research component of the study.

Pattern - a set of pattern piece shapes that when constructed create a garment.

Pattern library - a digital database of pattern and 3D-integrated product components, organised into relevant subfolders.

Pattern piece - a shape template that informs how fabric must be cut and sewn to produce a finished garment.

Process - a set of tasks or stages that must be undertaken to get a desired result
Product - an individual garment or garment variation.

Product architecture - a product engineering term used to describe the composition of components that make up a modular product.

Product Package - a folder containing the necessary files for that product to be uploaded onto Kapinua's online platform.

Production planning - the process of structuring and specifying the products that need to be developed and tasks that need to be completed to accomplish this.

Program - used interchangeably to describe software.

Render - a digitally produced image, typically of 3D scenes and assets.

Rules table / rule library - a set of data organised into 'rules' (see 'grading rule') that inform how a point is translated incrementally to create a range of additional sizes.

Samples - otherwise known as 'toiles', these are full or partial productions of garments - often in their early stages of development - typically created to determine fit and construction specifications.

Seam allowance - the additional fabric included on a pattern piece to account for the fabric required for seaming; industry standards for seam allowance is 6mm for knit/stretch fabric and 1cm for woven fabric.

Simple variations - garment customisation options that change surface or non-structural aspects of a product.

Simulation - the application of gravity and other 3D properties to a digital object like a 3D drape mesh.

Shaders - a function that translates fill colours and images into pattern surfaces on the 3D mesh, as it is referred to within Optitex software.

Sizing chart / sizing table - a set of parametric data.

Sizing parameters - a set of measurements either belonging to a participant/customer or to a specific product.

Slots - a product engineering term used to describe the way 'modules' or components connect with the larger product configuration.

Stitching - used in the context of computer aided design, stitching refers to the process of joining points or lines.

Streamlining - the act of simplifying or automating a workflow or process by identifying shortcuts, unnecessary repetition, helpful task-reordering opportunities, or suitable technological applications.

Style - either an individual or range of products, or the characteristics of a garment.

Style variations - within modular apparel production, refers to products developed from a particular base pattern or template.

Sublimation printing - a digital printing technology that prints ink onto a transfer which is then heat pressed onto a material or fabric.

Surfaces - a function that translates fill colours and images into pattern surfaces on the 3D mesh, as it is referred to within DAZ3D.

SVG (Scalable Vector Image) - a type of image file type that operates based on line and shape proportions rather than pixels and can be scaled limitlessly.

Templates - patterns or documents created to facilitate easy adjustment for a range of style variations.

Users or end-uses - those purchasing, wearing and interacting with the final product.

User-centred or human-centred - a type of design that prioritises the needs and desires of the end-user (the customer) over other influences of design like artist vision or desired markets.

User-experience - how a user interacts with a software, particularly relating to 'intuitive' design and the pathways a user uses when operating the program.

User-influenced - products or processes that have been developed at least in part due to feedback and input from the end-user (the customer).

User-interface - the visual layout design of a software.

Vector imaging - a type of imaging that operates on proportional line, shape and point placement that can be scaled limitlessly.

Vertical integration - refers to product production strategies where most, if not all, components of manufacturing, distribution and retailing are owned and operated by the one company.

Workflow - the process in which products or digital content is created.

3D-integrated - within this project, 3D integration refers to when products and garment patterns have been developed to have components and functions that operate in a digital 3D capacity.

3D virtual prototyping - the production of products utilizing digital 3D drape simulation functions.

Kapinua (Company Branding Shop) R&D Project

30 August 2017

Description of this R&D Project

v. The Brief

- Our R&D project has a central focus on developing our manufacturing capabilities through online customer driven 3D design workflow from requirements, to design, to manufacturing with automating components of the workflow.
- The central aim of this is to extend and optimise a customised digital apparel system to produce a single or multiple garment pattern outcomes for customers to ensure they fit a diversity of body styles, shapes and weights.
- What we are doing is bridging a diverse set of body sizes, shapes and weights.
- Being able to capture and archive a variety of body shapes that can then be used as realistic avatars of real people with diverse body shapes and weights.
- To do this we need to capture, translate and derive data around a diversity of body shapes.
- This will involve including integrating existing systems of motion capture and 3D scanning, using parametric design processes based on algorithmic thinking that enables the expression of parameters between design intent and a diversity of design inputs.
- We see this positioning internationally of Kapinua at the leading edge of our industry. Very few other companies internationally are able to provide this type of service.
- Our research has shown that most customers have difficulties in trying to imagine how a certain design could look like on their new garment such as a uniform when presented in a 2D format as seen on the existing website.
- We have started to develop online pattern making software with an integrated 3D visualisation functionality to present our customers with a true preview of their new product.
- Kapinua is one of a handful of companies globally that is at the leading edge of providing customer driven online 3D design creation through to production in our industry.
- We have achieved the initial stage of having this new online facility but this requires further major development, in particular specialist content as the next stage, to be undertaken with technical assistance from Massey University.
- The aim of this stage is to master 3D virtual prototyping to drape a garment on a 3D avatar.
- Critical steps in this R&D project include appraising a range of existing garment customisation and digital design response systems, for example, FullGear, developing an understanding of a modular apparel system for design and manufacture to cater to a specified price point, and creating testing and reviewing workflow.

- The 3D visual system will speed up the process the placing of orders by converting clicks on the website into order, ensuring the customer gets what they want which reduces disappointment and potential re-works.
- An additional development opportunity is to develop a plugin 3D app.

a) Technical Challenges

- A major challenge is being able to create and develop avatars that look like look book images for the website and 3D mesh structures, which has proved to be a very difficult task.
- Being able to develop a database library of avatars of 3D mesh structures that reflect diverse body shapes becomes a starting point.
- Integration issues in the development of an integrated modular system for customisation with different pattern design development options.
- Formatting the complex 3D mapping into a format that is presentable requires reduction in mesh count, shading and resolution.
- Being able to take the print image, mapping this to the 3D pattern body mesh avatars.
- Consideration of fabric stretch, weight and opacity or transparency to produce product images.
- The results of the product mesh in presentation look books in the web.
- Reducing mesh count and deleting shaders and faces.
- Difficulties with resolution, screen sizes for different browsers.
- Being able to get a good fit for different body shapes and sizes and most challenging.
- To lift efficiently the workflow process needed with individual names and numbers to deal with the common issue of last minute changes by customers.
- Working with placeholders at the moment. Want to design as one garment automatically ready to print, with being able to set up of an automated print template system compared with the several manual steps needed at present.
- Being able to effectively complete the integrated process of logging onto a sublimation printer in other locations overseas, for printing, stitching into a garment and sending to a customer.

b) Overcoming Technical Challenges

- Explore CorelDRAW, Optitex 3D software, and DAZ and alternative software options to ensure optimum option being used eg CLO 3D (new high end tool that Massey has been working with), Accumark, Photoshop, Illustrator.
- Appraise a range of existing garment customisation and digital design response systems, including FullGear.
- Develop an in depth understanding of a modular apparel system for design and manufacture.

- Explore pattern design development for customised garment design units to optimise efficient production using Optitex or alternative 3D apparel technology.
- Produce, review and test prototype modular garment units ready to be uploaded for website communication.
- Question is how to make modular, with a variety of methods to modularise design prototypes.
- Significant input into the process of creating avatars, 3D mesh and conversion, creating of shader placemakers, and setting up of an automatic print template.
- Overcome individual name and number design issues by developing automated processes.
- Develop bridges between multiple programmes to automate the process from online orders to the back end.
- Massey has a number of on site highly skilled technical ICT specialists who are able to help solve these problems.

c) R&D Project Contribution to NZ based R&D programme for the Kapinua business

- Opens up new fields in the emerging area of online textile 3D design creation through to manufacture including being able to contract manufacture at various partner locations elsewhere using Internet 4.0 integrated approach.
- Enabling all customer, including those who have difficulty buying off the shelf garments due to diverse body shapes, sizes and weight needs, to design and buy the product at all and at a competitive price, with an easier and faster design and approval process.
- Providing a platform for other sellers.
- An important aspect is that using parametric design a process based on algorithmic thinking that enables the expression of parameters and rules that together define, encode and clarify the relationship between design intent and a diversity of design outputs.
- This new project getting underway with Massey University is expected to position Kapinua within 12 months even more strongly as one of very few leading internationally in this specialist online international market.
- We are continually reviewing what we do to find better more innovative improvements to what we do and how we can better leverage new technology developments, with this current project expected to open up further new developments.

R&D Project Team

a) Key staff:

- Ingo Schleuss – as in online application
- Jodie Kahu – as in online application

b) External expertise:

- Gerd Ruschaupt – ICT specialist, experienced at developing ICT concept ideas. Online publishing and print publication experience, and software automation. Good at identifying businesses processes and converting these into software solutions.(plus rest of original online appl material)...
- Massey post graduate (person tbc) - With professional support from Massey University staff including from a team of experienced specialist technical experts with areas that includes computer modelling, digital fabrication, motion capture, 3D modelling, virtual and fixed reality, advanced pattern making, textile design and production processes.

Technical Objectives

1. Research diverse parameters and assess different software options.

Work Plan:

- Define and capture a set of diverse parameters for body shapes, sizes and weights.
- Assess CorelDRAW, Optitex 3D software, and DAZ and alternative software options eg CLO 3D, Accumark, Photoshop, Illustrator.
- Appraise a range of existing garment customisation and digital design response systems, including FullGear.
- Develop a platform for modular apparel design and manufacture to cater to a diverse and inclusive audience.

Deliverable:

- An in-depth understanding of the project processes and parameters as shown through the design and development of a prototypical workflow system.
- The context will be assessed on the suitability of the proposed design systems and their suitability for purpose and NZ based market.

2. A modular system for customisation.

Work Plan:

- To extend and optimise a parametric apparel digital system to produce a customised single or multiple garment pattern outcome/s.
- To explore pattern design development for customised garment design units to optimise efficient production using Optitex or alternative 3D apparel technology.
- To produce prototype modular garment system for online presentation.

Deliverable:

- A library of modular styles, appropriate for the identified Kapinua price point, ready for 3D virtual prototyping for a wide range of body measurement.
- A system for presenting and browsing the modular style in a web format.

3. 3D virtual prototyping 1st stage.

Work Plan:

- The aim of this stage is to master 3D virtual prototyping to drape a garment on a 3D figure.
- Consider fabric stretch, weight and opacity or transparency to produce product images.
- Prepare the product mesh for web upload and usability.
- Reduce mesh count and delete shaders and faces.
- Create the placeholders for the various shaders.
- Create customised avatars to create look book images for the website.

Deliverable:

- Cleaning up and formatting the models from the parametric pattern making stage into a web format so they can be browsed by customers.

4. 3D virtual prototyping 2nd stage including testing and finalising.

Work Plan:

- Explore and design experimental design applications.
- Create test and finalise customised avatars to create look book images for the website.
- 3D mesh development and conversion
- Create test and finalise shader placeholders
- Finalise set up of automatic print template for automated laser pattern cutting and dye sublimation printing.
- Final testing.
- Make recommendations for future customisation processes in apparel systems based on experience from existing prototype development.

Deliverable:

- A set of design prototypes for diverse body shapes with and without an avatar.
- Provide recommendations for future customisation 3D virtual prototyping from capture to design to production processes in apparel systems.
- A roadmap of the next new integrations with the design systems that have been developed in this project.

Technical objective 1

Technical objective 1

Objective Name:

Research diverse parameters and assess different software options.

Work Plan:

- Define and capture a set of diverse parameters for body shapes, sizes and weights.
- Assess CorelDRAW, Optitex 3D software, and DAZ and alternative software options eg CLO 3D, Accumark, Photoshop, Illustrator.
- Appraise a range of existing garment customisation and digital design response systems, including FullGear.
- Develop a platform for modular apparel design and manufacture to cater to a diverse and inclusive audience.

Start date:

01/10/2017

End date:

17/11/2017

Deliverable:

- An in-depth understanding of the project processes and parameters as shown through the design and development of a prototypical workflow system.
- The context will be assessed on the suitability of the proposed design systems and their suitability for purpose and NZ based market.

Technical objective 2

Technical objective 2

Objective Name:

A modular system for customisation

Work Plan:

- To extend and optimise a parametric apparel digital system to produce a customised single or multiple garment pattern outcome/s.
- To explore pattern design development for customised garment design units to optimise efficient production using Optitex or alternative 3D apparel technology.
- To produce prototype modular garment system for online presentation.

Start date:

18/11/2017

End date:

26/01/2018

Deliverable:

- A library of modular styles, appropriate for the identified Kapinua price point, ready for 3D virtual prototyping for a wide range of body measurement.
- A system for presenting and browsing the modular style in a web format.

Technical objective 3

Technical objective 3**Objective Name:**

3D virtual prototyping 1st stage

Work Plan:

- The aim of this stage is to master 3D virtual prototyping to drape a garment on a 3D figure.
- Consider fabric stretch, weight and opacity or transparency to produce product images.
- Prepare the product mesh for web upload and usability.
- Reduce mesh count and delete shaders and faces.
- Create the placeholders for the various shaders.
- Create customised avatars to create look book images for the website.

Start date:

27/01/2018

End date:

30/04/2018

Deliverable:

- Cleaning up and formatting the models from the parametric pattern making stage into a web format so they can be browsed by customers.

Technical objective 4**Technical objective 4****Objective Name:**

3D virtual prototyping 2nd stage incl testing and finalising

Work Plan:

- Explore and design experimental design applications.
- Create test and finalise customised avatars to create look book images for the website.
- 3D mesh development and conversion
- Create test and finalise shader placeholders
- Finalise set up of automatic print template for automated laser pattern cutting and dye sublimation printing.
- Final testing.
- Make recommendations for future customisation processes in apparel systems based on experience from existing prototype development.

Start date:

01/05/2018

End date:

30/09/2018

Deliverable:

- A set of design prototypes for diverse body shapes with and without an avatar.
- Provide recommendations for future customisation 3D virtual prototyping from capture to design to production processes in apparel systems.
- A roadmap of the next new integrations with the design systems that have been developed in this project.

vi. Parametric Research

Parametric Research - Men's

	Perceived Size	Chest	Waist	Hips	Neck	Kapinua Size
Participant 1	M-L	102.5	89	111	39	M
Participant 2	L	108	97	110.5	39	XL
Participant 3	S-M	93.5	95	99	40.5	M-XL
Participant 4	L	112	102	117	41	XL-2XL
Participant 5	XS-S	95	82.5	96	36	S
Participant 6	S fit, M length	93.5	93	102	36	S
Participant 7	S-M	99	84	102	38	S-M
Participant 8	XL-2XL	131	116	129	43.5	5XL
Participant 9	M (can fit S)	94	82.5	100	38	S

Participant 1 commented that the medium tee was too tight, especially around the waist and hips but the large tee fits well. The medium singlet was too tight, the large singlet was quite fitted and the extra-large singlet offered a more relaxed fit.

Participant 3 was torn between the small and medium tee. The small tee offered a more fitted style but the medium hung better. The participant commented that they would likely select the medium singlet for sportswear and the large singlet for streetwear.

Participant 4 found the large tee fitted tightly and believed the tee could be longer. The extra-large tee was better in length and fit but was slightly too narrow across shoulders. The participant commented that the extra-extra large hung nicer, was a nice length and fit better across the shoulders.

Participant 5 said that the extra-small tee was too tight and that the small tee hangs nicely but was slightly too narrow across the shoulders.

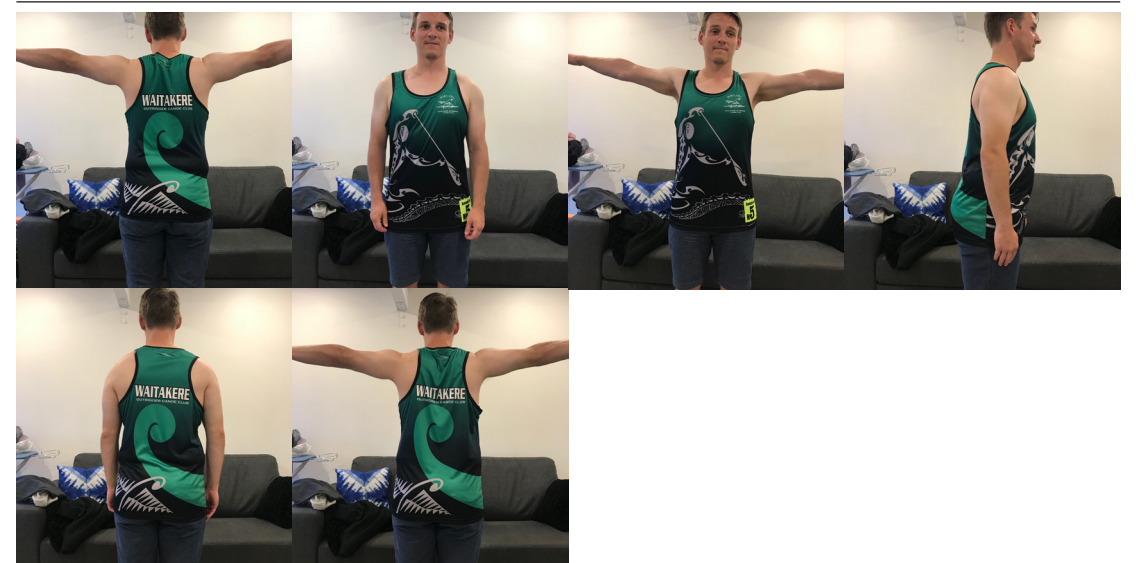
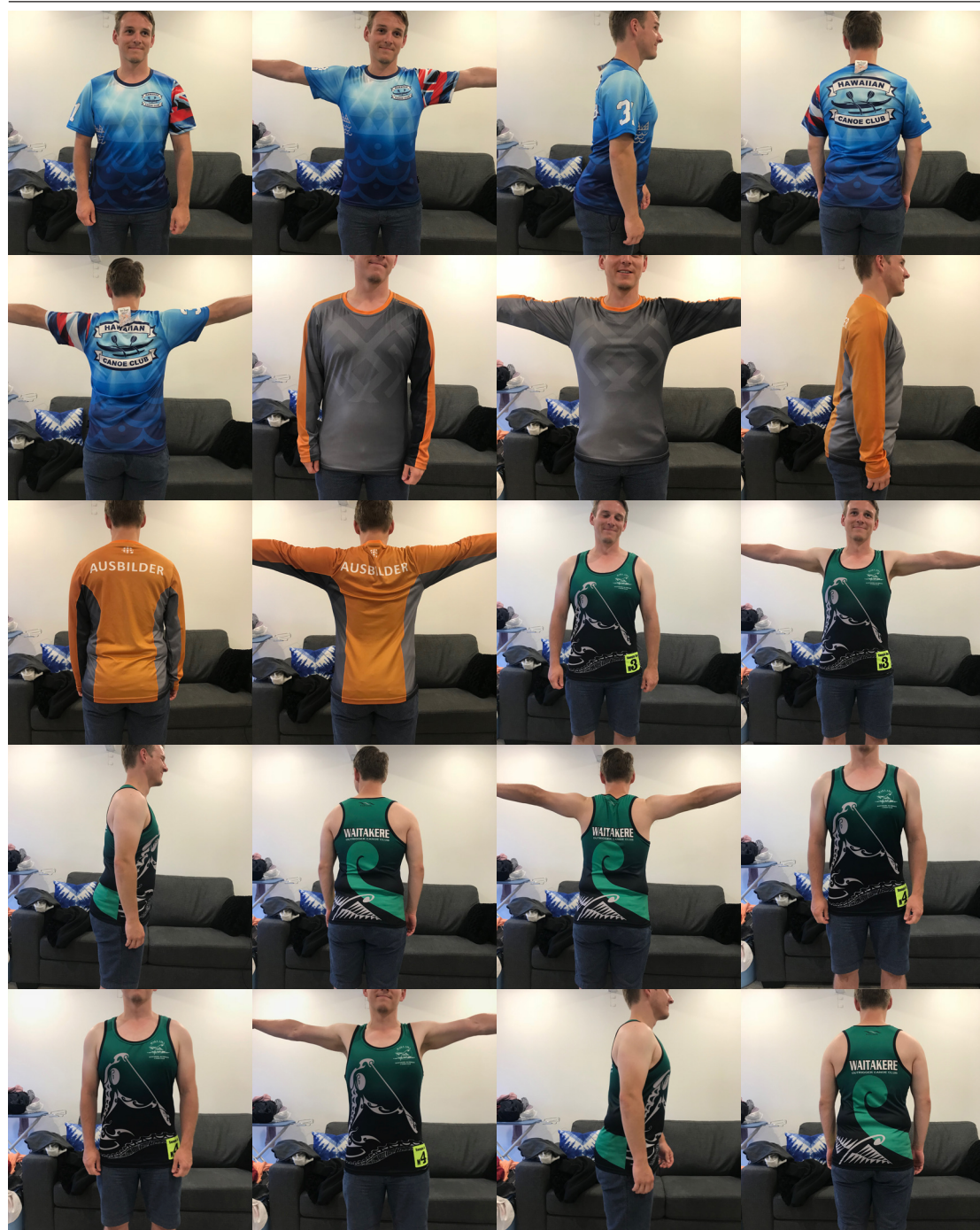
Participant 6 preferred the small tee due to the more fitted style but would also wear the medium. Medium was the preferred singlet fit.

Participant 7 fit the small tee but commented it could be a little looser around the torso. Though the medium hung better the participant did not feel the medium was right and still preferred the small. The medium singlet hung fairly well but was similarly tight around the waist. The large singlet had a bit more room but still quite tight across the stomach.

Participant 8 commented that based on his shopping experience, he thought the 4XL fit more like the 3XL tees he was used to. Additional comments on the 4XL were that the shoulder fit and length was pretty good, waist sat a little tightly, chest was a little too big and emphasised that the collar was "perfect" for him. The 3XL still fit well though he commented that it was more comparable to a 2XL or extra-large. Comments on the 4XL singlet included that the waist and length were good with the overall fit feeling "normal". He also mentioned that the shape of the racer back was nice but that there needed to be more fabric allowed at the front of the scye.

Participant 9 described the extra-small tee as "skin tight" but believed the small tee fit "almost perfectly", emphasising it was the perfect width across. Meanwhile, the medium tee hang a bit too tight for the participant's preferences. When trying the small singlet he commented that it felt like more of an extra-small and that it does not have enough room for his shoulder blades and pectoral muscles. The medium singlet hung better but was still a bit tight across the shoulder blades.

Participant I

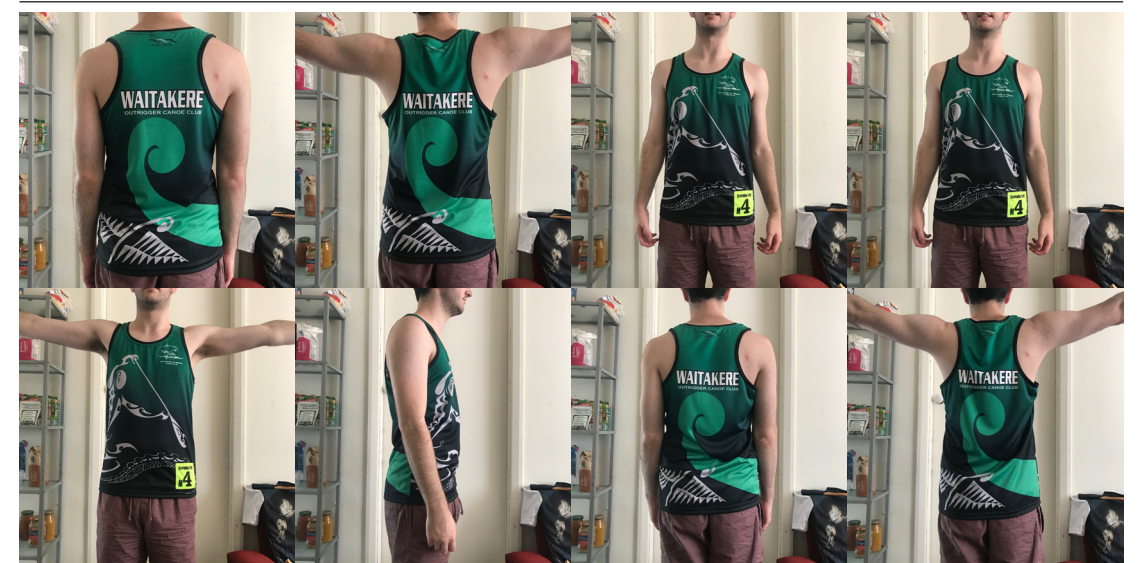
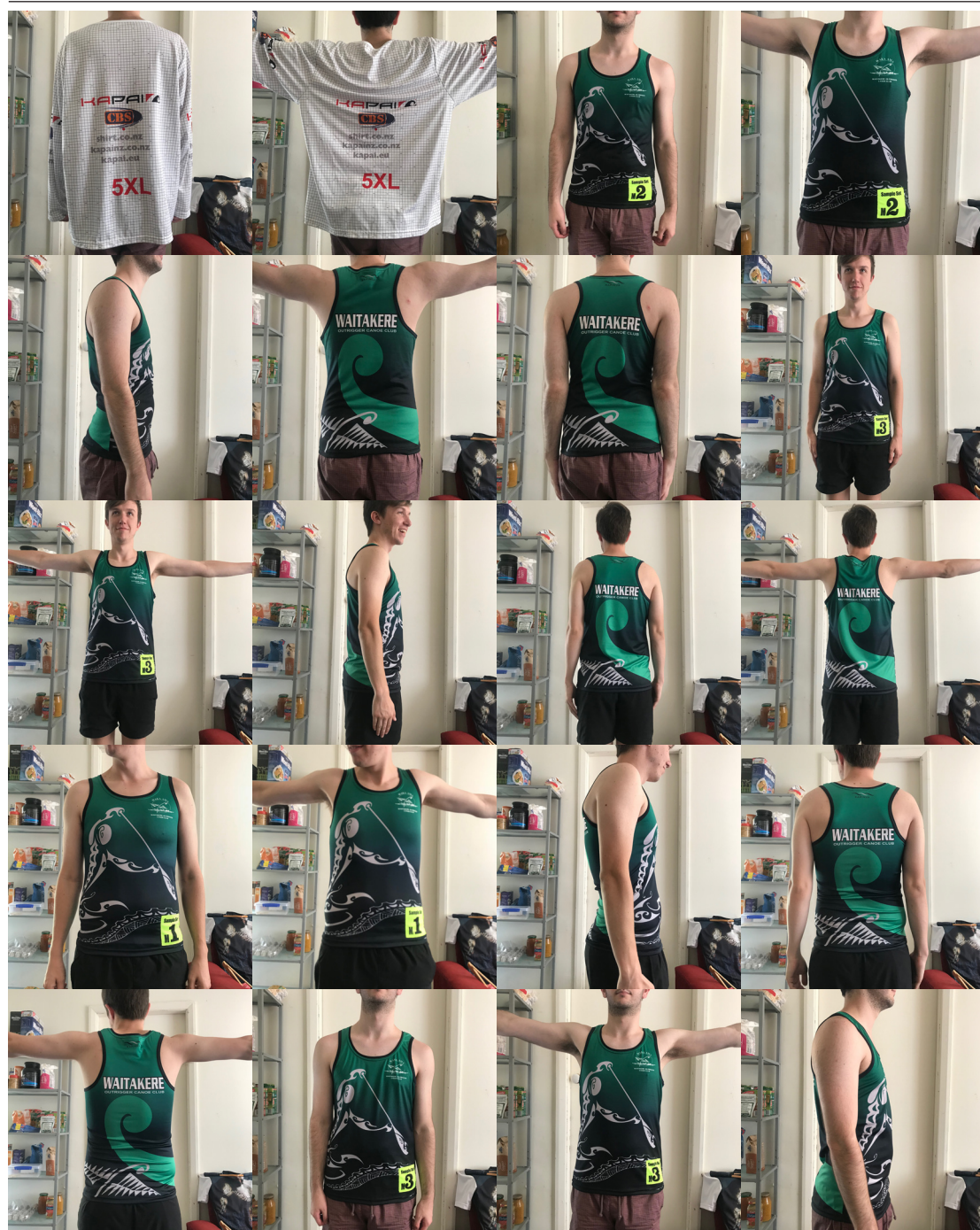


Participant 2



Participant 3

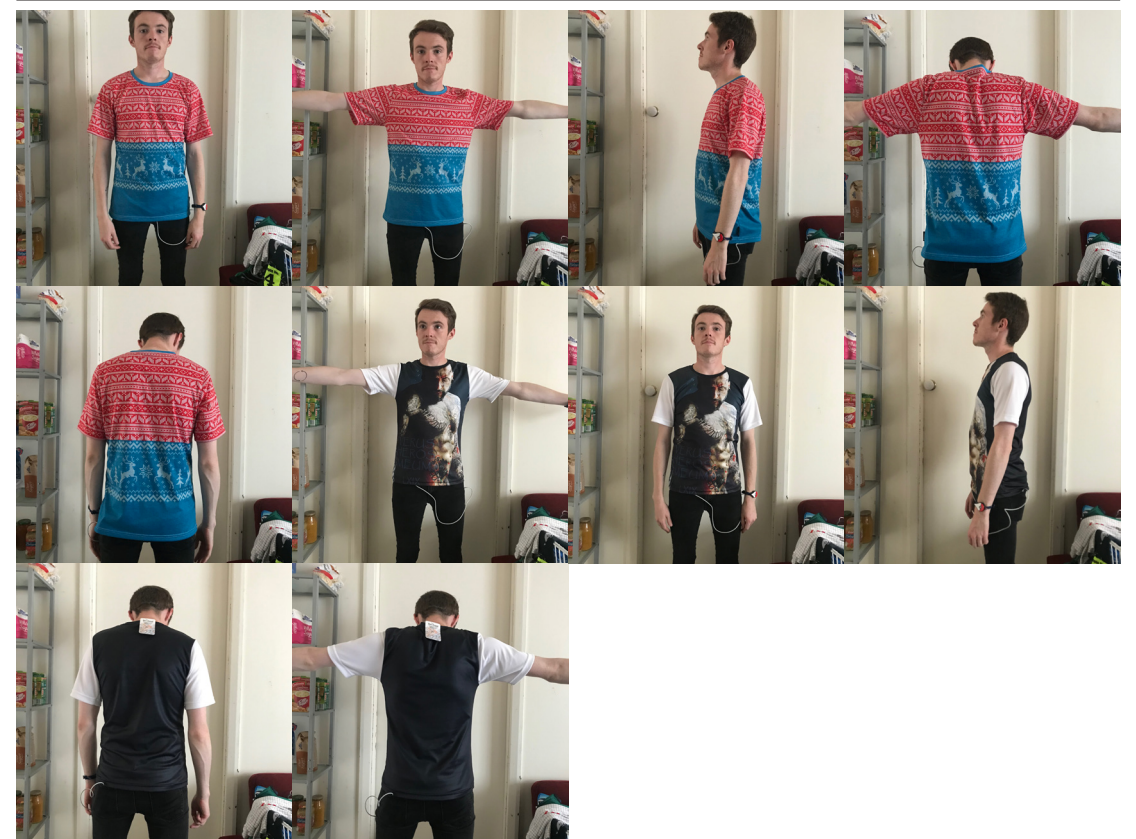




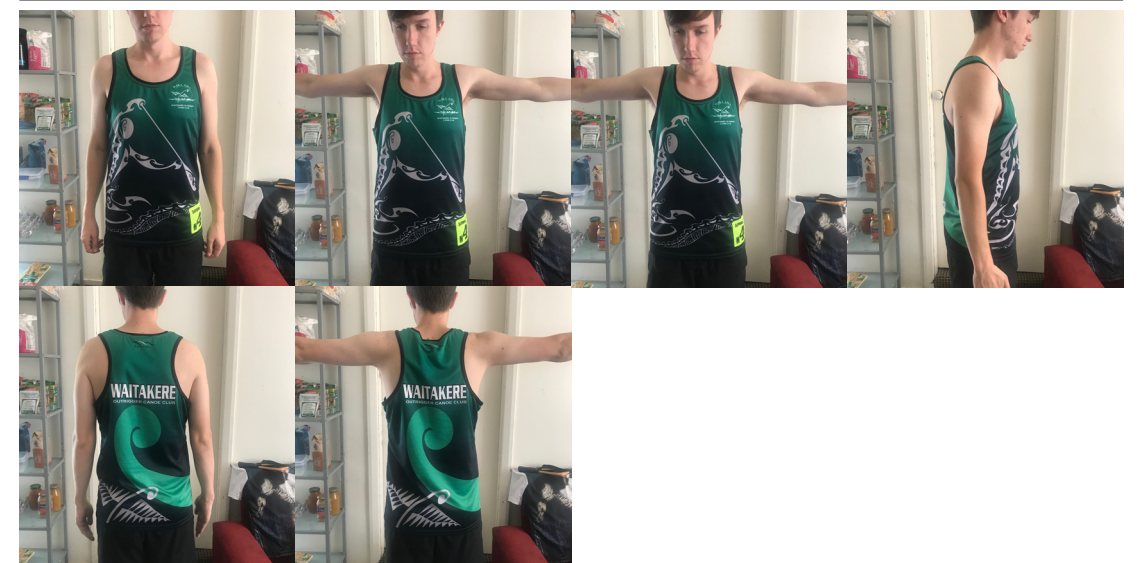
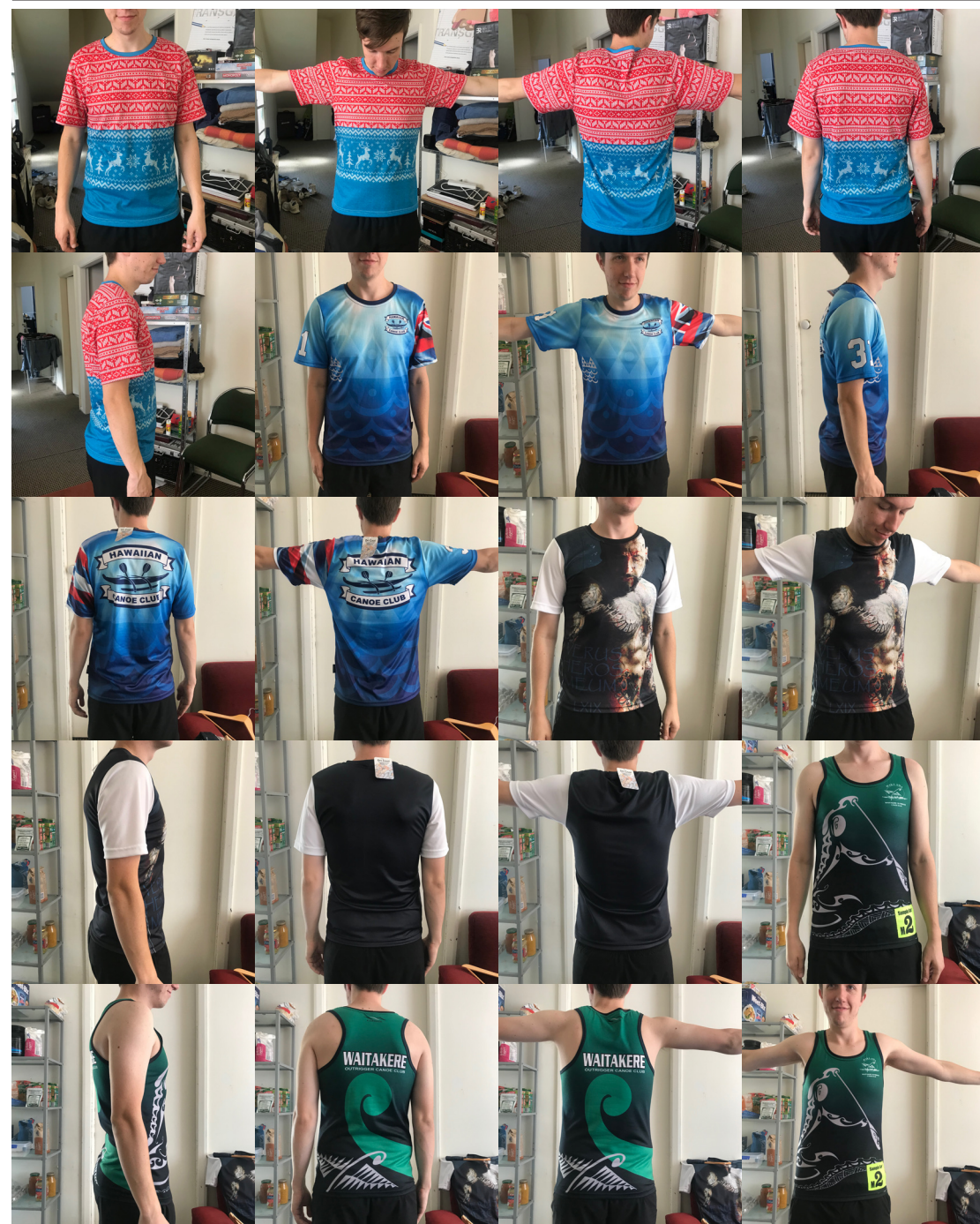
Participant 4



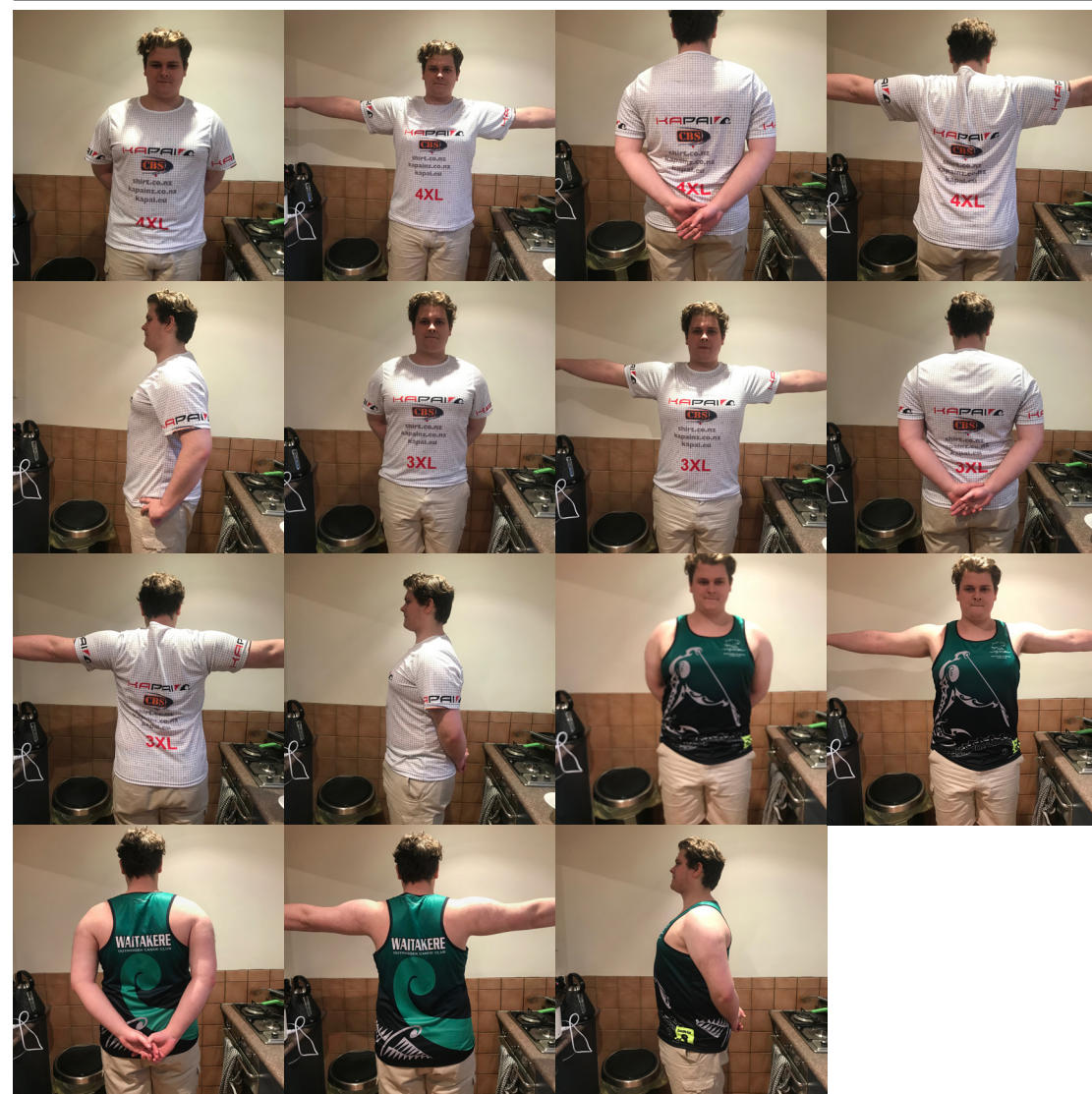
Participant 5



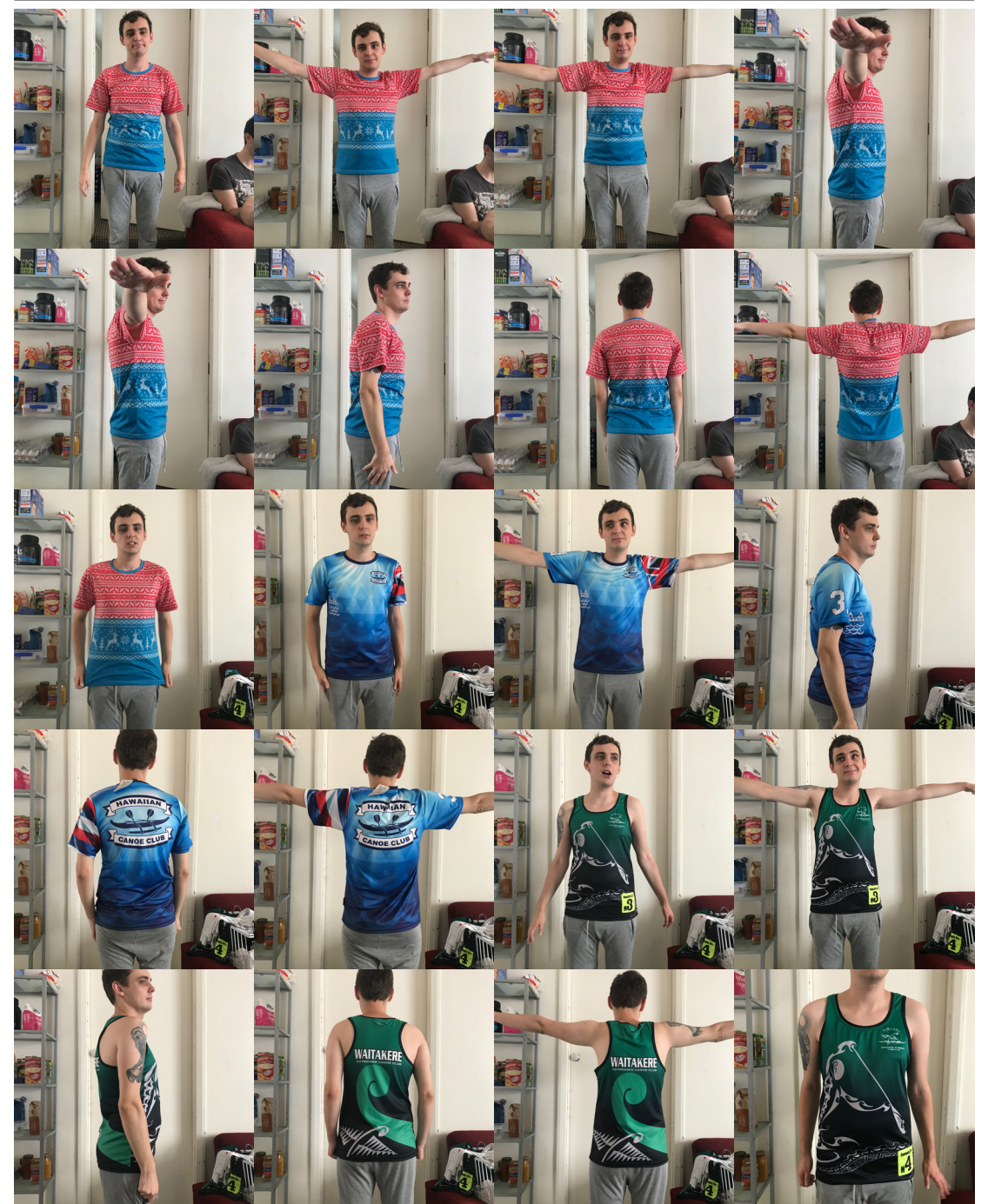
Participant 6



Participant 7



Participant 8





Participant 9





Parametric Research - Women's

	Perceived Size	Bust	Waist	Hips	Kapinua Size
Participant 1	12	101	84	104	16
Participant 2	10-12	95	75	126	10-16
Participant 3	8 (can be 6-10)	87	65.5	88.5	6-10
Participant 4	8-10	92	70	94	10-12
Participant 5	12	102.5	82	112	16

Participant 1 did not fall into one obvious size on the sizing chart as she was a size 14-16 based on bust and hip measurements but was about a size 12 in the waist. She liked the fit of the bust in the size 14 and mentioned that the 12 fitted but pulled.

Participant 2's measurements aligned with size 12 measurements. They believed they would be likely to select the size 10 tee for a more fitted style, and a size 12 for a looser fit, but overall liked the size 10 better.

Participant 3 has a size 8 bust, and size 6 waist hips according to the sizing chart. They liked the fit of the size 8 tee and would wear a size 10 if wanting a looser fit.

Participant 4 commented that the size 10 sat nicely. Her measurements would fall under size 10 in the bust and waist, and size 8 in the hips.

Participant 5 liked the size 12 tee for a fitted style and would prefer this size though they believed the 14 hung better. The participants parametrics were very similar to the fit requirements of size 16.

Participant 1



Participant 2



Participant 3



Participant 4



Participant 5

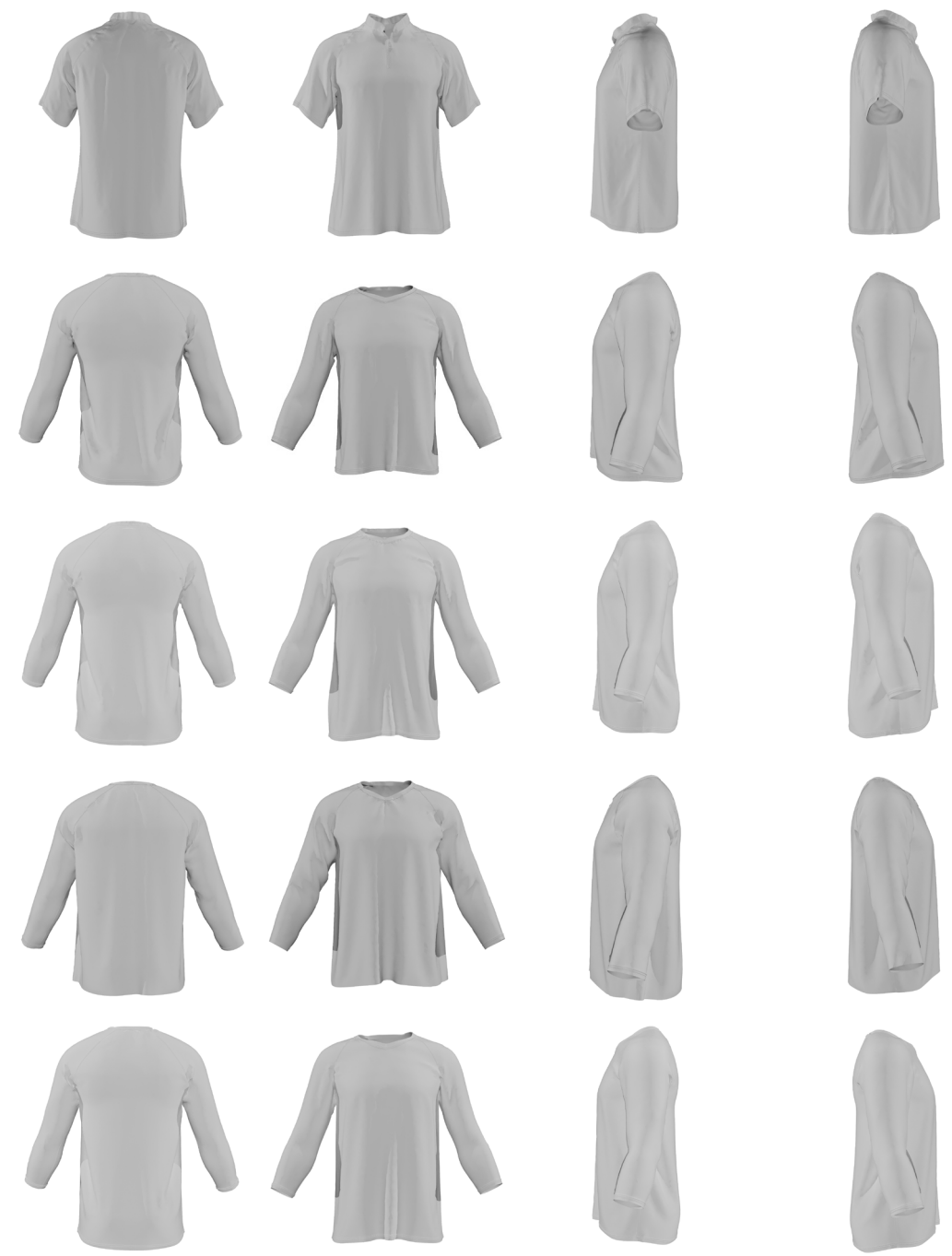


vii. Sizing Images



viii. Product Images







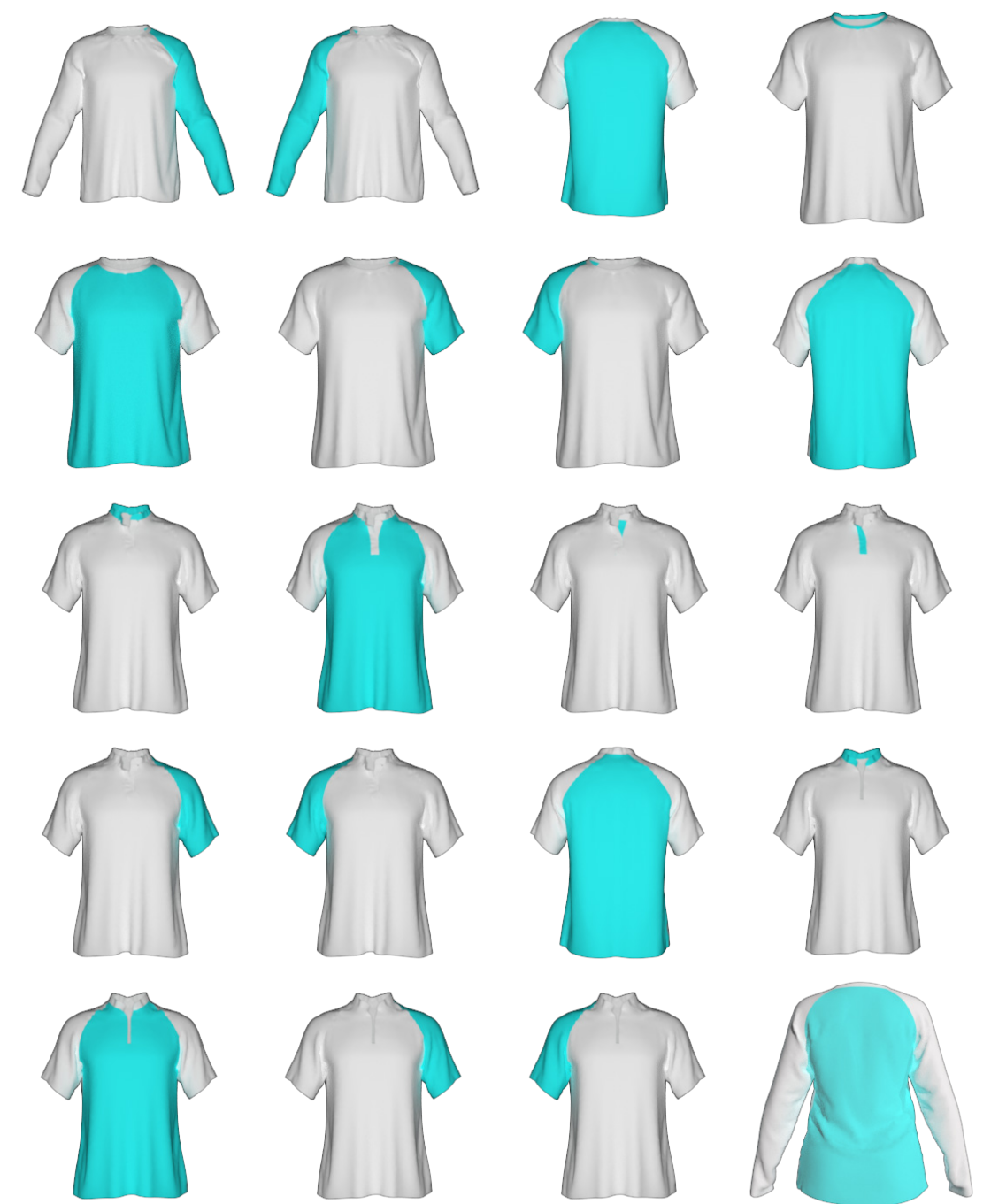








ix. Thumbnails

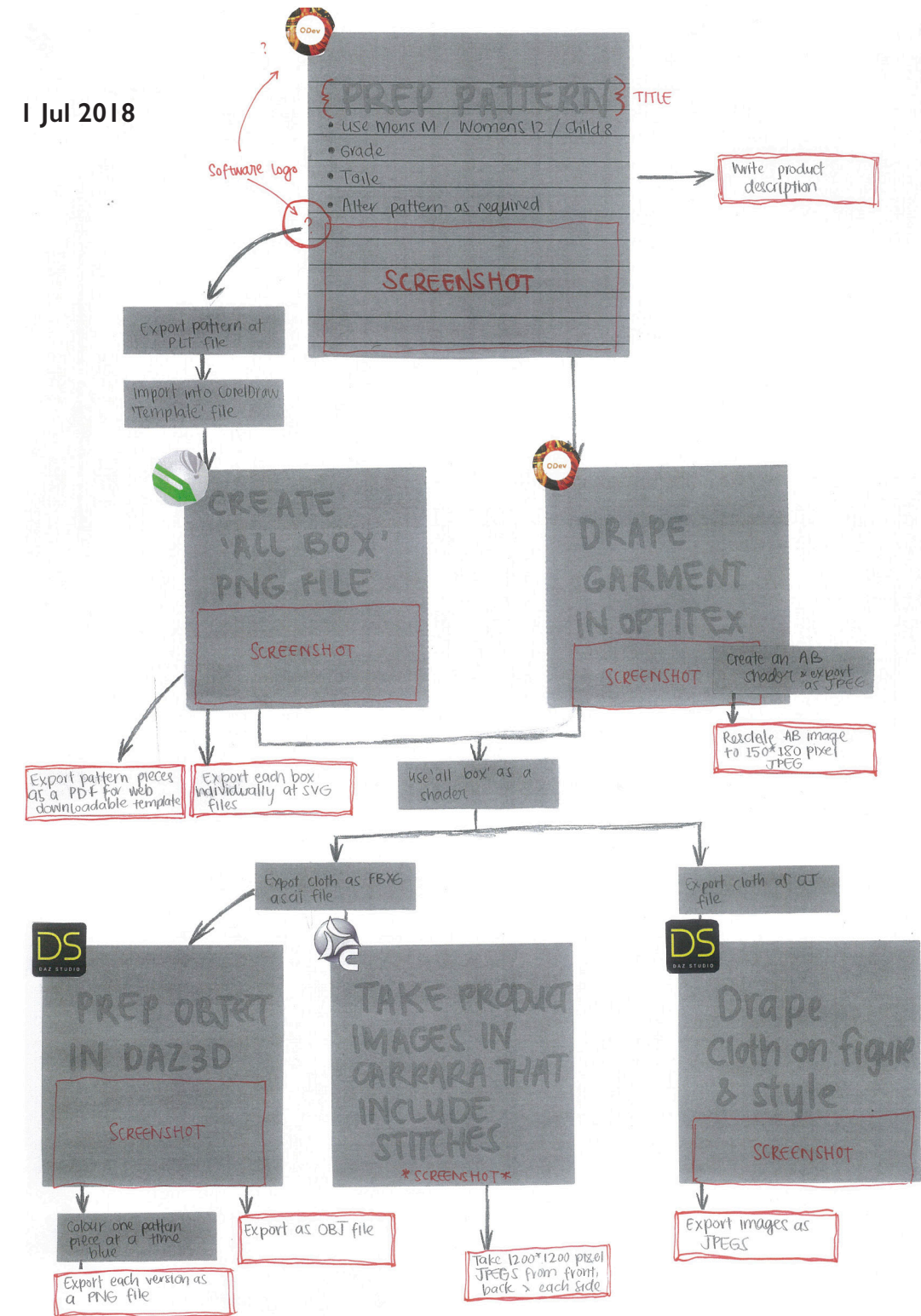




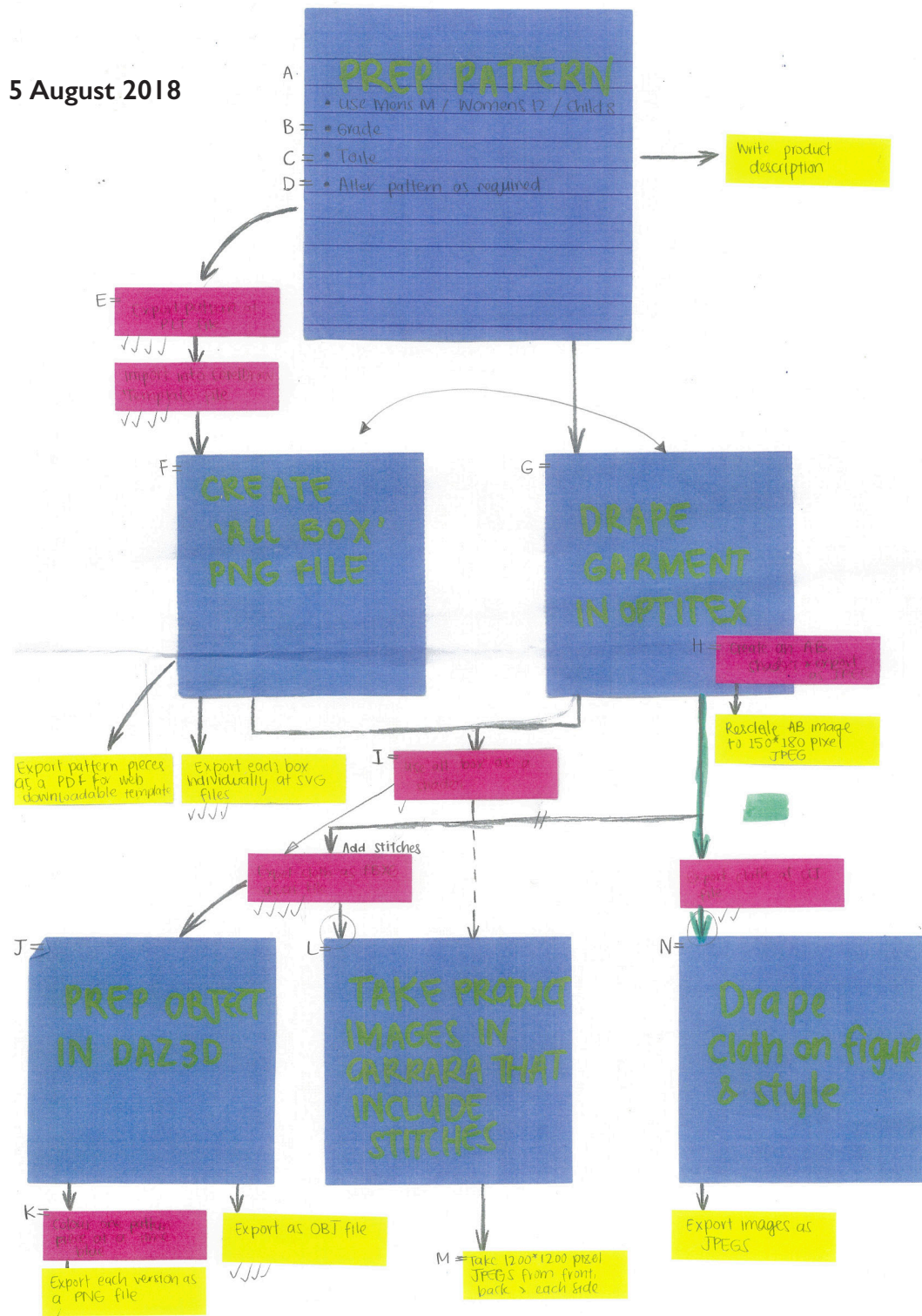
x. Cover Images



xi. Flow Chart Iterations

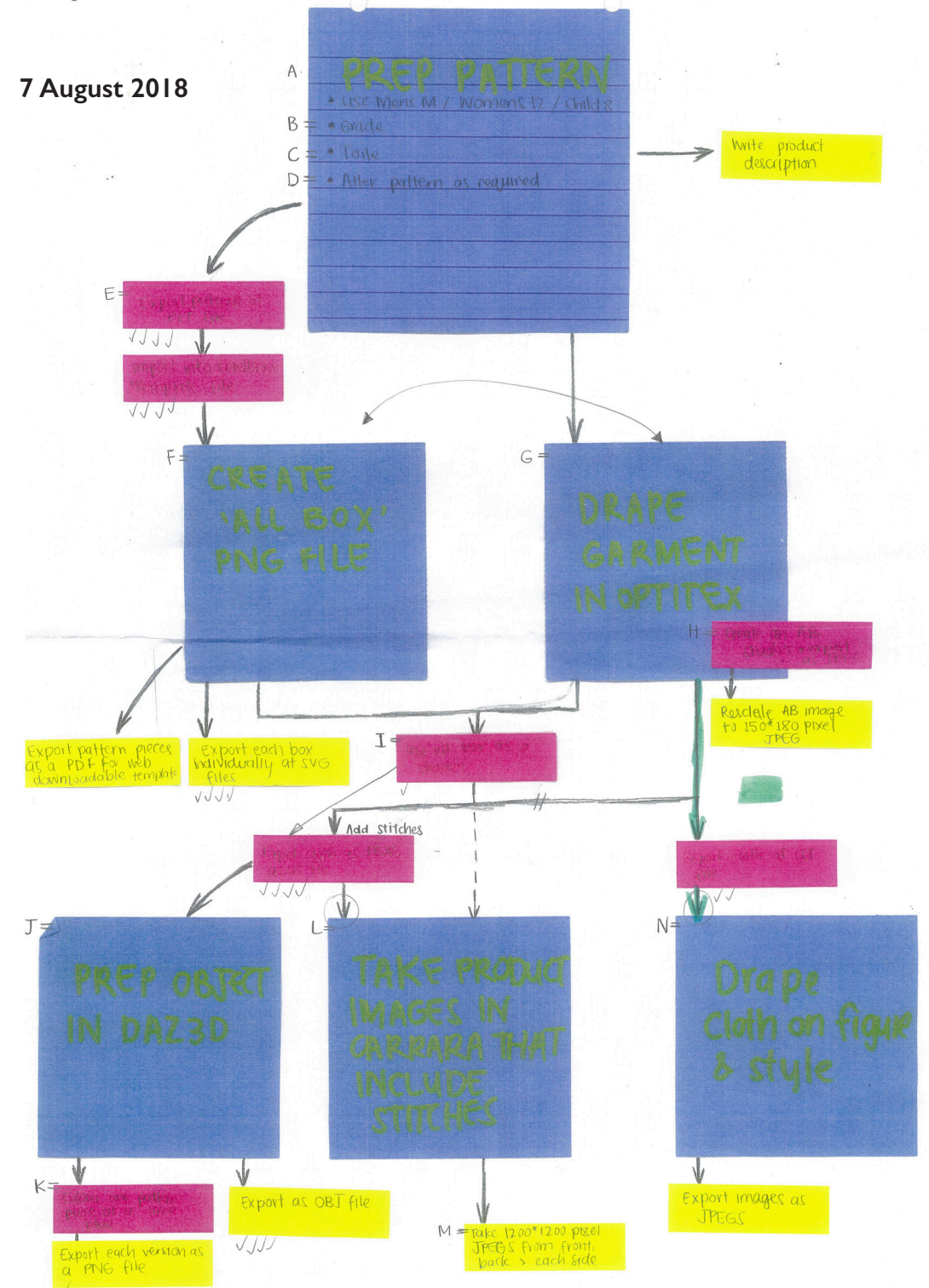


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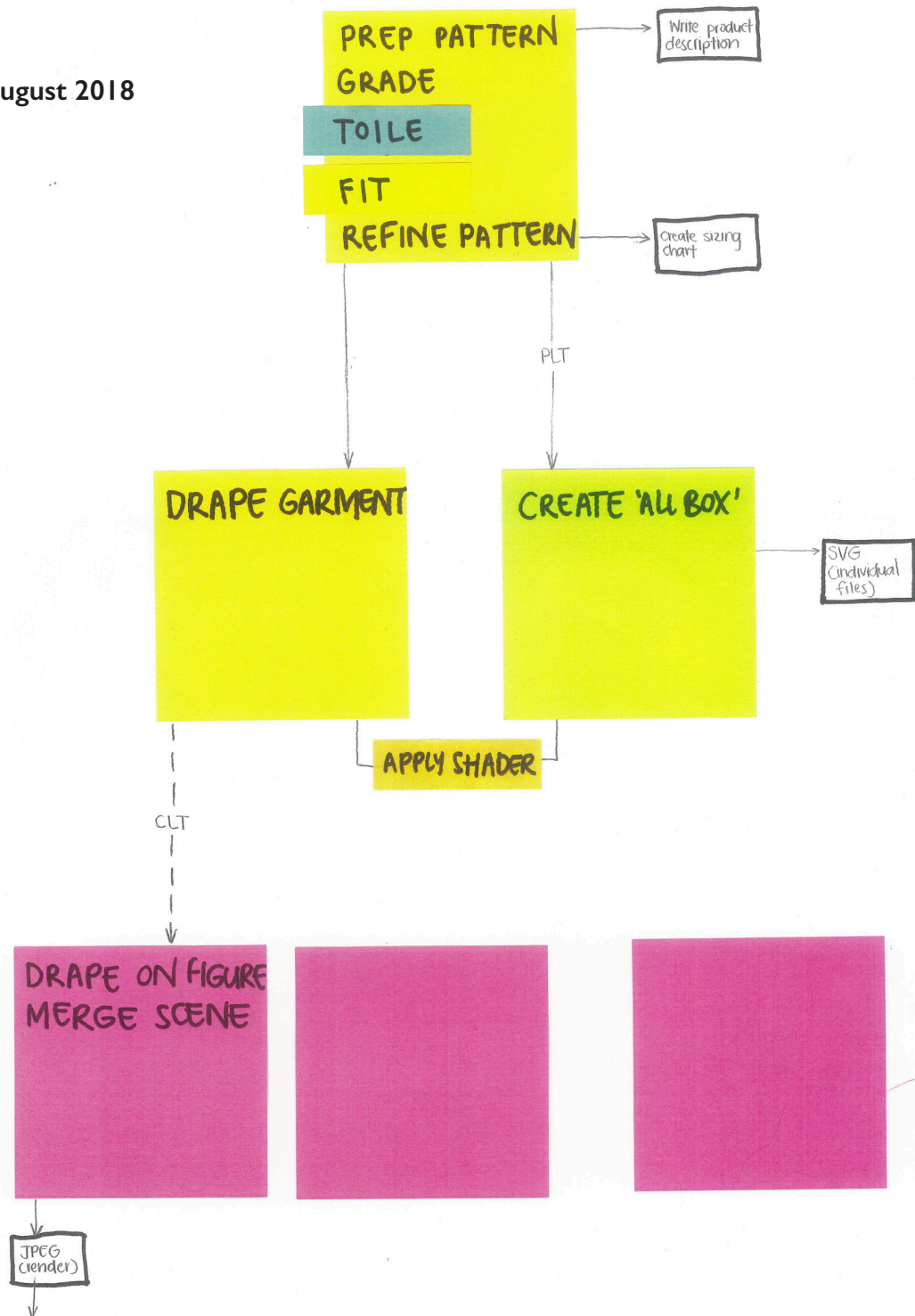


7 August 2018 #01

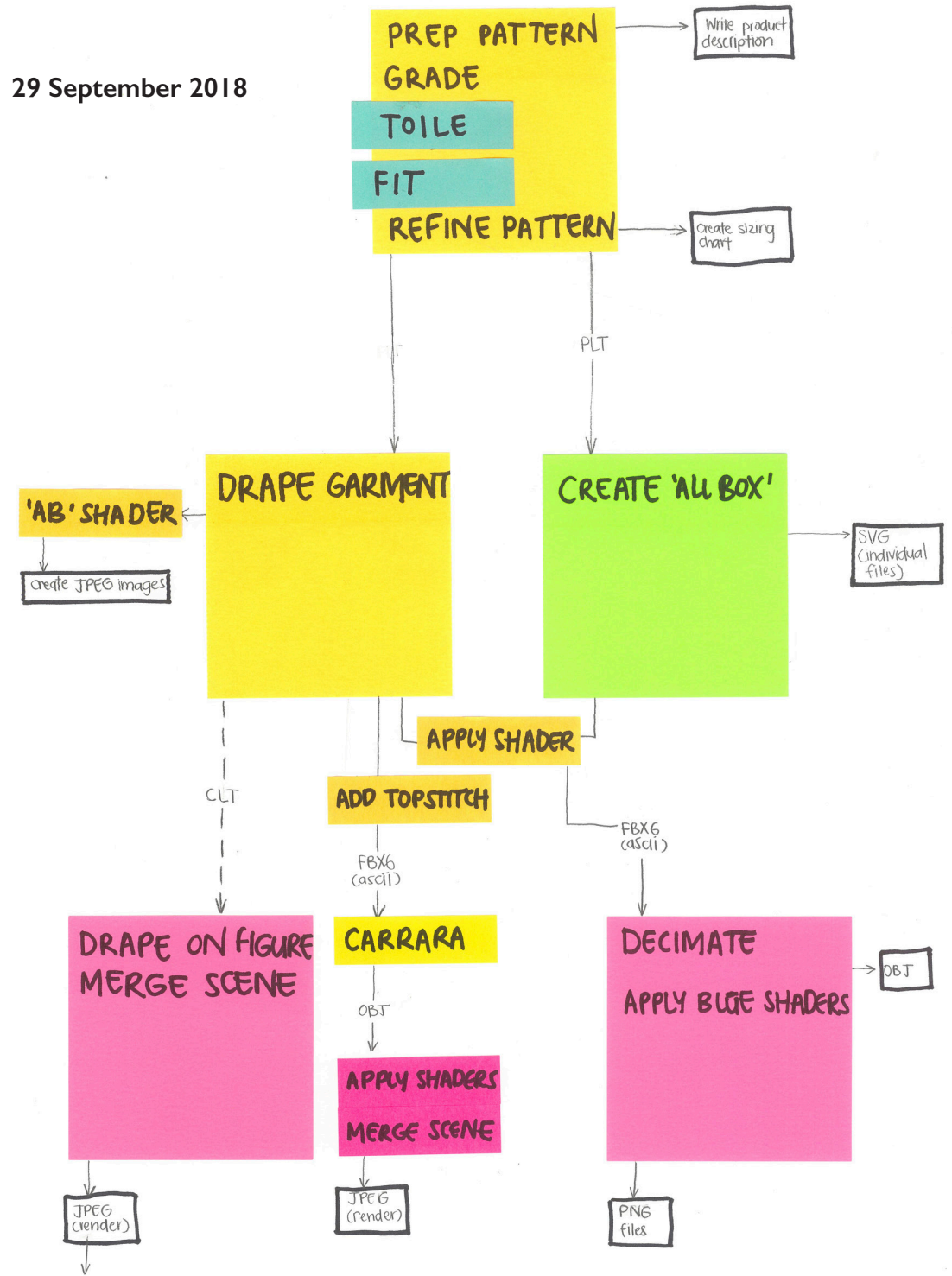
7 August 2018



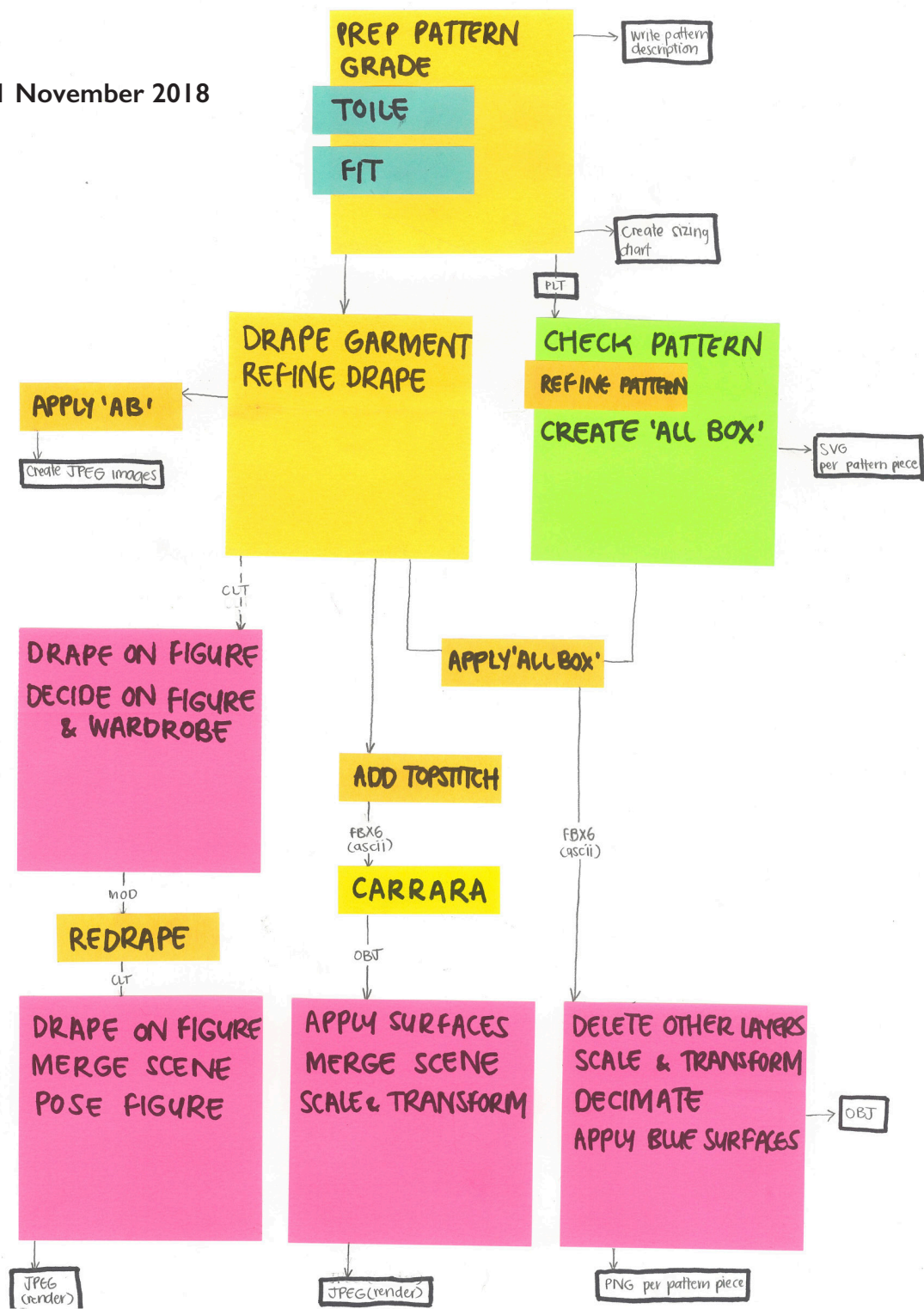
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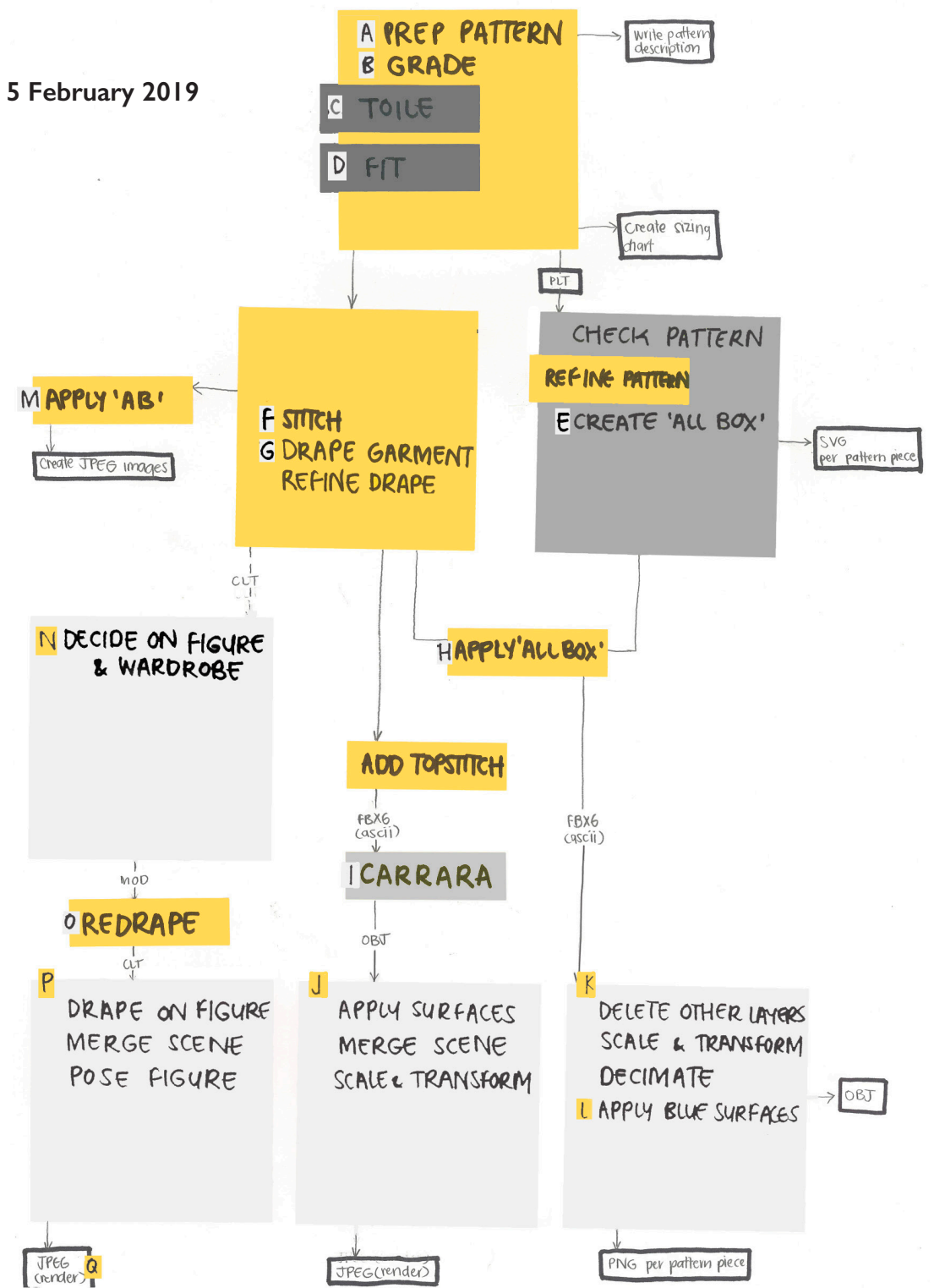
29 September 2018



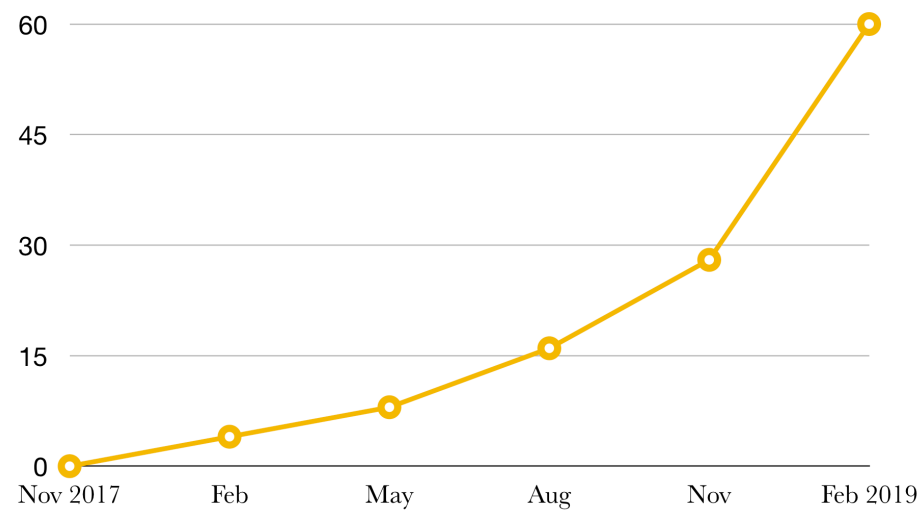
1 November 2018



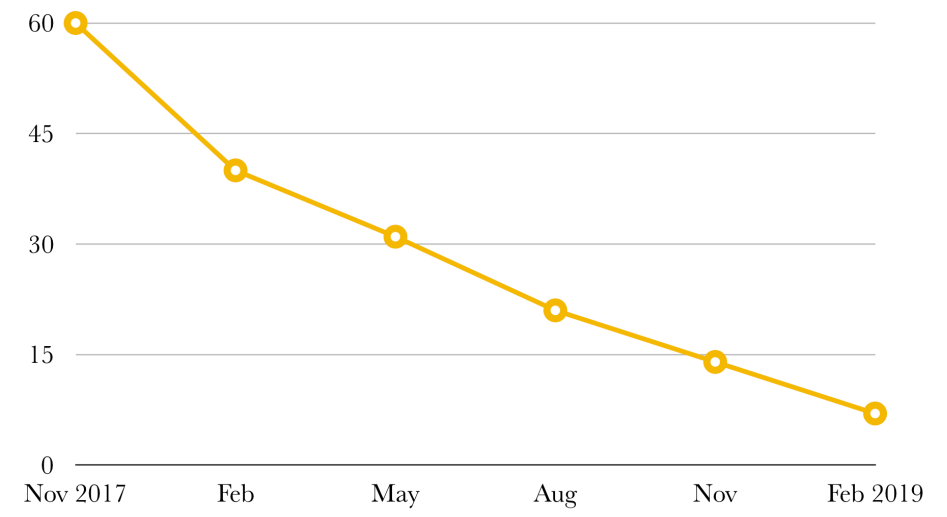
5 February 2019



xiii. Product Development Statistical Charts

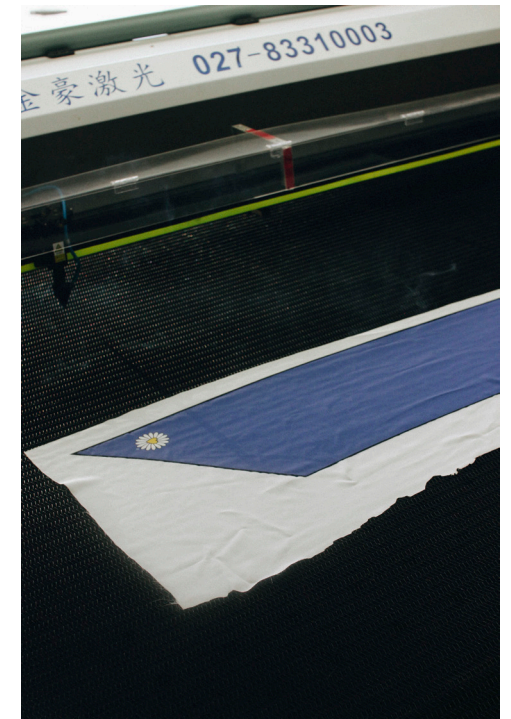
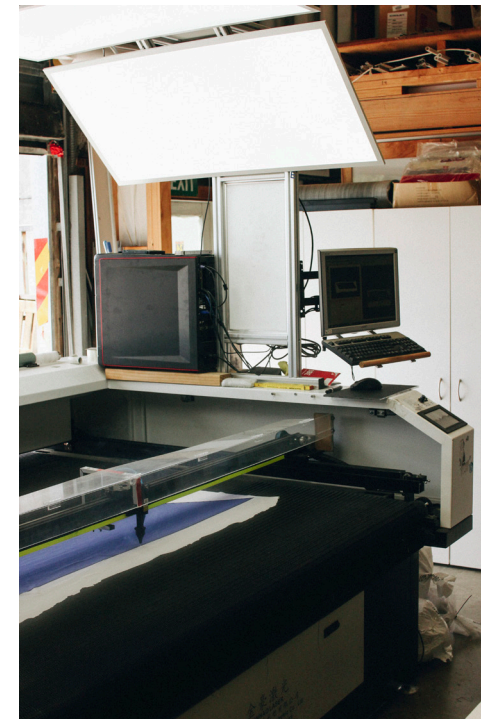


Number of products developed



Estimated days to create a product

xiv. Photographs of Manufacturing Process







Ko Tuhipa te maunga.

Ko Orauta te awa.

Ko Owhareiti te roto.

Ko Ngātokimatawhaorua te waka.

Ko Ngāti Hine te iwi.

Ko Ngāti Te Ara me Ngāti Kopaki ngā hapu.

Ko Tumatauenga te whareniui.

Ko Porowini te whare tupuna.

Ko Otiria te marae.

Ko Te Ruki Kawiti te tupuna.

Ko Colin Hoori tōku pāpā.

Ko Barbara Hunt tōku māmā.

Ko Te Paea Hoori tōku ingoa.

Te Paea



