THE UNIVERSITY *of* EDINBURGH

Nimble Fingers and Green Thumbs:

Materialising digital labour in contemporary art practice

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Abstract and Lay Summary

This practice-based research project in the field of contemporary art considers the relationship between craft, digital technology and ecology. The purpose of this research is to articulate under-recognised connections between these areas of study, and to explore how those connections might be made concretely visible in artworks. It draws upon the histories of computing and print culture, labour and media studies, adopting a material feminist methodology through which to engage with these subjects. This thesis has been produced with Dundee Contemporary Arts Print Studio as its industry partner.

The portfolio of artworks around which this project is centred comprise of three exhibitions in the UK between 2018 and 2019. These took place at David Dale Gallery, Glasgow, Bloc Project, Sheffield and Hospitalfield, Arbroath, and each presented environments in which a variety of contrasting elements were brought together. Envisaged as parts of an overarching system, the artworks that populate these environments act as metaphorical devices, bringing a series of cultural narratives into dialogue with one another. These metaphorical associations are explored using motifs; including the technological rationality of the computer mainframe, the ecological connotations of vegetal matter; technical processes linked to amateur handicraft, printmaking, computer-aided techniques; and materials signifying, amongst other things, second-wave feminist art practices, countercultural aesthetics and the creative economies.

The textual portion of the project comprises of a sequence of reflections on these artworks, placed alongside four chapters that each analyse a specific moment in the history of computing. Themes of these chapters include women's roles in developing early computer mainframes, the etymological roots of the phrase 'computer bug', ideologically motivated arguments for the innate suitability of non-white labour to the manufacture of integrated circuitry, and the influence of countercultural thinking on contemporary digital culture. These concentrate on how different visions of feminised craft labour and the natural world were employed in this industry and shaped who worked with computers. A recurring element of these explorations is how gendered hierarchies have been maintained by altering the narratives attached to certain forms of work.

The mutability of these narratives is a common element that joins the text to the portfolio. Together they consider how traditional definitions of 'women's work' become models for how we understand contemporary conditions of digital labour, as a site of simultaneous creative expression and exploitation.

Items Constituting this Thesis

Alongside this document this thesis includes a separate **Portfolio**. This provides documentation of the exhibitions *Noon,* David Dale Gallery & Studios, Glasgow, *Lowlight*, Bloc Projects, Sheffield, (both 2018) and *Hothouse,* Hospitalfield, Arbroath (2019). Each exhibition section begins with a short, written summary. There is also an **Appendix** which gathers the accompanying gallery texts.

You are invited to look through the portfolio before reading this document.

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Introduction

Preface: Binary Beginnings

In 1998 the cultural theorist Sadie Plant published *Zeros + Ones: Digital Women and the New Technoculture.* It became the key text for what became known as Cyberfeminism, proposing a haptic and tactile feminine framework of technology, and questioning the culturally dominant perception of digital technologies as a new edition to the history of technology, conventionally described in masculinist terms. Plant traces the history and cultural identity of digital technology through the connections between weaving and computer systems via mathematician Ada Lovelace, who was crucial in the development of modern computing. Considered through the lens of psychoanalytical feminism, Lovelace's biographical details are interwoven with the stories of computer scientist Grace Hopper, science fiction writer Mary Shelley, and a nameless array of machine operators, typists, and factory workers. Together these accounts make up an alternative history of digital technologies. Plant's central argument is that women have always been digital workers:

> When computers were vast systems of transistors and valves which needed to be coaxed into action, it was women who turned them on. When computers became the miniaturized circuits of silicon chips, it was women who assembled them … when computers were virtually real machines, women wrote the software on which they ran. And when computer was a term applied to flesh and blood workers, the bodies which composed them were female (Plant 1998, 37).

This analysis focuses on the interface between bodily flesh, computation, and gender, its goal being the creation of a feminist future in which women find themselves as the rightful heirs to digital culture. Although later criticised for its gender essentialism and digital-utopianism, Plant's work has had a significant impact on artistic practices and feminist technology studies from the 1990s to today (Paasonen 2011; Sollfrank 2019). But of course, in the twenty-five years since its publication, the relationship between gender and digital culture has changed, and not in the way *Zeros + Ones* imagined. Despite digital technologies proving an important tool for recent feminist activism surrounding gender inequality in online space, the development of social media has nonetheless been accompanied by growing numbers of attacks on women, particularly women of colour, far outstripping those on men (Amnesty International 2018). Notwithstanding numerous campaigns to get women into the computer industry, gender disparities still remain (Learn to Code 2021). Today only 33% of the women employed at Google identify as female and the number of non-white employees remains at the 50% mark (Lyons 2021). Even though Plant

and others have highlighted the importance of female labour in digital and computer history, today the computer remains highly masculine-coded, with white, cis, male ‘nerds’ remaining both the principal architects and cultural image of the internet and Silicon Valley (Chang 2018; Mundy 2017).

In response to these ongoing problems around gender and digital labour, one might wonder where the digital feminist utopia of the nineteen nineties went awry? Is the consideration of women’s work through a feminist lens still a useful tool with which to approach digital labour, and might our conceptions of craft labour play a part in this? Could Plant’s project be renegotiated for the technological and gender politics of today? If so, could the perception of masculinity and computer technologies be destabilised, and new technological futures be imagined?

Project overview

This thesis addresses these questions through artistic practice. *Nimble Fingers and Green Thumbs* takes the themes of ecology, handicraft, and digital labour, as originally explored by Plant, and seeks to expand them within the context of a series of contemporary art projects that are engaged with the history of computing. Rather than presenting a concealed narrative of female dominance, as Plant attempted, this research exposes how the gender-coding of pre-existing production technologies was used to alternatively value and devalue women in computing. In doing so, this project seeks to expose the mutability of gender-technology relationships, and to identify the means by which such complexities can be communicated, both visually and through the collation of a variety of discrete areas of critical discourse.

The artworks presented as a portfolio here seek to blend or interweave narratives drawn from different fields and debates. One of the innate capabilities of visual art I would suggest is its powerful ability to accommodate multiple concerns at once, and to act as a connective device capable of joining diverse elements together. Thus, I consider my exhibitions to contain a critical complexity that is difficult to achieve using written analysis. By comparison, the text that accompanies this portfolio of artworks dwells on a variety of historical accounts and is reflective of a body of research undertaken in conjunction with the exhibitions presented here. This document can be regarded in part as an expanded guide through which elements of my visual practice might be productively apprehended. The primary intention in compiling this written component was to identify points of crossover between various moments and times in the histories of computing, craft, environmentalism and print. These are the crossovers that find visual representation in the artworks that I make. The **Research Context** section that appears later in this introduction outlines prevailing concerns in a range of scholarly fields I have drawn from, and identifies in each, gaps that this project looks to address through a process of comparison.

Interspersed amongst four chapters that centre around particular case studies there are an additional sequence of sections devoted to technical and operative aspects of the artworks that feature in the portfolio. These sections have been positioned to stress certain affinities between the methods I employ as a visual artist, and the wider body of research that has informed them. Stylistically, I have chosen to emphasise the discontinuity of the relationship between the portfolio and accompanying writing. The following text does not function as a direct explication of the artworks presented elsewhere. Rather, these operate in tandem,

each presenting their own distinct insights into the topics addressed. Nor is the relationship between research and the production of artworks entirely linear. Often, the realisation of an exhibition has suggested areas for further research, creating a system of feedback between my written and visual practices.

Consequently, this text does not present a progressive, linear argument. Each of the four main chapters examines a case study from computer history. Following science-fiction writer Ursula K. Le Guin's provocation that linear narratives are grounded in a masculinist history of technology, the form of my essay resists a sequential chronology. The stories I tell do not attempt to create a grand history. Instead, this combination of case studies is closer in nature to the form of a fabric container outlined by Le Guin ([1986] 2019). They function like the warp and weft of interlaced threads, creating a kind of narrative scaffolding (Deloria 2004, 12). In turn, this textual structure echoes the material interconnectivity of various subject matter triangulated within this project: a piece of woven cloth, the circuitry of silicon chips or mycelial networks of fungi.

The purpose of this approach is to create a complex model of interactions, one that is critically grounded in material feminism. Due to the innate complexity of the topic, meaningfully engaging with it has required abandoning opposing binary conceptions, and the development of strategies through which ideologies and cultural artefacts can be mapped as relating to several things simultaneously. The structure of this text is arranged to reflect this approach, repeatedly seeking as it does to reposition findings from particular discourses in relation to others.

Nimble Fingers and Green Thumbs, the title of this submission, can be viewed as a metaphor for women's work within digital computing. Although I have chosen these phrases to designate two, distinct discussions within the history of computation — the history of women's work in the computer industry, and the importance of countercultural thinking on the development of computer technology — the metaphors of *Nimble Fingers and Green Thumbs* are closely intertwined. While these expressions are strictly speaking metonyms, across this thesis their function is metaphorical. In my art practice, the metaphor of *Nimble Fingers* speaks to the relationship between advanced technological work and domestic crafts evident in computer history and is demonstrated through my use of textiles and printmaking. The metaphor of *Green Thumbs*, by contrast, refers to the complex inter-relations of technology, gender and ecology, and finds visual form in the horticultural motifs in my sculptural works. As will be outlined in the **Methodology** section below, the use of materials and motifs in these artworks, and the technical processes employed to produce

them, are each suggestive of changing conceptions of gender in the computer industry. Additionally, such materials, motifs and processes are also meditations on how those conceptions might be reconfigured through reference to other debates and technological narratives found in craft and fine art discourses.

Industry Partner: Dundee Contemporary Art Print Studio

This project has been carried out in conjunction with DCA Print Studio, who act as an Arts and Humanities Research Council (AHRC) Creative Industries Partner to the University of Edinburgh. Working at DCA Print Studio, I engaged with a range of digital and non-digital print technologies they have on site. This equipment includes traditional printmaking technologies such as screenprinting, etching and relief presses, as well as digital equipment including laser cutters, CNC (Computer Numerical Control) routers, 3D printers and inkjet printers (DCA 2021). A key aim of this project was to develop methods of working with print technologies that situated them as a primary medium, as opposed to a secondary one, troubling the persistent cultural hierarchical separations between art and craft. A preoccupation of mine is how gender intersects with these classifications. This is a topic which, as this introduction will argue, a contemporary relationship between printmaking and print technologies further complicates.

The philosopher Gilles Deleuze famously stated: ‘machines are social before being technical. There is always a social machine which selects or assigns the technical elements used’ (Deleuze 1988, 34). However, printmaking is a field which has been described as ‘excessively technical’ (Emmons, Tillman and Urban 2018, 215). Consequently, I wanted to find a way to foreground the sociocultural aspects of print technologies, and to position this as part of a broader discussion around the fine art and craft divide. This in turn necessitates thinking through printmaking’s complex relationship to digital devices such as the ‘computer’. In this project I use the term computer to move away from an ambiguous ‘digitality,’ towards a concrete mechanism which can be imagined as an object. The term computer refocuses our attention on physical and infrastructural factors, materialising the digital as a site of production, rather than perceiving it as a type of untethered information. By doing so, my objective was to complicate binarised concepts of production such as digital/analogue, craft/industry, mechanical/hand produced, and masculine/feminine.

Research context

Art and craft, craft and technology

Prior to the commencement of this PhD project, my practice was concerned with the hierarchical values attached to art and craft. These are themes that persist in expanded form here. My artwork explores how do-it-yourself (DIY), and hobby techniques can be used sculpturally to question why certain materials have greater or lesser cultural value. Using methods and processes gleaned from how-to-manuals aimed at the home-crafter or hobbyist, my practice elevates what could be conceived of as amateur or domestic creations to the arena of fine art. This approach is not restricted to any medium and uses juxtaposition and assemblage to bring together specific materials or processes which connote different ideologies. Those materials include mass-produced plastics, tubular steel furniture, yoga mats or hand-dyed cloth. Furthermore, by framing their relationship to craft processes and domesticity through the materials they employ, these artworks actively associate themselves with the traditions and histories of women's labour.

Building on this set of concerns, this research uses craft discourse as a lens, in both the practical and textual aspects of the project, through which to examine digital labour. Although these two areas were notably brought together by Plant, at first glance craft and the computer may seem culturally antithetical, as the ideology of handicraft is often regarded as oppositional to the industrial basis on which computer technology is constructed. However, as historian Paul Greenhalgh points out 'both technology and craft are more complex than such a negative reductionism implies. The vision relies, in fact, on a falsification of the history of both' (1997, 105). Similarly, craft curator Glenn Adamson reminds us that our contemporary understanding of craft is formed inversely through its relationship to industrialisation in the eighteenth and nineteenth centuries. 'Craft was not a static backdrop against which industry emerged like figure from the ground,' Adamson states, 'rather the two were created alongside one another, each defined against the other through constant juxtaposition' (2013, iixv). Thus, as this thesis contends, the categories of craft and advanced conceptions of industry are not only interrelated. They are entirely dependent on one another.

From an art historical perspective, it was also during the industrial era that certain craft practices began to be coded with increasingly rigid ideas of class, gender and race. The cultural associations of these processes stem from the historical separation of the 'mechanical' from the 'liberal' arts, developed from the Renaissance and solidified by the

mid-nineteenth century. On the topic, craft historian Elissa Auther writes ‘associations of such work with ideas of usefulness, skill, adherence to traditional forms, or the use of “lesser” media like wood, clay or fibre were commonly accepted as distinguishing craft from art’ (2010, xv). Museological categorisations separating fine art from the decorative or applied arts persist to this day, subordinating items associated with a lower-class labour force (bricklaying or metalwork) or those produced by women (needlecraft and weaving) (2010, xv).

A process of invidious gendering is also to be found in the legacies of Karl Marx, arguably industrialisation’s greatest critic. Marxism’s use of the term ‘craft’ is vague, but it generally positions the types of craft labour that women traditionally performed as existing outside of the structures of capitalism proper. According to media theorist Jack Bratich, for Marx, ‘craft functions as both a de-valued, marginalized act (a residual activity that does not produce value) as well as a particular form of labour (the professional worker, with specialized knowledge)’ (2010, 315). The former, what we might term handicraft, is a type of labour linked with amateurism, the home, and in turn femininity. The latter, what I will call technical ‘craftwork,’ including techniques like spinning, weaving, or printing, would have been carried out by skilled labourers or artisans. These activities are associated with industry and masculinity, what feminist sociologist Cynthia Cockburn described as a ‘patriarchal craft culture’ (1983, 3).

Of course, for feminist artists handicraft has long been used productively to examine the hegemonic hierarchies of art and craft. During the 1970s, feminist artists including Miriam Shapiro, Judy Chicago, and Faith Ringgold employed techniques and materials which had been derided as women’s work, such as embroidery, collage, and ceramics, and subverted them to criticise the gendering and racialisation of such categories. This implicitly political endeavour was based on the conflicting conditions of handicraft described by art historian Rozsika Parker in *The Subversive Stitch: Embroidery and the Making of the Feminine* (1984). Parker writes that just as embroidery not only provides ‘the means of educating women into the feminine ideal… [it] has also proved a weapon of resistance to the constraints of femininity’ (Foreword, n.p.). Textile handicrafts such as needlepoint, quilting, knitting and crochet are particularly associated with Western feminist art practices. Despite charges of essentialism, these processes have continued to be employed in contemporary art as a method of disrupting artistic conventions and exploring the exclusion of female, queer, and non-Western practices from the artistic canon (Adamson 2007, 139–164; A. Jones, 1996; Molesworth 2000, 71-97). At once attempting to build upon such a tradition while calling into question certain material affiliations upon which it has relied, this thesis

uses handicraft as a tool with which to examine the history of women's work in digital labour. It is by identifying the parallels between these different forms that I believe this earlier activity can be both honoured and meaningfully extended upon.

Women's work and digital labour

In a scholarly landscape attempting to formulate intersectional frameworks for post-colonial and queer feminisms, the evocation of 'women's work' may appear outmoded. However, it has been given a new lease of life within recent digital media theory, and I use it particularly in relation to its employment by digital media theorist Kylie Jarrett (2014, 2015). Building on the labour theory of scholar Kathi Weeks, Jarrett employs the phrase 'women's work' not to denote the sex or gender of the individual worker, but to engage with the unequal history of labour for men and women (2011). '*Women's work,'* Jarrett argues:

> …is often associated with unpaid domestic labor, particularly in those feminist arguments that struggle to revalorize this and have it recognized as labor. This is not to imply that this work is exclusively done by women, nor to naturalize the categorization of such work as essentially feminine (2014, 15-16).

In this project, the vexed term 'women's work' is used deliberately to acknowledge that men and women still frequently practice different types of work, but that those labouring practices are not based on the aptitude of one sex or another, and instead operate as gendered constructions that forge distinctions between waged and unwaged labour (Weeks 2007, 238-39).

The concept of 'immaterial labour,' first coined by theorist Maurizio Lazzarato, is used to describe the shift towards cognitive capitalism from the 1970s onwards, and is considered one of the key attributes of digital economies (1996, 133–147). While this provides a powerful way to engage with contemporary attitudes towards work, what is less clear in this account is how the immateriality of information and computer-based work, or aspects of cultural production relates to the history of gendered labour. Responding to this issue, feminist thinkers have argued that writers such as Lazzarato, who perceive these issues as new phenomena, do not acknowledge that immaterial labour practices have firm roots in the feminised labour of the home (Federici, 2004; Fortunati 1995; Jarrett 2015; International Wages for Housework 1972). As sociologist Angela McRobbie writes:

> In the many articles and books written in recent years on the topics of precarious labour, immaterial and affective labour, all of which are

> understood within the over-arching frame of post-Fordist regimes of production, there is a failure to foreground gender, or indeed to knit gender and ethnicity into prevailing concerns with class and class struggle (2011, 60).

Or, as Jarrett puts it: 'it often seems as if immaterial labor was only "invented" when it moved out of the kitchen and onto the Internet' (2014, 15). As a means of counteracting this tendency, Jarrett uses the phrase 'women's work' to bridge the gap between immaterial digital labour and the immaterial labour of domestic work, such as child-rearing, emotional support or cleaning. Following her lead, I deploy the idea of women's work to bring together the conventionally considered immaterial realm of digital labour and the material world of handicraft. While it would be easy to see these worlds as distinct (given their apparent material differences), this thesis will demonstrate that they, in fact, share considerable commonalties.

Digitality and cyberfeminist legacies in contemporary art

In the last decade, digitality and digital culture have become a dominant theme in contemporary art. In the time since Claire Bishop wrote her article 'The Digital Divide' (2012), which admonished the artworld for ignoring the systematic changes to culture, labour and dissemination being brought about by the digital revolution, there have been numerous attempts to consider how contemporary art explores digital culture. Curators have suggested that contemporary artists exploring 'digitality' can be described as making work after, for, or about the internet. Theorists such as Boris Groys (2016) have focused on how the online dissemination of images alters Walter Benjamin's concept of 'aura' ([1936] 1968), while others, such as curators Melissa Gronlund (2016) and Janet Kraynak (2020), have positioned the concept of a comprehensive digitality as an everyday condition. No longer the domain of the computer arts alone, artists are not bound to any medium, exploring the subject of technologised connectivity both on- and offline, with a range of digital as well as analogue production methods. Such is the totality of this situation that even attempts to resist digitisation become bound up in it. This parallels the earlier formation of craft as a category formed in opposition to industrialisation.

Given this context, the cyberfeminism advanced by Plant in *Zeros + Ones* has undergone something of a renaissance. With attention on the subject having waned by the early 2010s, a new wave of interest in cyberfeminism emerged from 2014 onwards. This resurgence is evidenced by various events and exhibitions in the art world. These include the five-day event *Post-Cyberfeminism International* (2017) at the Institute of Contemporary Arts,

London; the panel discussion *Revisiting the Future: TechnoFeminism in the 21st Century* (2019) at the Barbican, London; *Producing Futures—An Exhibition on Post-Cyber-Feminisms* (2019) at the Migros Museum, Switzerland; and the group show *Hysterical Mining* (2019) at the Kunsthalle Wien, Austria. Additionally, artist and founder of early cyberfeminist group Old Boys' Network, Cornelia Sollfrank released the edited volume *Beautiful Warriors: Technofeminist Praxis in the Twenty-First Century* (2019), which brought together seven practitioners from art and activism to explore new positions in techno eco-feminisms. These projects and many more were recently catalogued in the comprehensive *Cyberfeminism Index* (Seu 2022). Within a diverse range of exhibitions, symposia, texts and art projects the terms 'post-cyberfeminism' and 'technofeminism' are used, often interchangeably, to critically engage with pre-millennial cyberfeminist discourse (Hester 2017).

Post-cyberfeminists often directly critique Plant yet continue to cite her as a key influence. Noting Plant's influence on her own 'xenofeminist' position, a form of anti-naturalist, technomaterialist and gender abolitionist feminism, the cultural theorist Helen Hester argues that the limits of Plant's project are within the textual leaps and connective associations she built up in *Zeros + Ones* (Cuboniks 2018; Hester 2018). Hester suggests that the 'insistent blurring of the boundaries between concepts strikes me as substantially restricting much of the text's diagnostic capacity and political utility' (Hester 2017). Elsewhere, curator Legacy Russell has seen the potential of the 'glitch' as a method of transforming the 1990s 'white cyberfeminist landscape [that] marginalized queer people, trans people, and people of color' (2020 33). In an argument that (as has been highlighted elsewhere) echoes cyberfeminism's own insistence on conditions of multiplicity, Russell argues that with glitch feminism, binaries are dissolved, gender becomes plural and there is no distinction between on- or offline space. By first accounting for and then moving beyond the original criticism of essentialism, both Hester and Russell are in effect renovating cyberfeminism using queer, post-colonial, and accelerationist theories.

While these important texts respond to the criticism levelled at Plant, and although feminised labour is highlighted as a topic, there is limited discussion in these more recent, post-cyberfeminist manifestos of how craft labour might relate to digital labour and its histories. This is surprising, since Plant's ideas of the entangled relationships between gender, the digital and craft are crucial to her account. I would argue this reflects the underacknowledged assumption that the labour conditions of digital culture are not new and formed on previous sociocultural constructs of gendered labour. Hence, beyond the models proposed by Hester and Russell, my formulation suggests the concept of female labour is

doubly subject to gendered conceptualisations — those pertaining to the digital but also to the material, as manifested in the labour of craft. Consequently, my research looks to expand and further articulate the post-cyberfeminist positions by reassessing the structuring influence of craft labour upon digital history. One of the primary methods it will employ is a consideration of recent findings in Science and Technology Studies (STS), which will be discussed shortly.

Beyond weaving as women's work

Of course, cyberfeminism was never a singular vision. Rather, it is often described as constituting multiple feminisms or defining itself through what it was not (Old Boys' Network 1997; Paasonen 2011, 342). Within this multiplicity, the links between textiles and computation, so clearly defined in Plant's work, formed a central theme, but the influence of such thinking did not materialise in craft-based outcomes. Instead, cyberfeminist collectives such as Old Boys' Network, SubROSA, and VNS Matrix drew on the metaphorical and historical links between the threads of textiles and networked systems to imagine the internet as a potentially feminist space (Ackers et al, 1997; Fernandez, Wilding, Wright, 2003; Barratt et al, 1991). One of the clearest examples is artist and filmmaker Lynn Hershman Leeson's feature-length film *Conceiving Ada* (1997) in which a contemporary female computer scientist communicates with the historical mathematician Ada Lovelace 'by tapping into undying information waves' (Callan n.d.).

Despite the limited discourse in cyberfeminism in recent years, in the field of contemporary art there are several artists actively exploring the connections between craft and computation. The relationship between the Jacquard Loom and the first computers developed by Charles Babbage and Lovelace in the nineteenth century has been an important touchstone for artists who desire, as Plant did, to link the process of weaving directly to computation. Long before Plant's contribution, a seminal work by Beryl Korot, *Text and Commentary* (1976), not only suggested technological links between textiles and computer code but created an installation incorporating print, woven cloth, video and audio to explore the structural limits of abstracted binary code, as they 'provide varying perspectives on virtually the same information' (Korot 2002, 13).

More recently, projects by artists such as Christine Borland, Crystal Bennes, and Ahree Lee have employed punch cards and woven cloth to explore commonalities in women's labour spanning from industrialisation to the computer age. Working collaboratively, Borland and Brody Condon produced the installation *Daughters of Decayed Tradesmen* (2015) in a

derelict watchtower at the New Calton Burial Ground, Edinburgh. This installation employed Jacquard loom punch cards, suspended in looping arrangements from the ceiling, as vehicles for the coded transcriptions of the oral histories of the last remaining alumnae of Edinburgh's Trades Maiden Hospital. Bennes' artistic project *When Computers Were Women* (2021) includes four handwoven Jacquard wall hangings of translated computer programs from CERN. Lee's *Pattern: Code* (2019) explores the intertwined history of weaving and computation, interspersing images of women working with punch cards to create a moving image work.

Expanding on such examples, which use the figure of weaving as the primary method through which to examine a gendered digital history, my research explores a succession of overlaps between craft and digital culture. One of the key elements that this project is claiming as its contribution to knowledge is the range and diversity of the overlaps that it highlights, seeking as it does to purposefully complicate simplified narratives around different forms of technological production and their societal coding. As has already been intimated, and as we will see in the remainder of this thesis, myriad connections between craft and digital history lie beyond that of the loom and computer. Heavily implicated within these same histories are our established conceptions of ecological order and geopolitical dynamics that have disproportionately redistributed menial labour towards low-income countries.

Plant, despite stating that 'weaving is the exemplary case of a denigrated female craft which now turns out to be intimately connected to the history of computing and digital technologies,' does not limit her understanding of female labour to such a narrow framework (2000, 332). In *Zeros + Ones* and elsewhere, she considers a whole host of materially productive labour — lacework, papermaking, and screenprinting — and administrative labour — telephone switchboard operation, secretarial work, and coding — to be part of the story of feminised technological labour (1998; 2000).

Following Plant's example, and the adaptable framework provided by Jarrett's definition of women's work, the exhibitions I have made for this project employ a range of textile, printed, computer-aided and readymade materials. By doing so, I aim to construct a complexity around what women's work is and can be defined as. This relates to both the work that I carry out myself, and how the labour of others can be figured or otherwise represented in the artworks that I produce. In particular, print and computer-aided technologies have provided me with a series of conceptual and material slippages that have allowed the complex gendering of those technical processes to come to the fore. Rather than presenting craft and computation, the analogue and digital, and DIY and mass-produced as binary concepts, this

thesis maps how they bleed into or commingle with one another. This approach is central to the contribution that this thesis makes to contemporary artistic research.

A turn to print

As I have suggested, to expand upon ideas of women's work in my artistic practice, beyond a variety of blind spots I have identified in the critical positions examined above, I have turned to print and printmaking. Print technologies and techniques cross multiple fields and disciplines and are employed in commercial printing, publishing, ceramics and printed textiles. Consequently, they appear on multiple substrates and have a more complicated relationship to the regimes separating art from craft than textiles. Printmaking, or the fine art print on paper, has historically been referred to as a 'handmaid' to the fine arts (Dossie [1758] 2006). The editioned print or sculptural multiple is often positioned as 'secondary' in status to the 'primary' art mediums of painting and sculpture. Moreover, printmaking is often still not able to shake its associations with commercial print and industrial publishing. This has left printmaking peculiarly placed within the fine arts. As print historian Susan Tallman writes, print finds itself with a:

> …"neither fish nor fowl" problem. Partly handmade and partly automated, partly populist and partly elitist, the original print has struck many as either a fussy little craft or as posters with pretensions (Tallman 1996, 9).

In its characterisation as a 'handmaid,' there is no mistaking the gendering of the language that seeks to separate printmaking from fine art. This is not an entirely un-redemptive position to occupy, as such a form of marginalisation from the elevated status of fine art has allowed some artists and theoreticians to productively gender-code the discipline as feminine or queer (Reeves 1999; Harding 2013). However, print technologies could also be perceived as gendered masculine in a different context. Equipment used to produce prints, such as etching presses or screenprinting beds, were often designed for industry, only to be superseded by new technology and relegated to the domain of fine art. It is with this downgraded status that this apparatus can take on more feminine characteristics, being no longer effectively productive.

This situation can be further complicated. Although the products of printmaking studios are frequently regarded as subordinate to unique artworks, the technical prowess that is required to master processes of editioning continues to align itself with the performative aspects of masculine craftwork. Indeed, as recent art historical research has shown, male printmakers in fact used gendered language in the construction of their medium throughout the

nineteenth and twentieth centuries. For example, feminised attributes were recognised in the dexterous and delicate labour required by nineteenth-century wood engravers (Roberts 2019). In her study of the experimental print studio Atelier 17 in New York, art historian Christina Weyl describes how, in modernism, gender becomes a key device to legitimise printmaking as a fine art medium to the detriment of the studio's female printmakers. As Weyl writes:

> The sharp engraver's burin was a weapon when handled by a man, but a dangerous liability for women. Textural elements, which appeared regularly in soft ground etchings by both men and women, quickly assumed associations with women's innate femininity and traditional handcrafts, while being neutral of positive features of men's prints (2019, 49–50).

In other words, the very same features of a print and the same tools or procedures were interpreted differently, depending on whether the printmaker was male or female. Weyl's argument demonstrates how gendered language was used to reinstate the divide between art and craft within the field of printmaking during the 1940s and 50s. As a medium with a pre-existing, marginalised status, the effects of this reinstatement are particularly complex. Not only does this illustrate biases against female artists generally, but it also shows how deeply gendered artistic mediums were in the first two-thirds of the twentieth century. Indeed, the practices reported by Weyl echo critic Clement Greenberg's call for medium-specificity, in which, according to several scholars including Elissa Auther, the disciplines of fine art were buttressed against craft by using explicitly gendered terminology (2010, xvi-xx; 2004, 339–364).

Beyond these questions of gendered identity, what is also overlooked in contemporary art is how ubiquitous the techniques and technologies of print and printmaking are. Reproductive methods used in printmaking feature repeatedly in artworks not explicitly classified as editioned prints, and are employed in the production of unique works categorised as painting, installation and sculpture. Although these methods often go under-acknowledged, their omnipresence does raise the question of whether it is any longer necessary, or possible, to position print as either an outsider or underdog in debates concerning the hierarchy of disciplines (Tallman 1996, 10; Balfour 2016). Moreover, print technologies are often framed in terms of their relationship to other forms of media history (Cubitt 2014). This was perhaps most famously exemplified by media theorist Marshall McLuhan, who in *Gutenberg's Galaxy* (1962) envisioned movable type and other forms of printing processes as precursors for twentieth-century telecommunications technologies. It is with these factors in mind that my engagement with the print studio has proceeded. Following on from the

supposition that craft and computing cannot be positioned as polar opposites, print is presented here as a point where a variety of competing concerns coincide.

The Flip: STS and sociological analysis

Though this project adopts a deliberately loose temporal framework, both the artworks presented and this text draw heavily on historical accounts of the US between the 1940s and the 1970s. These dates are defined by computer historian Mar Hicks as the period in which computing in the West transformed from a feminised field to a masculinist one. On the subject, Hicks has said:

> In the 1940s, computer operation and programming were viewed as women's work — but by the 1960s, as computing gained prominence and influence, men displaced the thousands of women who had been pioneers in a feminized field of endeavor, and the field acquired a distinctly masculine image (2017b, 1).

A substantial portion of my focus in this thesis is on historical examples from this era. In her reflections on the topic, historian Janet Abbate points out that during this period 'masculinity and femininity were part of the cultural vocabulary that was used to define what a computer was and who was best qualified to use one' (2012, 4). Put another way, by looking at the history of the computer, we can see that it has developed out of contradictory ideologies, which exemplify how technology both forms and is formed by gender, or how our understanding of the computer and its potential applications have been 'socially-shaped' (MacKenzie, Wajcman 1999, 17).

This research can be seen as part of a wider trend in STS, in which the histories of workers in the field have been analysed, parting from previous practice of focusing on the biographies of a few important technical innovators. Along with Abbate and Hicks, another key contributor to this discourse includes digital media theorist Lisa Nakamura, whose research has been crucial in demonstrating the importance of looking not just at programmers and office workers, but at those employed as factory workers. As Nakamura writes 'in the spectrum of digital labor, factory work soldering chips for iPhones, missiles, and servers is as close to the machine as one can get' (2014, 938). What her acknowledgement of the different kinds of labour that make up the computer industry strongly echoes are sentiments from recent craft theory and its desire to move beyond inherited categories, to consider how bespoke manual labour, often carried out by self-employed individuals,

operates in relation to mass production. This is an activity that, as Adamson puts it, requires us to look ‘not just in studios, but in factories as well’ (2013, xiv).

Alongside the feminisation of the workforce, there is another important shift in the post-war history of computing that must be considered. Today’s digital culture is based on a complex set of conflicting values which blends environmentalism and technocratic entrepreneurialism, a combination that was famously first described as the ‘Californian Ideology’ by sociologists Richard Barbrook and Andrew Cameron (1996). Although this ideological shift does not at first glance relate to a concept of women’s work as it has been laid out here, this thesis posits that the way in which counterculture interacted with technological utopianism presents a fertile space within which the subject of feminised labour and the computer can be examined. This is in part due to the contradictory nature of the threads of influence that make up what might be characterised as the California Ideology.

It is in Barbrook and Cameron’s account that we can trace the germs of masculinist computing employment, one where operators are assumed to be male. It is in this sense a misogynistic tendency with clear roots in the postwar commune movement. Yet at the same time, the 1960s counterculture from which the California Ideology emerged was resistant to mass production and engaged in developing sustainable ways of making that were deeply indebted to pre-industrial society. In that way, it was invested in activity understood to fall outside productive pursuits and in turn, to be coded feminine. As art historian Julia Bryan-Wilson points out, a feminist positioning of handicrafts is vital to our understanding of hippie aesthetics, ‘because it drove much of the return to craft within both the art world and in the hobbyist countercultural movement’ (2017, 68). This is a theme that in turn can be traced to the technological developments brought about in the era of personal computing, which I will explore in the section **tie-dye, patchwork and macramé** and the chapter ‘Green Thumbs II: Cybernetic Fields’.

Methodology: Feminist materialism

To link material drawn from historical and critical sources to my artistic practice I have developed what could be classified as a practice-based, material feminist methodology. This methodology employs the metaphors of nimble fingers and green thumbs to link practice to historical case studies. In this way, materialism runs through both the textual and practical aspects of the thesis, physically materialising digital labour history in response to the widespread perception of its immaterial conditions. As this enquiry attempts to bring subjects from fine art, craft and STS together, material feminism is well suited, as the theories are employed and developed across each of these fields. Adamson, Auther, Bryan-Wilson, Parker, and Griselda Pollock, for example, have all revealed the manifold ways in which the art and craft divide is gendered through material and social relationships. My understanding of material feminism is indebted to these thinkers, as well as forms of posthumanism advanced by Rosi Braidotti and Donna Haraway. Furthermore, my position is specifically informed by sociologist Judy Wajcman, who argues for the potential of materially-based metaphors. Wacjman suggests that, if used correctly, metaphor and materiality are powerful tools to question gender-technology relationships. In the exhibitions that this project is constructed around, specific motifs, processes and materials are brought together as metaphorical agents. Furthermore, I consider my practice to embody a 'myth-science,' one that arises from the production of what could be termed 'fictioning,' as outlined by the artists and theorists David Burrows and Simon O'Sullivan (2019).

Metaphors and materiality

According to linguist George Lakoff and the philosopher Mark Johnson 'the essence of metaphor is understanding and experiencing one kind of thing in terms of another' (2003, sect. 5). In this way, a metaphor can be considered as a device for comprehension. An extension of this, they argue, metaphors have the ability not just to help us understand new objects or actions. They also act as crucial mechanisms for cultural change. 'New metaphors have the power to create a new reality,' Lakoff and Johnson argue, 'much of cultural change arises from the introduction of new metaphorical concepts and the loss of old ones' (sect. 145).

As you might imagine, the computer occupies a complex relationship to metaphor. For example, the notion of a computer desktop, which now refers to the backdrop of a digital screen, was taken from the literal surface of a desk where administrative work was

performed. Similarly, files and folders designate space within computer hard drives, mimicking the sorting and storage capacity of their real-world counterparts (Coyne 1995, 250). Before these metaphoric innovations, it was difficult to explain what computers were. 'Metaphor, it turns out,' technology writer Steven Levy notes, 'is the key to making computers comprehensible' (1994, 69). But they are not only described by metaphor, as media theorist Wendy Chun suggests:

> Computers … are metaphor machines: they both depend on and perpetuate metaphors. More remarkably, though, they — through their status as "universal machines" — have become metaphors for metaphor itself (2011, 54).

Arguably, because of the computer's unique relationship to metaphor, it has been necessary to employ fiction and the alternative metaphors it might provide to critique technology, to generate new visions of how it could operate. According to art theorist Simon O'Sullivan, one of the modes in which such fictions are created is 'myth-science' (2016). 'Myth-science' argues O'Sullivan, 'functions by producing alternate perspectives and models, revealing habits of thought concerning physical, historical and social realities as yet more myth' (with Burrows 2019, 1). Perhaps the most famous of these metaphors is Donna Haraway's cyborg, a conceptual mechanism which rejects rigid binaries between human, animal and machine. First described in 1984, Haraway's cyborg was employed to rupture feminism's long-held difficulty with patriarchal classifications of technology and sought to bring into being a new 'ironic political myth faithful to feminism, socialism, and materialism' ([1984] 2016, 5).

However, as numerous critiques of cyberfeminism have noted, there are limits to the productivity of this metaphor. Influenced by Haraway's cyborg, by the 1990s cyberfeminism was attempting to reformulate a more positivist gendered relationship to technology, particularly cyberspace and the internet. However, as Wajcman argues, this 'utopian optimism' for digital technology is just another form of technological determinism (Wajcman and Mackenzie, 3–27). As a way of addressing these idealistic concerns, Wajcman herself argues for metaphorical and material relations that 'engage with the process of technical change as integral to the renegotiation of gender power relations' (2004, 103). This requires imagining technology as a 'sociomaterial' product in which gender and technology operate in mutual relations:

> Technology must be understood as part of the social fabric that holds society together; it is never merely technical or social. Rather, technology is always

> a sociomaterial product — a seamless web or network combining artefacts, people, organizations, cultural meanings and knowledge (2004, 106).

Within this structure, we must, Wacjman suggests, identify concrete examples of where and with whom technology interacts, lest the combination of material and metaphorical concerns her model of techno-feminism relies upon become unstable.

Keeping in mind these critical complexities, the metaphors of nimble fingers and green thumbs that drive this project have been chosen for both their material and metaphorical potential. The phrase ‘green thumbs’ suggests a person who has a natural flair for gardening, but is not generally someone who takes it up professionally. Similarly, ‘nimble fingers’ is usually associated with domestic handicrafts rather than mass manufacture, even though an argument for the dextrousness of female manual skill was used for recruitment in the sewing industry (Elson and Pearson 1981, 89). My use of both phrases as metaphorical structures encapsulates a set of operative concerns tying this text to the artworks and exhibitions that I have produced. In both instances, I have dwelt upon how the properties of ‘nimbleness’ and ‘greenness’ might help to articulate categories of labour, or better help us understand how nature and technology are interrelated, and how they might serve to join a sequence of narratives together. Their purpose as framing devices is to blend a range of prompts derived from the fields of handicraft, horticulture and digital technology.

Metaphorical links between the computer, nature and industrial forms of human activity are what frequently act to bind together these elements in my artworks; a feature that recurs in this text. Both reflect on how forms of metaphor are fundamental to how we conceive of and speak about new technologies. To give a few examples, the ‘digital’ refers not only to the virtual space of the computer but also to our ten fingers — our digits. We continually use fibrous structures to describe the physical and virtual aspects of contemporary technology, such as the ‘net,’ worldwide- ‘web,’ and ‘fibre’-optic cables. Computer scientist Tim Berners-Lee even called his autobiographical account of the invention of the internet *Weaving the Web* (1999). Pre-existing things taken from the natural world have been used to anthropomorphically name technological devices and systems, including the mouse, virus, cloud, and root (for a comprehensive list see Thomas, 2013, 4). These are associations that I have at points rendered concrete in artworks such as *Ponics* (Figures 40–41), *Saboteur* (Figure 10) and *Hothouse* (Figures 17, 43–4).

Nimble Fingers and Green Thumbs introduces a complexity that aims to reshape gender constructs by embracing elements that are deeply rooted in art discourse and charged with

feminist politics, such as textile craft processes and botanical imagery. By leveraging the unique capabilities of printmaking, this project intertwines textile crafts and digital technologies to broaden the technofeminist application of craft and textiles. For thinkers like Plant, the historical and metaphorical connections between textiles and networked systems, such as the internet, offer vast possibilities for carving out new feminist spaces. However, as I have argued within the cyberfeminist artistic outputs to date, these themes and ideas have seldom been expressed through craft processes. When artists have investigated the intertwined history of computer technology and craft, weaving is often the sole textile technique considered, thereby restricting the complex interplay between different forms of production. Further, absent from this dialogue is also print, which not only has numerous connections to digital fabrication and networked thought but likewise to craft traditions. As I have previously indicated, printmaking can be a strategy for forging new dimensions within craft processes. It can blur, disrupt and complicate the categories that define gender, art and technology (as discussed in 'Turn to Print'). Embracing this complexity allows print to challenge boundaries and dismantle established categories, forging new metaphors for the discourse on feminised labour across both theory and practice. Containing both traditional and innovative methods, printmaking has the potential to evolve the motifs and materials of the cyberfeminist stance. In doing so, it can provide a lens with which to reflect on contemporary gender and labour conditions.

Fictioning: counterenvironments

There are two approaches which build upon the material and metaphorical strategies of 'nimble fingers' and 'green thumbs'. Across this project, I combine processes of exhibition-making and fictioning to reimagine the art gallery as a type of space that makes visible the diverse forms of labour it contains.

‘Exhibition-making’ is a term that has been colloquially in use in the contemporary art community since the 2010s to describe specific ways of engaging with the exhibition space. However, its nuances are seldom explored academically, where installation art and relational aesthetics continue to dominate. Even in texts which explore the concept of the ‘exhibition as medium,’ the defining principles of the gallery itself are prioritised (Souter 2019). Similarly, in texts that analyse ‘the exhibition as a critical form,’ artists such as Carsten Höller, renowned for creating large-scale community-engaged projects, are used as key examples (Voorhies 2017). Although exhibition-making practice comes from such traditions, it varies from them by moving away from immersive or community-based actions to smaller gestures, considering how artworks interact within the exhibition to create a narrative effect. Although

this approach has the potential to become more market-facing than its predecessors, it often employs the legacies of institutional critique and acknowledges the artist's complicity in the global art market.

The practices of artists such as Dora Budor, Magali Reus, and Amanda Ross-Ho exemplify what I define as ‘exhibition-making.’ For example, Reus's 2022 exhibition at the Nasher Sculpture Center, Dallas, uses the concept of a script as a sculptural framework. The title *A Sentence in Soil* implies a linguistic underpinning to the exhibition, and the placement of the floor-based sculptures aims to use the framework of a script to guide the viewers around the space, creating a kind of spatial narrative to produce new connections between the objects on display (Cochran 2022). Similarly, in Budor’s work, the exhibition has been described as ‘a reactive organism and artworks as complex systems’ (Filipovic 2019). Narrative and meaning are created within her shows through the relationship built across the works within the exhibition, which is itself conceived as a site of interaction. Of Ross-Ho's work, which can include enlarged everyday objects, assemblages, and pictorial tableaux, curator Andrew Berardini suggests that 'a story is implied, but its truth always seems tantalizingly out of reach…' (2011). Unlike previous approaches, I would argue the space between works is perceived as an active site of artistic agency as much as the works themselves. As there is a blurred line between installation art and exhibition-making practice, on some occasions these artists may employ operations more akin to installation. However, I believe the potential of discrete objects to create an effect through the relation between them is different from installation with its emphasis on immersion. I consider my approach to have affinities with that used by Budor, Reus and Ross-Ho, focusing similarly on the narrative potential and relational systems of the art object within the exhibition.

Consequently, the artworks presented in this project employ exhibition-making as a process of fictioning, akin to that outlined by Burrows and O’Sullivan, to reimagine the art gallery as a different type of space, making visible the forms of labour it contains this is to produce, as I will outline in the main body of the text, a ‘counterenvironment’ (See **moths** and **‘**Green Thumbs II’). Although gallery and art venues are often presented as blank, as art critic Brian O’Doherty famously made clear, these spaces are anything but neutral (1999). By presenting these locations, intended as sites of non-productive activity for the general public, as fictitious sites of labour, I seek to emphasise that art spaces are also places of work. The venues in which I have exhibited, much like DCA Print Studio, where a portion of the fabrication for these projects was carried out, form part of the ‘creative industries,’ an area of the economy where the lines between amateurism and professionalism, and leisure and work, have become blurred (Fuller, Hamilton, Seale 2013). Indeed, it has been suggested

that this work-life more broadly collapse is characteristic of contemporary labour conditions brought about by the digital economy (Wajcman 2015).

Reflecting upon various modes of production in their outcome, these exhibitions consider the boundaries between personal time and employment, amateurism and professionalism, leisure and labour. By visualising sites of labour (farming structures, office spaces, computer rooms) in these spaces of leisure, I intend to explore the erosion occurring between work and life in contemporary culture, while drawing out the role computer technology has played in its breakdown. It is within such an artistic framework, I would assert, echoing O'Sullivan, that we 'can produce new images and sequences — new myths and new dream worlds' (2016, 88). With the conventional avenues for resistance being limited by the decentralisation of power that digitalisation has brought about, I would assert that these 'new dream worlds' are a valuable place in which a new kind of political agency might be formed: the physical aspects of these artworks being a location where elements of the collective imaginary and the socio-material can operate in relation to one another.

Layout

The structural arrangement I have adopted is stylistically indebted to earlier feminist explorations of technology, particularly the framework Sadie Plant would use in *Zeros + Ones*, which considers the history of women's work and computation across seventy-five evocatively titled sections including, 'hooked,' 'ada' and 'grass.' It is worth noting that the textual research, practice, and writing did not necessarily happen in the order that it appears here. Certain periods of research into craft or computation led to the motifs, processes or materials employed in artworks. However, the presence of those figures in the exhibitions I produced to represent my findings led to further connections coming to light, which have in turn exerted considerable influence on the construction of this text. In other words, the writing and practice were mutually shaped, a state of affairs that I consider to embody the materialist underpinnings of this enquiry as a whole. In this regard, I am not the first to point out that practice and textual research occupy a dialectical relationship in artistic research, informing, supporting and extending one another (Bolt 2006; Candy 2006; Elkins 2014; 2021; Gere 1996, 2).

The textual aspect of the thesis examines the operative concerns present in the portfolio of artworks in two separate but interrelated ways. This text features five stand-alone sections that are titled after the materials, processes and motifs used to produce the artworks presented. These are titled **mainframes**, **microchips**, **moths**, **tie dye**, **patchwork and macramé** and **vegetal matter.** These sections provide insight into the motivations and procedural decisions that underpinned the three exhibitions comprising the portfolio: *Noon, Lowlight* and *Hothouse*. The final section, **vegetal matter**, outlines in further detail an innovative process of printing sculptural material that I developed while resident at DCA Print Studio, involving screenprinting onto CNC-cut acrylic material and subsequently shaping it using heat.

These five, stand-alone sections punctuate four longer chapters, based around specific case studies that address topics outlined in this introduction. These four chapters follow the overarching logic of the thesis, being titled 'Nimble Fingers I' and **'**II' and 'Green Thumbs I' and **'**II' respectively. Each explores one aspect of how the computer industry has been influenced by metaphors from craft, ecology and environmentalism, and reflects upon how this resulted in the gendering of operative processes, professional status, and labour hierarchies.

The focus of ‘Nimble Fingers I: From Military to Office Mainframes’ is on recent critical discussions concerning the beginnings of computer technology during the Second World War. This section traces the origins of the term ‘software’ in the military-industrial complex of the 1940s, when developing hardware was seen as the ‘real’ job of computing, and women took on the supposedly less important ‘soft’ work. It is here that a gendered division of male and female work forms, repeating structures implemented in the textile industries during the nineteenth century. As the computer industry developed during the 1960s and 70s however, programming and coding were not only discovered to be important but became regarded as creative and highly skilled. At first, software was considered appropriate ‘women’s work,’ but when its full potential was uncovered, women were systematically pushed out of the field.

‘Green Thumbs I: Bugs in the Machine’ commences with an anecdote concerning computer scientist Grace Hopper, who supposedly coined the phrase ‘computer bug’ after a moth flew into the relays of a mainframe computer on which she worked in 1947. This anecdote is used as a method to unpack the various meanings of the term computer bug, which has its origins before Hopper’s account. I connect this false etymology concerning the ‘bug’ to the history of machine breaking carried out by textile workers during the nineteenth century, or what would become known as the Luddite Revolts. These two distinct moments are employed to posit how the concept of a ‘bug’ can be considered in the computer industry as an updated form of ‘sabotage’.

In ‘Nimble Fingers II: Weaving the Integrated Circuit,’ I leave the subject of computerised clerical labour to consider how handicraft, perhaps surprisingly, plays its part in assembly lines generating electronic components. In the 1960s, computer hardware manufacturers fashioned a link between chip manufacture and pre-industrial craft traditions, a phenomenon that would later be described by sociologists as the ‘nimble fingered thesis’ (Elson and Pearson 1981). This thesis was based on the perception that women were patient and dextrous, and thus ideally suited to employment in factories of the burgeoning micro-electronics industry. This chapter focuses its attention on the Shiprock Semiconductor Plant, operated by Fairchild Camera and Instrument in New Mexico. Based on a Navajo reserve between 1965–75, the Shiprock Plant Fairchild created a blueprint for employing women in the electronics industry that would subsequently be applied across the whole of Southeast Asia.

The final chapter, ‘Green Thumbs II: Cybernetic fields,’ describes the importance of environmental and ecological thinking on emerging computer technologies. To do so, it draws on recent research into the 1960s and 1970s counterculture, including historical

analysis by Fred Turner and Andrew Kirk. This chapter explores how environmentalism became interlinked with technological thinking in the commune movement, shifting the image of technology from one of militarisation to personal expression. Ideologically and geographically, digital culture began on the West Coast in the San Francisco Bay area. In this region we find direct links to the birth of 1960s counterculture and 1990s digital culture, and the individual DIY ideology that penetrates both, known as the 'Californian Ideology.' In this chapter, I discuss these links, describing how the ideology of countercultural, DIY crafting played its part in the construction of the working worldview of digital culture.

Combined, these sections — both those that reflect upon my artistic practice, and those based around case studies — allow for parallels to be drawn between areas of discourse that might otherwise be regarded as disparate or unconnected. *Nimble Fingers and Green Thumbs* reflects on how with new forms of technology come old forms of exploitation, asserting that the double-edged nature of feminised handicraft — as both a genuine site of pleasure and as a trap within which gender roles are performed — has been transferred to digital labour in the nascent stages of the computer industry. And yet, looking back to the late twentieth century when the computer was still relatively culturally unformed, we can see how flexible and intertwined our conceptions of technology and gender are. In making these histories visible, the potential for change today is opened up, allowing us to imagine new ways in which the categories of craft, art and technology can be reimagined. I employ art in this context to play upon pre-existing cultural associations of craft and technological production, and in doing so hope to expose the fiction which grounds these assumptions. The novel and unruly combinations of forms, materials and references in this thesis present a 'plastic,' sensory demonstration of alternative possibilities and future imaginaries.

mainframes

Across *Nimble Fingers and Green Thumbs,* the motifs and materials were chosen to speak to the histories and materiality of technology. The visual representations of computer mainframes in *Noon*, *Lowlight* and *Hothouse* exemplify different attitudes to this approach. In *Hothouse,* I use computer-aided print technologies to create a fabric that covers the cuboid structures, highlighting the importance of print in the history of both crafted textiles and computing (detailed in **microchips**). Conversely, in *Noon* and *Lowlight,* I employ dyeing and macramé in the series *Irrational Cabinet* (Figures 1–2 and 32–33)*,* drawing on women's and DIY craft techniques creating direct associations with feminist history and the importance of the countercultural ideology in the development of computing (detailed in **tie-dye, patchwork, and macramé** and 'Green Thumbs II'). Beyond these direct material connotations, this inclusive approach to production addresses exclusion in the field of technology in two ways. The first is to visually rematerialise the stories of women who have been deleted and excluded from the history of technology, a system of structural exclusion detailed in the case study chapters 'Nimble Fingers I' and 'II'. The second is to employ the processes most closely associated with women's handicrafts, which have been omitted from the category of technology, in direct conjunction with materials historically coded as male. In this section, I will analyse how I came to understand this position for craft, which goes beyond its traditional framework to questions the nature of the category of 'technology' itself. Finally, I examine my use of the mainframe motif in relation to 1960s sculpture and contemporaneous photography of women working with early computers.

Across her work on feminism and technology, sociologist Judy Wajcman has described how 'male orientation of most technological research has long obscured the significance of "women's sphere" inventions, and this in turn has served to reinforce the cultural stereotype of technology as an activity appropriate for men' (2004, 15). For feminist thinkers, this has been a longstanding point of contention, as even ancient technological artefacts obscure women's inventions. Archaeologist Eleanor Wayland Barber argues that the omission of early women's technologies is in part because they disappeared from archaeological records (1994, 4-8). These technologies were often made and used in settings where children were cared for, so sharp-edged tools were swapped for the looms and spinning of textiles. Moreover, these artefacts which could make up a history of women's technologies, such as cloth and embroidery have decomposed, while stone axe heads or bronze age blades have persisted, buried in the earth for thousands of years. This has led to a cultural assumption that the first tools were stone weapons, but as Elizabeth Fischer points out, in reality, 'many theorizers feel that the earliest cultural inventions must have been a container to hold

gathered products and some kind of sling or net carrier' (1980, 59). Along these same lines, Wajcman believes that treating woven items as technological provides a means to radically reframe technology as an area of feminist discourse. As she points out:

> A greater emphasis on women's activities immediately suggests that women, and in particular indigenous women were amongst the first technologists. After all, women were the main gatherers, processors and storers of plant food from earliest human times onward. It is logical that they should be the ones to have invented the tools and methods involved in this work, such as the digging stick, the carrying sling, the reaping knife and sickle, pestles and pounders (2004, 15).

If this is the case, a feminist approach requires reconfiguring the category to include a wider array of 'women's sphere technologies'.

The idea that craft and technology should be considered intricately linked is a central premise of the artworks I make, and the procedural decisions that inform them. Dyed fabrics, knotted threads, and other processes associated with handicraft and domestic production are visible in each of the exhibitions presented here, alongside a range of digital and analogue methods of print and computer-aided production. I would argue that this approach echoes but differs slightly from earlier feminist projects using similar processes, which have employed craft as a form of artistic subversion. My approach to the topic looks to reposition craft outside a debate solely concerning artistic hierarchy, reflecting upon the multivalent interpretations through which the term can be engaged within contemporary culture. Rather than considering the relationship between the materials and processes I employ as forming binary oppositions, or even a gradated spectrum, I am attempting to present a range of production methods as a complex network of overlapping concerns. Therefore, in each work and exhibition, no single type of production is explored in isolation. In the exhibition *Noon* for example, CNC-cut plywood meets macramé, welded metalwork joins prefabricated silicone caterpillars, and vinyl-cut moths appear near tie-dyed sculptural forms.

In keeping with this position, all the work I make requires handicraft to some degree, but I would not distinguish between manual techniques that are enabled by computerised processes and those that are not. The techniques I use include but are not limited to, delicately placing vector points on a digital drawing with a mouse, pulling ink with a squeegee for a print, tapping metal threads, cutting plastic sheets, sticking vinyl collage, smearing glue, or knotting yarn. My own hands are an implicit presence in most aspects of my artwork's production. Such an acknowledgement is another attempt to move beyond the hierarchies perceived as existing between different forms of labour. Pointing this out is not to

suggest that my manual investment is of significant value, as has often been emphasised in the history of art, but by contrast to signal that my labour is equivalent to the work of others. For example, throughout history, the artist's hand has been emphasised as a direct line to expression and genius. This assumption of value has been questioned both in its relationship to replication imprints and sculptural casts (Didi-Huberman 1997; Krauss 1981). In the context of this project, the work of others would include those who made the prefabricated scaffolding parts I later constructed, or who printed the digital fabric I stretched. It would also extend to the hours spent programming the software that I consistently employ, or the mass manufacture of electronic components in the computerised devices I use, made by countless invisible workers around the globe, often women. Furthermore, the particular techniques of handicraft I draw on — crochet, dye, macramé and, I would contest, certain detail-oriented aspects of printmaking — have their roots in the traditional labour of women's work. By drawing on these techniques I hope to make visible the labour of those who came before me. Indeed, I would argue that the image, metaphor, and actual labour of *Nimble Fingers*, mine and the many who preceded me, function as a material strategy.

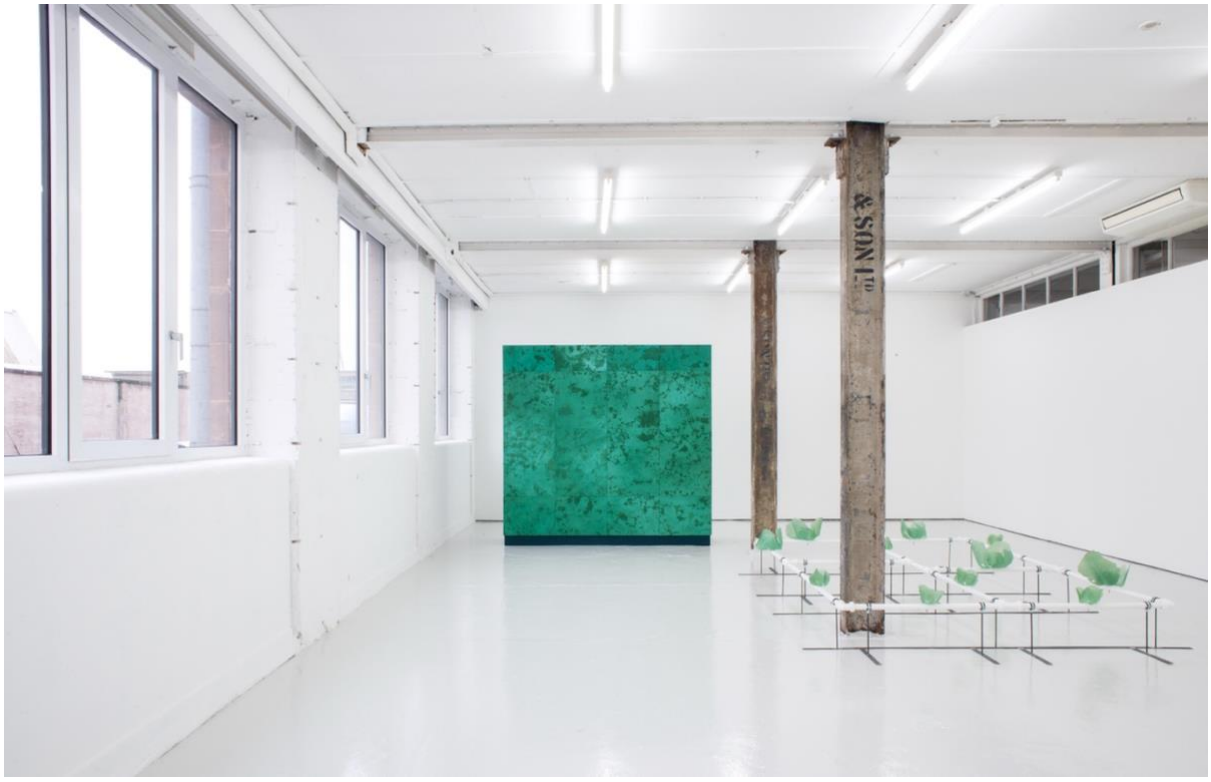

Figure 1 *Irrational Cabinet I*, (background). Exhibited in *Noon,* 2018. David Dale Gallery & Studio.

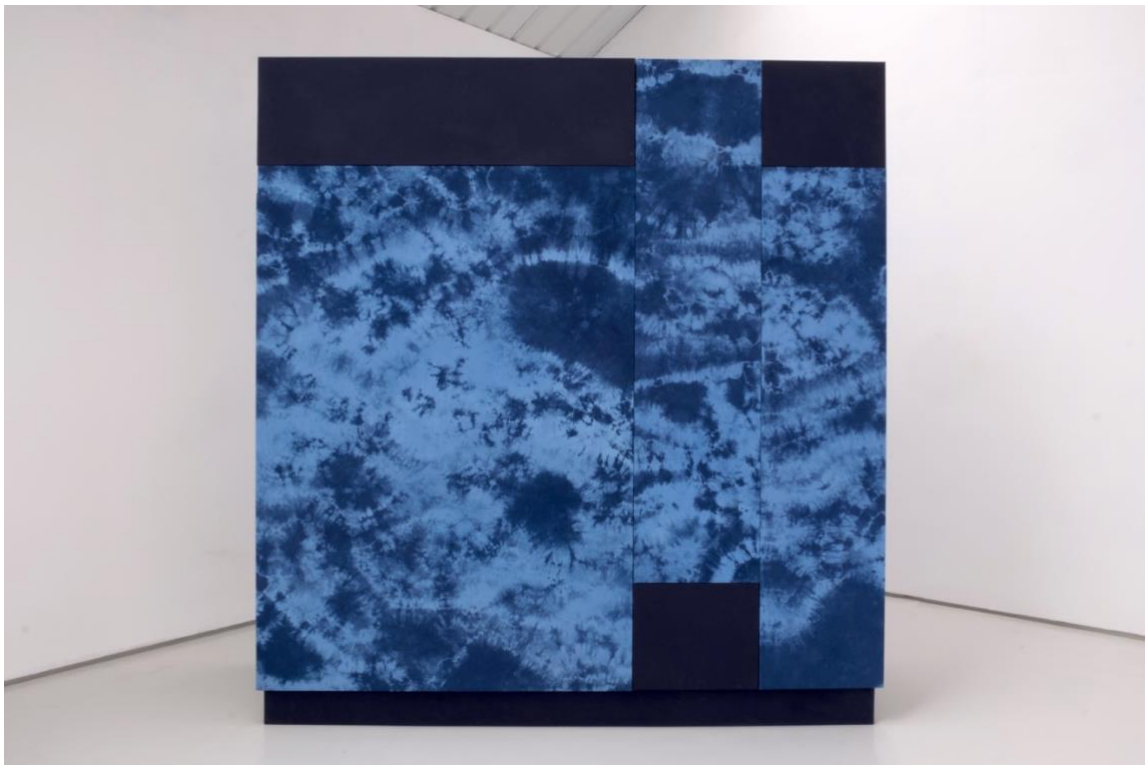

Figure 2 *Irrational Cabinet II*, 2018. Exhibited in *Lowlight*, Bloc Projects.

Alongside this strategy, the exhibitions in this project use the computer mainframe as a central motif. In *Noon* and *Lowlight,* these forms were titled *Irrational Cabinet I* and *II* and consisted of a timber cuboid structure covered in hand-dyed cotton (Figures 1 and 2). The titles of these works originate in media theorist Charlie Gere's scholarship on the computer of the same name, which looks at how digital technology comes to be understood as part of material culture (1996). The method by which this fabric was adhered to the timber structure, using a starch-based paste, originates in early wall coverings in which textiles were used before the mass production of wallpaper. In this way, these artworks can be viewed as akin to forms of furniture from several historical periods, and hark back to the earliest iterations of computer mainframes, which were housed in ornate cabinets (Harwood 2011, 71-3). The front and back of these two works were split vertically into panels, each of which was divided horizontally, creating a smaller panel at the top and a larger one below. The entire structure sat on a recessed base. The panelling and size of these sculptures mimic the aesthetics not only of specific mainframe designs of the 1960s and 70s (particularly those manufactured by International Business Machines (IBM) under the leadership of industrial designer Eliot Noyes) but also of contemporary server farms and data centres.

I employed the mainframe as a central motif in this project due to its historical and metaphorical significance in twentieth-century computing. Since the opening sequence of Stanley Kubrick's *2001: A Space Odyssey* (1968), blank, monolithic structures have remained a visual shorthand for technological futurity and opaque systems of control, a theme extended elsewhere by the film's depiction of computerised intelligence. The early mainframes that inspired Kubrick, such as the military-funded UNIVAC, tied the computational metaphor to the industrial complex and carried with it the connotations of intelligence beyond human comprehension. However, once they became available to commercial businesses, these machines began to shrink in size, while at the same time becoming more associated with secretarial labour. Consequently, as mainframe computers intruded ever further into the office they occupied a contradictory position, appearing both as symbols of cutting-edge technology and as terminals for menial female labour. It is a situation that led to the same modernist aesthetic that defines *2001: A Space Odyssey* finding its way into marketing materials for computer mainframe manufacturers, advertising often marked by its overtly sexist content.

Irrational Cabinet I and *II* also allude to the 'unitary forms' of minimalist sculpture that began to appear at the same time as mainframes, like the IBM 360, began to be marketed as modular solutions for the competitive office (Morris 1968, 228). These sculptural objects, exemplified by the work of artists Donald Judd, John McCracken and Tony Smith, have

become associated with both a technologically progressive position and conceptions of modernist masculinity that accompany it. Just as computer technologies were perceived as part of the visual identity of the military-industrial complex, minimalist art is associated with similar power dynamics. These objects' look of 'plain power,' as Judd phrased it, has been critiqued by feminist thinkers as replicating the US's rhetoric of patriarchy, strength and dominance (cited in Chave 1990, 44). On the topic of what values might be projected onto such neutral surfaces, constructed from readymade industrial materials, art historian Anna C. Chave writes, 'the blank face of Minimalism may come into focus as the blank face of capital, the face of authority and the face of the father.' (59)

In the immediate wake of Minimalism's critical success in the mid to late 1960s, and featuring several of the same artists initially associated with it, 'Postminimalism' appeared as a type of counternarrative. Emblematised by sculptural objects constructed from loose, soft and flexible materials — epitomised in the works of Alice Adams, Eva Hesse, or Robert Morris — many of these works were quickly coded as feminine, and classified as embodying irrational or 'eccentric' properties (Lippard 1971). The importance of second-wave feminism to the development of this sensibility cannot be overstated. As art critic Robert Pincus-Witten would write in 1977:

> [Postminimalism's] relationship to the women's movement cannot be overly stressed; many of its formal attitudes and properties, not to mention its exemplars, derive from methods and substances that hitherto had been sexistically [sic] tagged as female or feminine, whether or not the work had been made by women (1986, 11).

This would lead to the construction of a binary value system that classified the use of rigid industrial materials as masculine and the use of more pliable matter as a feminist rejoinder to it. While this division has continued to inform art historical narratives of this period, the relationship between the two was in fact more oblique. One individual occupying the interstices between these dualistic positions was Anne Truitt. Truitt's geometric structures in painted plywood fit within the rubric of Minimalism. Yet, at the same time, the titles of her works, such as *Dawn City* (1963), *Flower*, *Morning Moon*, and *Root* (all 1969) and their evocative colouring appear to contradict the objects' supposed objective rationality. The romantic register adopted by Truitt, as well as several other female practitioners who continued to work in a reductive manner, is more characteristic of the rhetoric of hippie 'flower children' than the technological logic of unitary forms. This includes Agnes Martin, whose evocative titles for her minimal paintings include *Friendship* (1963) and *Morning* (1965).

Such a nuanced straddling of categories had a direct influence on the approach that was taken for the works presented in this project. Operating in the same vein, the facsimiles of mainframes produced as centrepieces for these exhibitions were envisaged as loci capable of bringing various discourses together. These directly apply the 'funky' materials of Postminimalism to the rigid rectilinear forms of Minimalism. Just as Truitt's titles linguistically link her sculptures to the poetic naturalism of the hippie movement, the tie-dyed fabric that covers *Irrational Cabinet I* and *II* was also intended to generate associations between computer technology and the DIYism of the countercultural movement. Bringing together these elements signals the changing ideologies the computer was associated with in the late 1960s, at a point when it shifted from being interpreted as the preserve of militarised governments, to a democratically available device through which ecological connectedness could be imagined.

Photographic imagery of the mainframe era has played a part in the realisation of these artworks and has exerted an important effect on the way that this text has been arranged. Of particular interest to me is the array of photographs available that depict female operators and the large-scale computers they worked alongside (such as Figure 3). Each of these images highlights one or more aspects of the paradoxical roles women were expected to play in these situations: as caring custodians for these machines, as subject to the objectifying gaze of male managers, or as an anonymous and readily replaceable labour force. Of equal importance is the changing technological means through which such imagery can now be accessed. Blogs such as *Rare Historical Photos* and *Vintage Everyday* collate large bodies of imagery of women operating gargantuan mainframes each capturing a theatrical situation of some kind of another. Drawn from marketing materials, photographic archives or employee snapshots, and brought together without regard for chronology or geography, these online repositories sever these images from their original context, and aggregate them as part of a generalised aesthetic of a technological past. There is a distinct irony that the anonymity of these female computer workers is reinforced by the way in which their likenesses now float untethered from identity, place or date across the internet.

Figure 3 Anonymous computer operator, n.d.

Figure 4 Anne Truitt at her exhibition. *Truitt: First New York Exhibition,* André Emmerich Gallery, New York, 1963.

Researching 1960s mainframes, I was struck by the visual similitude between documentation of Truitt posing in a 1963 exhibition of her work at André Emmerich Gallery, New York, and these images of anonymous female computer specialists and operators (Figure 4). Pictured beside looming volumetric forms, the women are equally implicated in institutional systems not entirely of their own making, occupying sterilised spaces, be that of the white cube gallery or of the ‘white room’ environments constructed to safely accommodate mainframes. This juxtaposition of the organic and the inorganic informs the presence of *Irrational Cabinet I* and *II*. In the exhibitions that I have produced the body of the spectator comes to stand in for those women, sharing their space with these imposing forms.

Nimble Fingers I: From Military to Office Mainframes

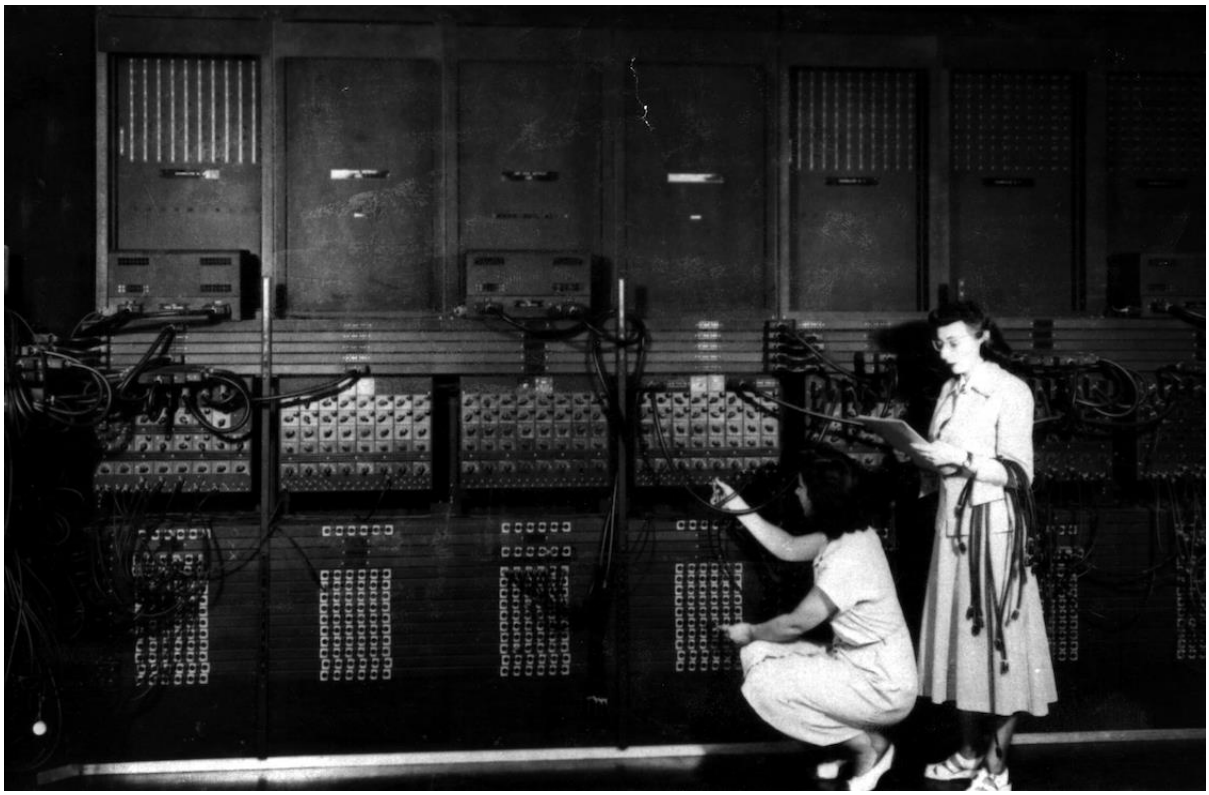

Figure 5 ENIAC Programmers, January 1946. Ruth Lichterman (crouched left) and Marlyn Wescoff (stood right).

The ENIAC and the double helix

During World War II, women's roles in the workforce were in flux, conditions created by the conscription of men to military service. Despite women's consistent employment in nineteenth-century factories, many jobs were still perceived as male, blue-collar labour. To mitigate this, allied governments attempted to naturalise jobs for women. The famous 'Rosie the Riveter' campaign attracted women to manufacturing by comparing housework to factory work. 'If you've used an electric mixer, you can learn to run a drill press,' claimed one American wartime campaign (Abbate 2012, 19). However as historians have pointed out these roles did not dissolve pre-existing gender hierarchies, and were non-permanent, rather than liberating women often these opportunities tended to reinforce their subordinate status. Margaret and Patrice L. R. Higonnet suggest that a 'structure of two intertwined strands' or the metaphor of the 'double helix' is useful to explain male and female relations during World War II remarking 'the female strand on the helix is opposed to the male strand and position on the female strand is subordinate to position on the male strand' (1987, 34). Consequently, while women's jobs changed the status afforded to them did not. Often these new roles for

women were described as adjacent to domestic work ‘despite the fact they were formerly done by men’ (Light 1999, 461).

Compared to blue-collar factory work, computing occupied a peculiar position in this gendered interpretation of work. Historically, both men and women performed the duties of human computers, but by the 1940s the position had become predominantly occupied by women and was viewed as repetitive and low-skilled work. This shift led to a significant number of women obtaining mathematics degrees. While such educational achievements might imply favourable career prospects from a modern perspective, the reality in the 1940s was quite different. Women with such degrees often faced constrained career paths, typically becoming schoolteachers, or relegated to the monotonous work of computing, while men with similar or lesser qualifications had greater access to higher-paying and more prestigious positions in science and technology.

‘Computing’ offered two different areas of employment for women at the time: scientific projects — where women completed desk calculations by hand — and administrative data entry — where women operated machines. Although these roles required quite different skill sets, they were often conflated, which led to all women’s computing work being viewed as machine-operating work. Consequently, university-educated male engineers saw all computing as ‘too tedious’ for them, leaving women with the same credentials to be perceived as the perfect candidates (Light 1999, 461). Necessity compounded this issue. As computer scientist Herman Goldstine notes, by World War II, ‘there were a few men [computers] but only a few. Any able-bodied man was going to get taken up into the armed forces’ (as cited in Light 1999, 460). As a result, the pre-existing relationship of female human computers was drawn upon to make mechanised computer work appropriate for women.

This was true of the Electronic Numerical Integrator and Computer (ENIAC). Completed in 1945 to help with ballistic calculations for World War II, it was developed by the U.S. Army and the University of Pennsylvania’s Moore School of Electrical Engineering by engineers John Presper Eckert and John Mauchly. The machine replaced the labour of 200 human computers which would take a month of continuous work to create a single ballistics table (Abbate 2012, 16).

However, the ENIAC still required human computers to operate it. Applicants for ‘Project X’ had to pass a two-stage selection process and have a university degree. Six women were selected, four with mathematics degrees: Frances Bilas (Spence), Ruth Lichterman

(Teitelbaum), Kay McNulty (Mauchly Antonelli), Jean Jennings (Bartik), Frances Snyder (Holberton), and Marlyn Wescoff (Meltzer). The complexity and importance of their work surprised everyone involved. These women, known as the 'ENIAC girls,' became the world's first computer programmers.

For everyone involved in the ENIAC project, it soon became clear that the women's work was much more complex than expected. In an interview, Litcherman described the difference between programming and operating work:

> [Interviewer]: When you say you programmed the machine, did that mean physically that you took these plugs from one place and plugged them into another place?
>
> [Ruth Lichterman]: Well, now, program means several things… You got a problem, and you started with pencil and paper, and you decided how you were going to do this problem and which numbers went where… you drew a diagram of all this stuff and then you actually went on the machine, and we call that "plugging in" rather than "program." (as cited in Abbate 2021, 31).

Today, this would be described as the distinction between programming and operating. But, as computer historian Janet Abbate has argued, 'since the role of programmers and operators was not well understood in the early years of computing, gender stereotypes partially filled this vacuum, leading many people to downplay the skill level of women's work and its importance to the computing enterprise' (2012, 24).

Indeed, Goldstine and Mauchly both had thought that the roles of the women would be similar to operating, or what was then referred to as 'coding'. 'Coding,' writes computing scholar Nathan Ensmenger, 'was regarded as a "static" process… one that involved writing out the steps of a computation in a form that could be read by the machine, such as punching cards, or in the case of the ENIAC, plugging in cables and setting up switches'. The word 'programmer' was specifically chosen by the ENIAC team to better describe the creativity of this work and to situate their role in the highly technical militarised field (2010b, 36).

Despite the women of the ENIAC being recognised as programmers, this title did little to dismantle the inherent gender hierarchy of the project. Women had a 'subprofessional' rating, as McNulty remembered, 'the girls were told that only "men" could get professional ratings' (as cited in Abbate 2012, 20). Although the term 'programming' was originally

chosen to reflect the complexity of the work, it was virtually always perceived as secondary to the engineering of hardware.

The distinction was stark: the prestigious 'headwork' of designing and managing the machine was reserved for men, while the women were confined to the perceived lower-status 'handwork' – bar aiding with the 'factory-like' involvement in assembling components (Abbate 2012, 20). This gender hierarchy was not lost on the ENIAC women. 'Oh, yeah: engineers think they're much better than programmers' Jennings suggested, 'I don't know whether or not they were prejudiced because I was a woman or because I was a programmer!' (as cited in Abbate 2012, 103–4).

The division of work was maintained through a tangled web of contradictory beliefs about labour. The work undertaken by women was perceived as less physically demanding and less skilled than engineering while being intellectually creative and complex and simultaneously administrative and menial in nature. The masculine status of certain forms of scientific labour was maintained by creating associations between programming and administration or craft. As Ensmenger argues: 'the telephone switchboard-like appearance of the ENIAC programming cable-and-plug panels reinforced the notion that programmers were mere machine operators, that programming was more handicraft than science, more feminine than masculine, more mechanical than intellectual' (2010b, 15). Ultimately, any increase in status for these pioneering women was constrained by a persistent double helix of gender disparity, ensuring their roles and recognition remained secondary to their male counterparts.

Hidden history

While male engineers gained acclaim in their lifetime, the women who worked on this project remained obscure. Until the 1990s the role that the ENIAC women played in programming the machine was not publicly known. One of the most widely published photographs of the ENIAC appeared in the *New York Times* in 1946, but when it was reprinted for an army recruitment advert, two female programmers originally documented were cropped out. When women were allowed to be present in these photographs they were dismissed as 'refrigerator ladies'; models merely there to demonstrate the machine (Sheppard 2013). As historian Jennifer S. Light discovered, in at least some of the photography given to the press, captioning with the names of the women was supposed to have been used. However, she argues, this had the contradictory effect of reinforcing gender stereotypes, rather than

commending their skill. The captions describe how ‘Miss Snyder is setting program switches on an accumulator; Miss Jennings is setting up numbers to be remembered in the function table…Miss Frances Bilas… is plugging in a program cable in the master programmer’ (cited in Light 1999, 447). In comparison to the description of the male ‘maintenance engineers’ these captions, Light asserts, serve to deskill and in turn denigrate female programming work.

Despite their jobs being marked by sexism, for the programmers of the ENIAC there were life-changing opportunities. Compared to most women employed during the war they were afforded a relative amount of agency and were often able to continue this form of employment in peacetime. Snyder, for example, wrote the first ever generative programming system and, after the conclusion of the ENIAC project, she worked with Grace Hopper’s team to develop the computer languages COBOL and FORTRAN. Anatouelli is credited as inventing the subroutine and, after marrying Mauchly, worked on the commercial BINAC and UNIVAC projects with him. Nevertheless, in many ways, the ENIAC proved double-edged for these women in much the same way that industrial and domestic craft work had historically been (Parker 1984; Wosk 2001, 38–42). Programming offered these individuals an opportunity for creative expression, but they still found themselves subordinate and underpaid due to their gender. Most of the programmers of the ENIAC left the project voluntarily, to get married or have children, although the role they pioneered was eventually viewed as a valuable asset, and gained a professional rating by the US Civil Service in 1946. It is worth noting that the ENIAC women’s ability to keep their jobs after the war may have been in part due to their marriages to high-ranking engineers on the project, as this status could have led to their work being received more favourably. Whatever the case, by the end of the war they were seen as a valuable army asset (Abbate 2012, 36).

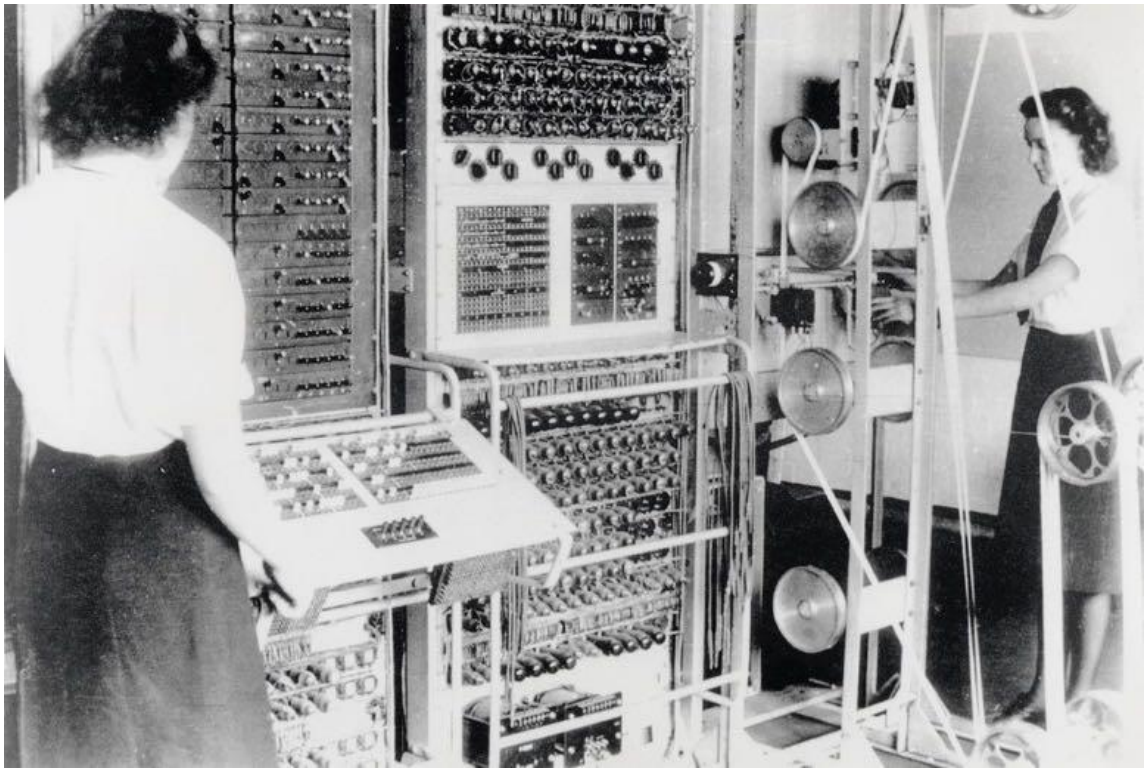

Figure 6 WRNS (members of the Women's Royal Naval Service) working on a Colossus Mainframe, 1945. Dorothy Du Boisson (left) and Elsie Booker (right).

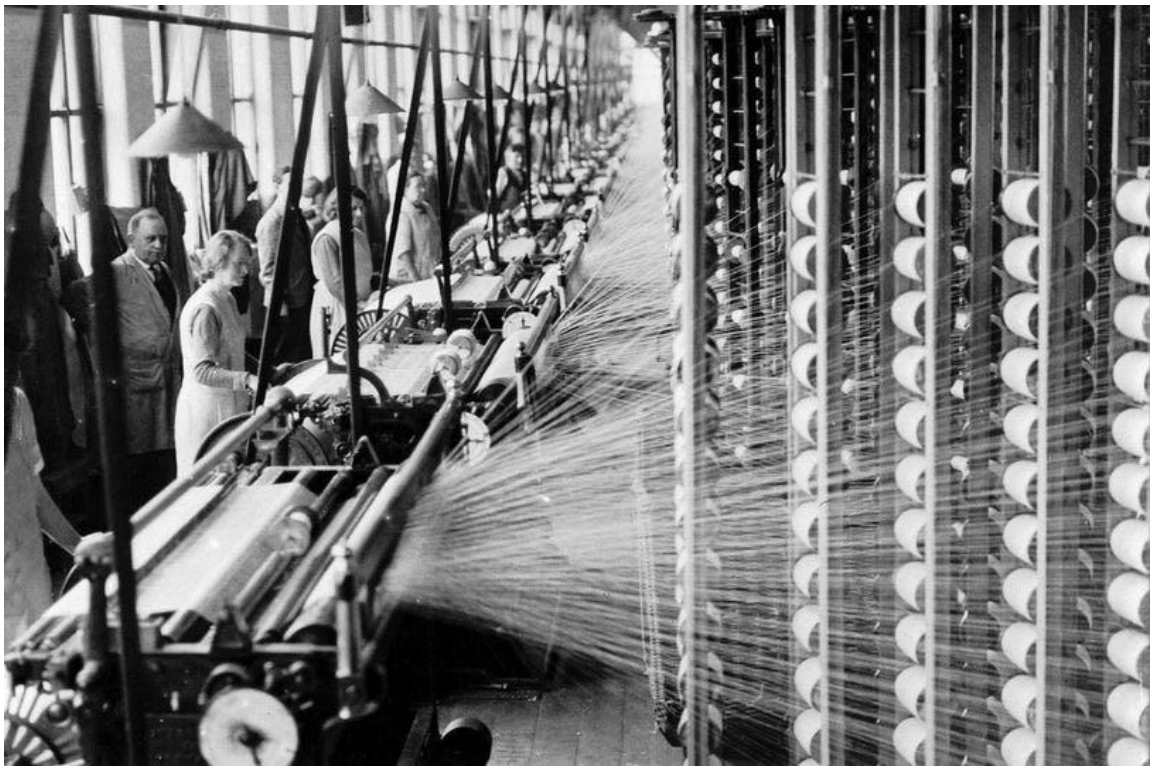

Figure 7 Women working in Regent Cotton Mill, 1935 on machines like those used for the production of cotton thread throughout the Industrial Revolution.

Newmanry

By way of comparison, we can turn to another wartime computer mainframe developed on the other side of the Atlantic: the British Colossus developed at Newmanry, a subdivision of Bletchley Park. The story of the ENIAC programmers serves as a popular example of what Wajcman would call 'hidden history' (2004, 42). The women at the heart of the story have become a symbol of heroic female scientists in a male-dominated field. However, the opportunities given to women programming the ENIAC represent somewhat of an outlier and can mask the struggles and discrimination encountered by the numerous women employed elsewhere in the computer industry. The women of engaged in the Colossus project, for example, faced stark limitations in their roles.

The first Colossus was built in 1943. Built for codebreaking as part of the British war effort, this mainframe was vital to the Allies' victory in the war. Mirroring the sexual hierarchy of the ENIAC, there were two male engineers at the top of the employment pyramid who operated the machine, under whom served sixteen machine-operating women who were part of the Women's Royal Naval Service (WRNS). Whether working on the Colossus, or its mechanical predecessor the Bombe, the labour carried out was described as 'gruelling and tedious' (Hicks 2017b, 29). The women, all of whom were young, middle class and unmarried, were viewed as unskilled machine operators. Conditions were harsh. The whirring machinery generated sweltering work environments. They were far from home, barely able to leave Bletchley Park, alone and given virtually no time off. The WRNs' demanding operating work, unlike the men's, was split into fixed jobs and watches, and complemented by brutal early morning army drills (Abbate 2012, 28). Indeed, the hundreds of women working at Bletchley Park were described by computer scientist Alan Turing simply as 'slaves' (cited in Chun 2011, 230).

Although the Colossus was relatively programmable, the WRNS's roles were limited compared to their American counterparts. Like with the ENIAC, the work they were expected to carry out exceeded the complexity originally anticipated, encompassing physical, intellectual and creative challenges. Yet, their efforts went without ceremony or reward. This work was analogously linked to the custodial aspects of child-rearing. Joan Murray, one of the rare high-ranking women involved described overnight machine care at Newmanry (the section housing the Colossus, named after the head engineer Max Newman) as 'minding the Baby' (cited in Plant 1998, 148). But Murray, who was once engaged to Turing, stood out as an exception. Of the sixty women who were employed at the Newmanry's peak, she was one of the only women to gain some professional status (Plant 1998, 148). Historian Jack

Copeland observes, ‘In those deeply sexist times, no woman rose to a senior management position … and none achieved the status of cryptographer’ (2010, 159).

It is hard not to draw visual comparisons between the work at Bletchley and the labour performed by women in the textile industry during the Industrial Revolution. In a photograph taken in 1943 (Figure 6), two women work on the Colossus. Long strips of paper tape wind up and down over wheels, traversing and coiling through and around mechanisms. Intricately wound amongst spinning machinery, the paper mirrors the appearance of thread found in steam-powered cotton spinning machines, such as that depicted in an image of Manchester’s Regent Cotton Mill from 1935 (Figure 7). This comparison is not merely limited to the visual similarities of the materials used. In both instances open-frame machinery was run and operated by women, in dangerous and poor conditions, working for extraordinarily long hours, day and night. Historian Maxine Berg has described how the work of numerous historically invisible women powered the industrial revolution, across trades including bleach works, pottery, wallpaper printing and textiles. ‘When we talk of industry in the eighteenth and early nineteenth centuries,’ she reminds us, ‘we are talking of a largely female workforce’ (1993, 29). Berg points out that the industries that came to define the mechanised progress of the era, and the profits it yielded, such as factories that produced cotton and flax, were entirely dependent on women’s labour. Repeating this earlier precedent, war-time computing was also powered by machine-operating women who would, yet again, receive insufficient recognition for their labour.

Cosmopolitan women

The Computer Girls

BY LOIS MANDEL

A trainee gets $8,000 a year
...a girl "senior systems analyst"
gets $20,000—and up!
Maybe it's time to investigate....

Ann Richardson, IBM systems engineer, designs a bridge via computer. Above (left) she checks her facts with fellow systems engineer, Marvin V. Fuchs. Right, she feeds facts into the computer. Below, Ann demonstrates on a viewing screen how her facts designed the bridge, and makes changes with a "light pen."

Twenty years ago, a girl could be a secretary, a school teacher . . . maybe a librarian, a social worker or a nurse. If she was really ambitious, she could go into the professions and compete with men . . . usually working harder and longer to earn less pay for the same job.

Now have come the big, dazzling computers—and a whole new kind of work for women: programming. Telling the miracle machines what to do and how to do it. Anything from predicting the weather to sending out billing notices from the local department store.

And if it doesn't sound like woman's work—well, it just is.

("I had this idea I'd be standing at a big machine and pressing buttons all day long," says a girl who programs for a Los Angeles bank. I couldn't have been further off the track. I figure out how the computer can solve a problem, and then instruct the machine to do it."

"It's just like planning a dinner," explains Dr. Grace Hopper, now a staff scientist in systems programming for Univac. (She helped develop the first electronic digital computer, the Eniac, in 1946.) "You have to plan ahead and schedule everything so it's ready when you need it. Programming requires patience and the ability to handle detail. Women are 'naturals' at computer programming."

What she's talking about is *aptitude*—the one most important quality a girl needs to become a programmer. She also needs a keen, logical mind. And if that zeroes out the old Billie Burke-Gracie Allen image of femininity, it's about time, because this is the age of the Computer Girls. There are twenty thousand of them in the United *(cont. on page 54)*

Photos by Henry Grossman. Dress by Gino Charles.

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Figure 8 Lois Mandel, 'Computer Girls,' *Cosmopolitan*, April 1967.

Emerging out of wartime necessity, the practice of hiring female computers to interact with mechanical ones would persist for several decades. One of the most striking examples of female recruitment into the computer industry appeared in 1967 when the popular women's magazine *Cosmopolitan* ran an article entitled 'The Computer Girls' (Figure 8). The piece was illustrated with images of glamorous women with fashionable short hair and bold print shift dresses, operating mainframe consoles, pressing buttons and showing punch cards to their male supervisors. It outlines why computing is a new field of opportunity for women:

> 'It's just like planning a dinner,' explains Dr. Grace Hopper, now a staff scientist in systems programming for Univac (She helped develop the first electronic digital computer. the ENIAC, in 1946.) 'You have to plan ahead and schedule everything so it's ready when you need it. Programming requires patience and the ability to handle detail. Women are "naturals" at computer programming.'
>
> What she's talking about is aptitude, the one most important quality a girl needs to become a programmer. She also needs a keen, logical mind. And if that zeroes out the old Billie Burke-Gracie Allen image of femininity, it's about time, because this is the age of the Computer Girls (Burke [1967] 2015).

This passage abundantly demonstrates the contradictory gendering of computer-based activity in the late 1960s. The image of the 'Computer Girl' simultaneously relies upon and casts off feminine stereotypes. On the one hand, it conjures the image of an organised housewife, and on the other, it rejects the frivolous femininity of actors and vaudeville stars. In its wake, numerous adverts of the time would repeat this vision of a female computer specialist as the epitome of a 1960s modern woman (Hicks 2017b; Ensmenger 2010a). Short-skirted women were routinely printed on the pages of industry brochures and magazines. Like the women described in the *Cosmopolitan* article, they were portrayed as independent but never antisocial, alternatively logical and free-spirited. The social advantages of being situated in this field are stressed by this article, later describing the numerous and quality dating opportunities in a field 'overrun with males' (Burke [1967] 2015).

This recruitment drive was necessary in part because, by the late 1950s, there was an ongoing, and seemingly never-ending, 'labour crisis' in the computer industry. In the mainframe era, companies who had been involved in the war effort were keen to monetise their military products. US International Business Machines (IBM), Radio Corporation of America (RCA) and a host of other firms began to bring their machines to the commercial market. As business sales increased, so did the demand for employees to work with

computers. In 1961 the popular trade magazine *Datamation* suggested there was a 'programming gap' and *Fortune* magazine noted that 'programming has become probably the country's highest-paid technological occupation… Even so, some companies can't find experienced programmers at any price' (cited in Ensmenger 2010b, 18). One way that companies sought to rectify this situation was to focus their attention on attracting women to the computer industry. Computing was a field in flux, and the distinctions between machine operation and programming remained unclear. Consequently, companies often confused these roles. Mar Hicks has suggested that 'women computer operators, though not given the title, were usually programmers as well' (2021). In either case, the goal, in a drive which mirrored employment strategies in the Second World War, was to get female workers into computing.

Domestic metaphors

To reinforce the concept of computational labour as women's work, companies would employ domestic metaphors to market programming as work appropriate for women. As early as the 1940s, domestic handicrafts were used as a metaphor for the patience and attention to detail required of the female computer specialist. Betty Campbell noted, 'nobody, of course, was trained in computers, so they were looking to hire people with certain characteristics, like if you played chess. Well, I didn't play chess. And then they said, "…and people who knit," and I thought, "I've made it: I knit!"' (cited in Abbate 2012, 67). Similarly, a 1968 UK personnel document argued that 'girls sometimes make better programmers than boys… an intelligent girl who has the patience to do embroidery has just the right mentality to do the job' (cited in Abbate 2012, 67). Meticulousness and perseverance were often stressed using domestic allegories. Speaking of her own gender, Hopper said of women programmers in an interview in the 1980s:

> I think that it's always been true that women were more willing to finish the job. They'll stay with it; tie up all the loose ends. If they make a dress, they put the snappers and button holes in. . . .Then I always said that the concept of getting the data all together so you could operate on it was the same thing as getting a dinner ready. (cited in Abbate 2012, 67).

An editorial piece in *Datamation*, 'The Woman Programmer' (1963) by Valerie Rockmael, describes the key contradictions for the employability of women in the computer industry at the time:

> Intuitive generalizations made by some personnel managers are that women have greater patience than men and are better at details, two prerequisites for the allegedly successful programmer. On the subject of whether women possess logical, analytical minds the controversy becomes more intense (cited in Abbate 2012, 67).

As Abbate points out, domestic metaphors were employed both to take advantage of the female labour force, but also to bind programming to supposedly feminine skills which were low-paid. As she writes: 'To help make women feel welcome, female programmers and those urging their employment used metaphors that associated programming aptitude with more "feminine" pursuits such as knitting, music, and cooking, thus casting women's participation in computing as natural and desirable' (Abbate 2012, 65). The result was contradictory, as female programmers were radically rethinking concepts of masculine skill and technical prowess at the same time as their labour was being devalued. 'In the programming field,' she observes, 'the conceptual categories of skilled work and women's work were not mutually exclusive but rather existed in ambiguous tension … Domestic metaphors took advantage of this ambiguity to invite, explain, or justify women's participation' (Abbate 2012, 68).

This meant programming was a double-edged proposition for women. Programming was not only better paid than other types of computer work, but it could also be much more rewarding, and in some cases had job development potential. Yet at the same time, the feminisation of programming, helped by domestic metaphors, allowed other aspects of computing to become associated with women's work. This did not mean women were the only group working as programmers. Although programming offered benefits for female computer specialists, male programmers were still preferred by the industry. This created a class structure where women often remained subordinate and underpaid compared to their male managers and colleagues. In 1969 the average American pay for a female programmer was $7763, the highest salary of any woman's job on the list but amounted to a fraction of that paid to men employed in the same job that year (Abbate 2012, 90).

Just as domestic and craft metaphors were utilised to make programming appropriate for women, in the 1960s early computer design was often based on earlier production technologies. One of the earliest examples of this tendency is demonstrated by Charles Babbage's early language for computers, which took as its basis the textile industry. Included in this lexicon of terminology were a 'store' of information and a 'mill' through which that information would be processed, descriptions echoed later by John von Neumann (Swade 2008). In IBM's history, similar technological metaphors were present. Brought to

work under Eliot Noyes in 1957, industrial designer Edgar Kaufmann Jr. suggested that a modern computer should be split into the ‘parlour’ — where the human operator interfaces with the machine — and the ‘coal cellar’ — the hidden space where the mechanical operations take place. Using this principle, the ‘parlour-coal cellar’ or ‘furnace approach’ to computer design became a leading principle for the company and was vital in the creation of modular systems such as the System/360 and their famous ‘white room’ aesthetic.

The ‘parlour-coal cellar’ analogy, suggested Kaufmann, created an opportunity to bring out the ‘inherent drama’ of the computer, ‘Users of computers are immensely proud of a new dimensioning their world: inherent drama is part of computer, and as little likely to fade with time as the drama of airplanes’ (as cited in Harwood 2016, 81). He encouraged engineers and designers to, ‘Dramatize consoles and keyboards to the fullest (movement and colour included); keep the rest in the ‘grandfather’s gold watch’ technique unless you are ready for the ‘parlour-coal cellar’ division which can be used to the same effect (as cited in Harwood 2016, 81).

Here Kaufmann is describing two aspects of computer design which splits the operator and machine. The ‘gold watch’ principle to which Kauffman refers was a method of keeping the complexities of a computer concealed in some way. Like a panel on a gold watch, which is opened to reveal the inner workings of cogs and levers necessary to keep time. The ‘parlour-coal cellar’ principle kept the inner workings visually and spatially distant from the machine’s operators. As Kaufmann wrote, ‘only the components used by the staff are explored on a main floor and all others are buried in the cellar or in a back room’ (as cited in Harwood 2016, 81) While at first glance these two techniques seem only subtly different, the latter serves to cause a distinct split between interface and mechanical working. In the ‘parlour-coal cellar’ model there is no reveal of the ‘guts’ offered by the ‘gold watch principle’ — the coolant tubes, wires and connectors — they are entirely concealed from the user. As architectural scholar John Harwood points out, Kaufmann seems to have been the first to create this distinction between an operator’s interface and the operating mechanism that powered it. This principle would have long-standing ramifications and is still an integral aspect of computer design today.

The parlour-coal cellar metaphor is a surprising line of thinking to be explored by a major corporation, as it distinctly mirrors the split between public and private space in the home, as opposed to space as it might function in a business. Of course, the work/home dichotomy is not split at the front door either. Although the home can more generally be viewed as a feminised space, it contains both private and public rooms, and different types of activity

take place in these spaces. Feminist theory describes how this dichotomy of the public and private restricts women in the household, often limiting them to those areas designated as private or domestic (Wajcman 1991a, 112–3). During the Victorian era, areas of the house had distinct uses, creating separations between the private and public, male and female, and master and servant. The parlour was specifically kept for socialising and contained the very finest furniture and interior decor the household could afford. As historians Leonore Davidoff and Catherine Hall write, 'segregating the mess and smell of food preparation from the social ritual of eating became an important hallmark of respectability and meant that the kitchen became ideally as remote as possible from the living rooms, no matter the cost in servants, or wife's time and labour' ([1987] 2019, 383). Celebrating the 'parlour,' to use Kaufmann's metaphor, while hiding the domestic mess, is to regard some types of activity as needed to take place beyond the public gaze. Here, we might equate the mechanical operations of the computer with the hidden labour of women and servants operating in a patriarchal context.

Creating stereotypes

At the same time as domestic metaphors were being used to recruit a female underclass, other metaphors became prevalent in the field. In *The Computer Boys Take Over: Computers, Programmers, and the Politics of Technical Expertise* (2010) Ensmenger describes in detail how metaphors of artistic and artisanal production were employed through the 1960s to create obstacles for women in computing. He writes:

> The various ways in which the language of art, aesthetics, and craft is used throughout the history of computing to elevate, denigrate, or castigate programmers and other software specialists. By characterizing the work that they did as artistic, programmers could lay claim to the autonomy and authority that came with being an artist (2010b, 48).

Ensmenger suggests that the 1968 NATO conference held in Garmisch, Germany was a key turning point for the computer industry. Here, a wide range of computer specialists met to discuss the crisis in the software industry. This was not just a crisis of employment, but one of terminology. The term 'programmer,' which had been selected to distance these new roles from the uncreative work of desk calculating, had now become fully associated with women. It was at Garmisch that the phrase 'software engineer' was settled upon as a new descriptor. The phrase software engineer consolidated the concept that programming belonged in the arena of science, not of creative individualism. It also began a process of dissociating the role from the female labour force who had been undertaking this work.

While domestic metaphors that were key to the construction of a low-skilled role in computing was in development, metaphors from art and craft that focused on individual male genius were key in creating the image of the stereotypical male computer programmer at the same time. Literature from the industry makes clear that, by the late 1950s, 'real' programming was anything but low-skilled clerical work. Another vision of programming was on the horizon. This new programmer was an individual, a creative outsider, a type of artistic genius. As John Backus, one of the developers of FORTRAN wrote, in the 1950s, programming was 'a black art, a private arcane matter… [These individuals had a] chauvinistic pride in their frontiersmanship and a corresponding conservatism, [regarding themselves] as members of a priesthood guarding skills and mysteries far too complex for ordinary mortals' ([1980] 2014, 126–127).

This attitude was absorbed into the ideology of the programmer. In a classic text computer specialist Frederick Brooks would write 'the programmer, like the poet, works only slightly removed from pure-thought stuff. He builds his castles in the air, from air, creating by exertion of the imagination' (1975, 7). This masculine programmer existed in countervailing tension with the deskilled world of female labour, a figure embodied by 'the computer girl'. At the NATO conference, the uncomfortable relationship between masculine and feminine visions of programming was effectively removed. The 1968 conference papers claimed that 'software writing started to make the transition from being a craft for a long-haired programming priesthood to becoming a real engineering discipline. It was the transformation from an art to a science' (cited in Ensmenger 2010b, 196–7). What this meant for the field was dramatic. Programming, a term originally chosen to give women credit for their work, and dissociate their role from manual labour, was now a diminished category. As Ensmenger suggests, 'an activity originally intended to be performed by low-status, clerical — and more often than not, female — computer programming gradually and deliberately transformed into a high-status, scientific, and masculine discipline' (2010b, 239.)

Although computer historians debate the deliberateness of gendered metaphors and their use to push female employees out of the field, generally it is agreed that by the 1980s computing had become a hostile environment for women. From 1984 onwards, the number of women entering the profession with or without college-level education began to fall dramatically. At this time the stereotypical masculine hacker had come to the fore, and the field had become an early version of what would by the twenty-first century be described as a 'brotopia' (Chang 2018). Sherry Turkle's research into the computer industry in the 1980s studies the extreme masculinity of hacker culture. As Turkle noted, 'there are few women hackers. This is a male world. Though hackers would deny that theirs is a macho culture, the

preoccupation with winning and of subjecting oneself to increasingly violent tests make their world peculiarly male in spirit, peculiarly unfriendly to women' ([1984] 2005, 194).

While the appearance of these antisocial individuals is often linked to the advent of personal computing, these archetypes were in formation much earlier, as Ensmenger summarises:

> The social construction of the computer programmer as a nerdy eccentric predates the personal computer by several decades. It originated in the early association of programming ability with chess playing and mathematics puzzles, was reinforced by scientifically dubious aptitude tests and personality profiles, and by the early 1960s had become embodied in the hiring practices of the growing commercial computer industry. The institutionalization of gender norms in this period highlights the ways in which structure and culture are mutually constitutive, and ultimately self–replicating (2010a, 137).

The results of not having many women working in the creative side of IT in recent decades have proven significant; consequently, the digital systems that make up our world have predominantly been designed by men. How data collection, machine learning, artificial intelligence and algorithms are subject to gender bias is the premise of important research currently underway (Saka 2020). What we see in offices of the 1960s is the beginnings of a narrative that constructs computer work as men's work, acting to the detriment of the women who were within the industry. Bar the few exceptions who made it into higher paid management roles, most of the female workforce in computing were perceived as disposable. This chapter argues that ideas and the language of craft played an important role, in shaping who is employed and how they are valued in the early years of the computer industry.

moths

Figure 9 *My Monster*, 2018. Exhibited in *Lowlight*.

Figure *10* *Saboteur*, 2018. Installation view. Exhibited in *Lowlight*.

In the early stages of this research, a central strand of enquiry was imagery documenting the 1960s and 70s computer industry, particularly photographs of the women who worked within it, or depictions of the machines they worked alongside. Imagery such as this directly responded to or employed photography from the narratives outlined in the previous chapter. What was initially envisaged as the outcome of this research was the production of artworks materially linked to the history of the technologies they employed, to loop together technological processes and historical narrative. Initial experimentation resulted in a series of etchings using photographs of prominent women from the history of computing. An underlying rationale for this decision was that the techniques used to produce printed circuit boards and etched printing plates are virtually identical, as both employ light-sensitive photo-chemical etching processes on metal sheets. Results from this body of enquiry included *My Monster* (2018) displayed in *Lowlight*, a photo-etched portrait of computer scientist and Naval Captain Grace Hopper (Figure 9). Hopper is regarded as one of the most influential computer scientists of the modern age for her work developing the programming language COBOL, the Harvard Mark I, II and UNIVAC. Programming the vast and complex mainframes of the Harvard Mark I was an arduous task, requiring continual rewrites, as the hardware was altered daily by her colleagues. Hopper would describe the Harvard Mark I as 'my monster' (cited in Plant 1998, 151).

While working on this print, I discovered that Hopper was the supposed originator of the apocryphal etymology of the term 'computer bug', which opened up the project to a different set of concerns. In this story, which will be discussed more fully in the following chapter, an insect flew into the Harvard Mark I's relays and ground the computer to a halt. This anecdote prompted me to reconsider the interwoven relationship between women's labour and the natural world, and how this connection might pertain to technological narratives typically interpreted as a male preserve, such as conceptions of 'culture' as the opposite of 'nature' (see **vegetal matter**).

In direct response to Hopper's anecdotal 'computer bug' across the exhibitions *Noon* and *Lowlight,* the gallery spaces were occupied by representations of black and white moths. The work, *Saboteur*, comprises a series of small stickers made from self-adhesive vinyl. It used a vinyl plotter, a CNC technology in which a small blade accurately cuts detailed shapes or lettering into thin material. In this piece, rather than digitally printing the imagery, I used a form of vinyl-on-vinyl collage to construct each one. Each moth is approximately 40mm square, and although they use the same template each one is unique, due to the way in which different layers of patterning are applied to the contrasting black or white base.

These were dispersed throughout the exhibitions, increasing in number around *Irrational Cabinet I* and *II*, sculptural forms resembling computer mainframes (Figure 10).

Although two-dimensional, when configuring *Saboteur,* the aim was to employ these vinyl decals throughout the exhibition space sculpturally. With this work, I considered how small-scale, graphic objects can be used to activate the gallery space. The stickers are placed around the room, in high and low positions as a means of drawing the eye. Sometimes they were sparsely placed, and at other points, they were arranged more densely. Their spatial arrangement and interaction with the other sculptures in the exhibitions employed a method of drawing the gallery viewer through the space. This also emphasised the collapsing narrative that was being constructed in the exhibitions as a whole; at first glance, the set-up of the white room appears ordered, but the detailed moments of the holes, moths and caterpillars come into focus as the corruption of this. Simultaneously building up and dismantling the environment, a narrative and counter-narrative can begin to run simultaneously.

Beyond its function in the gallery space, *Saboteur* is a meditation on both the myth of the 'computer bug', and the history of the term 'sabotage'. The moth acts metaphorically, as a method of alluding to sexism in computing during the twentieth century and today. As a literal 'computer bug,' this biological entity supposedly stopped the functioning of a computer mainframe, and in doing so disrupted the masculine-coded, techno-rationalist endeavour in which the machinery was engaged. Thus, through this project, the moth is treated as a method of joining feminist practice to wider discussions of sabotage as class resistance. Specifically, this plays upon the jamming of mechanisms by which a hegemonic capitalist order ceaselessly functions, narratives centred around the practice of Luddite machine-breaking. If the concept of sabotage is constructed around a false etymology concerning the throwing of wooden clogs into mechanical looms, as analysed in the next chapter, I imagined *Saboteur*, which expands on the same theme, to stand as a similarly adaptable symbol with which to apprehend contemporary forms of immaterial labour.

There is little doubt that our working conditions have been completely transformed by the ubiquity of digital devices in our lives. One aspect in particular is the length of the working day, a subject that has long since concerned those seeking to diagnose how surplus value is created at the expense of workers as epitomised by Karl Marx ([1867] 1982, 340–411). Built around just-in-time supply chains and an internet of things, today's economy embraces a virtually sleepless work pattern: factories run all night, emails are sent in the early hours and services are expected to operate 24/7. As cultural critic Johnathan Crary suggests:

> 24/7 is a time of indifference, against which the fragility of human life is increasingly inadequate and within which sleep has no necessity or inevitability. In relation to labor, it renders plausible, even normal, the idea of working without pause, without limits (2013, 9).

As Wajcman notes, the perception that information and communication technologies have both sped up our working lives and eroded the line between work and home life is a persistent contemporary narrative: 'there are plentiful discussions about the inexorable extension of working time, reflected in terms such as work-to-family spillover, the colonization of time, and the blurring, merging and morphing of work-life boundaries' (2015,137). With this in mind, the moth, like the clog before it, provides an intriguing motif through which such a situation might be approached. The moth is a night insect, small and industrious. It is awake in the hours when most are not, working long into the night. Perhaps it could be useful as an image to consider the history of women working in computing. At first glance, female computer scientists appear like a bug or glitch in a broken system, but later you realise the industry was teeming with women.

Figure 11, Henry B. D Kettlewell, One light and one dark form peppered moth (Biston betularia) on a lichen-covered tree illustrating the relative merits of camouflage, 1956.

Coloured in black and white, *Saboteur* also references the peppered moth, a famous example of species alteration in response to environmental change. Until the nineteenth century, this type of moth was said to be white, with black speckles over its wings. However, during the mass industrialisation of the UK, the population began to change. As entomologist J. W. Tutt wrote in 1896:

> Near our large towns where there are factories, and where vast quantities of soot are day by day poured out from countless chimneys, falling and polluting the atmosphere with vapours and gases, this Peppered Moth has, during the last fifty years, undergone a remarkable change (cited in Owen 1997, 177).

As the moth's white wings were highly visible to predators against the soot-covered trees their numbers reduced dramatically. What had previously been a scarce number in the population, the dark phenotype, was now visually camouflaged against lichen-free bark. Moths of the dark form became more numerous than their white counterparts (Figure 11). This is the first known example of industrial melanism by natural selection. The Clean Air Act of 1956 reversed the peppered moth population's colouring from black back to white, further demonstrating the impact of industry on the environment. I consider this an apt motif for female computer specialists. Like the culture surrounding women working in the computer industry, the environment allowed moths to thrive or fail, based on pre-existing characteristics. But the peppered moth also demonstrates that when surroundings change, those that were previously left behind can prosper, and as such provides a hopeful future for what the computer industry could be for women.

The moth's presence is also evoked by the inclusion of readymade small white silicone caterpillars, which peak through the holes of an operator's desktop in *Infestation*, and can be seen traversing the faux cabbage leaves of *Ponics*. Those articulated forms were purchased as mass-produced, readymade elements and are usually used as fishing lures (Figure 12). The inclusion of elements that I have not directly fabricated myself was a deliberate attempt to draw into question the agency we each have when we make use of the labour of others. As Julia Bryan-Wilson's recent book *Fray: Art and Textile Politics* has importantly clarified, the idea that mass-produced items are not handmade creates false distinctions between factory and home-based production. Reebok trainers, for example, take 200 pairs of hands to produce but the opacity of global factory systems makes it virtually impossible to visualise this labour in a single mass-produced item (2017, 257).

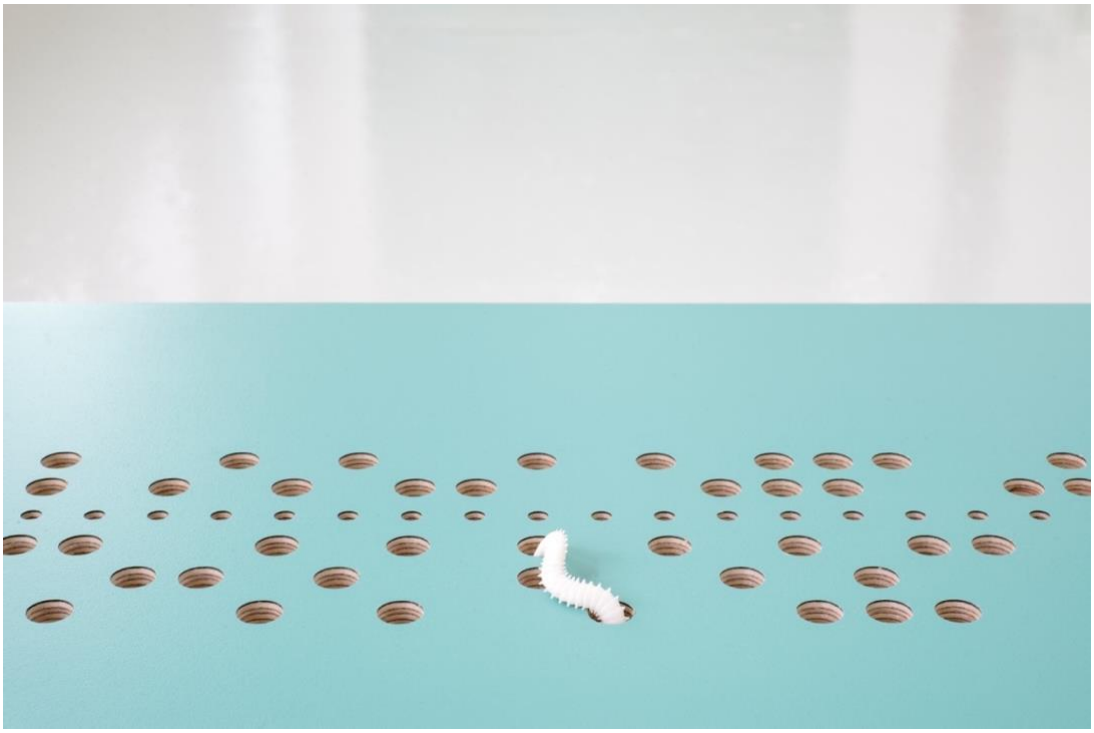

Figure 12 *Infestation* (detail), 2018. Exhibited in *Noon*.

This motif of insects disabling computers from the inside is a pivotal element in director Saul Bass's film *Phase IV* (1974), which was screened at David Dale Gallery as part of an accompanying events programme for the exhibition *Noon*. In this film, ants are depicted as superior to the human world they are colonising. The technological rationality of the research laboratory is employed by Bass to suggest something that could be overcome by a new social order, one that is based on the distributed nature of the insect colony. In much the same way, the caterpillars and the holes they create in *Infestation* act as moments of disruption and entropy in what at first glance appears as a clean and sterile site. Much like the exhibitions, which present themselves as speculative ecosystems, the larval stage of the moth and the damage that they are depicted creating suggests an intertwined or ecological process at work. In *Infestation*, caterpillars peak through a series of mechanically spaced holes, reflecting the pattern of punched tape used as data storage in early computation systems. To extend the concept of a single, interlinked system across the exhibition, the hole motif repeats across the leaves of *Ponics* and a series of suspended lamps titled *Lowlight*. This is a recurring feature of the artworks included here, as each is presented as acting upon the other in some way. The combinations of these elements are key to their effect and the complexity of inter-relating narratives that they can bring together.

I describe this approach to exhibition-making as the creation of a counterenvironment. Coined by architectural historian John Harwood, the term refers to the comprehensive

human-machine design developed by IBM in their 1960s computer rooms (see ‘Green Thumbs II’). It transcends traditional installations or exhibitions, focusing on the relationship between object, narrative and environment. My exhibitions acknowledge and respond to site and context while presenting an alternative, fictionalised version of that environment. This creates space for the audience to engage with ideas of hidden or alternative histories. Recognisable or proxy spaces are created through the interaction of familiar and unexpected sculptural forms and materials. For example, by juxtaposing digitally fabricated plastics with hand-dyed and recycled textiles, I aim to create an unsettling temporality—an anachronistic timeframe that exists neither in the past, present, nor future. These arrangements mirror my material enquiries, bringing various technological narratives into dialogue and presenting something akin to an alternative reality. Often these effects rely on the aesthetics of science-fiction films of the 1960s and 70s. A utopian future which never came to be, a tomorrow stuck in time, and one that we collectively stopped imagining.

This approach is akin to the two logics of fictioning practice outlined by Simon O’Sullivan. He observes the first is ‘the production of untimely images – that speak back to their producer’ and the second is ‘the layering of motifs to produce an accretion of sorts, resulting in an opacity’ (2016, 83). I argue that the creation of what I term a counterenvironment produces ‘untimely images.’ I engage with real histories, histories that are overlaid to reframe the art venue as an alternative space. In this way, the exhibitions ‘speak back’ as a mode of critique. O’Sullivan’s second logic of fictioning, the ‘layering of motifs’, is embodied in how the individual elements of *Nimble Fingers and Green Thumbs* combine. Additionally, this aligns with artist and theorist Mark Staff Brandl’s proposed model of contemporary art in which, ‘form and the content are inextricably interwoven, each mirroring the other in its own terms. This multiplicity and intertwining are usually grounded in, and the breeding ground for new, intricate compositions of metaphors’ (2023, 30).

As counterenvironments *Noon*, *Lowlight* and *Hothouse* combine recognisable imagery from offices, computer rooms, and agriculture to create spaces which bring together various narratives around technology into dialogue with one another. For example, I took the specific nature of David Dale’s and Bloc Projects’ white cube galleries and staged the space as a 1960s-style ‘white room’ or ‘computer lab. In *Noon* this included a mainframe computer (*Irrational Cabinet*) and desk (*Infestation*) based on the scale and fashions of the time. The exhibition modelled itself on the human-machine spatial layouts popularised by IBM as will be discussed in ‘Green Thumbs II.’ Alongside these recognisable tropes of the office, I created a cabbage patch (*Ponics*) and cabbage lamps (*Lowlight*), alongside moth-stickers, caterpillars and holes (*Saboteur* and across *Ponics* and *Infestation*), which brought

horticulture into the closed system of technology. This effectively aligns agricultural labour with administrative work. Similarly, in *Hothouse*, computing and farming are brought together via temporary agricultural structures covered in microchip-print patterned mesh and filled with printed synthetic mushrooms and palms. This work, much like the reimagined spaces of *Noon* and *Lowlight* creates a site of speculation and fiction, drawing out the relationship between these different types of labour.

One of the key methods used within my practice is a type of skeuomorphism in which objects are formed in an alternative material. One existing example of such an artefact is the Toyota Camry dashboard. Cultural theorist Katherine Hayles describes the control panel as, ‘covered by vinyl moulded to simulate stitching. The simulated stitching alludes back to a fabric that was in fact stitched, although the vinyl "stitching" is formed by an injection mold’ (1999, 17). It is no surprise that skeuomorphism is to be found in computer technology as they are a useful device to help us become accustomed to change, or newness. Often a skeuomorph can hold innovation in one hand and tradition in the other as a method of creating a psychological space for change. Similarly, in this body of work materials mimic those they are not; synthetic plastic replaces botanical leaves, stretched and pasted tie-dye fabric replaces the outer casing of the computer and recycled dead-stock yarn mainframes mimic computer cables. In these instances, skeuomorphism creates the effect of uncanny and familiar at the same time. One in which you recognise something, but on closer inspection it, like the Camry’s dashboard, is a facsimile. This form of double-bluff conjures a particular relationship to temporality. Or, as Hayles puts it ‘like a Janus figure, the skeuomorph looks to past and future, simultaneously reinforcing and undermining both’ (Hayles, 1999, 17).

The work *Saboteur* and the silicon caterpillars exemplify the use of skeuomorphism within the counterenvironments my exhibitions create. The entomological elements in the exhibition disrupt the apparent order and sterility of the gallery space, simultaneously constructing and deconstructing narratives. Acting as symbolic disruptors in the technological environment, the moths, caterpillars and holes reference the apocryphal etymology of the computer bug while challenging the masculine-coded rationality of computing spaces and drawing upon feminist histories. Organic entities are figured in synthetic material, purchased from a contemporary, decentralised or just-in-time supply chain. Familiar motifs are recontextualised to highlight dialectical tensions, ultimately prompting a reconsideration of the intersections of labour, gender, and technology within the gallery space. This epitomises the way in which the counterenvironment functions: using narratives from alternative occupations to ask questions about our own labour.

Green Thumbs I: Bugs in the Machine

Computer bugs

On the 9th of September 1947, the Mark II computer stopped working. The Mark II was at this time the cutting edge in technology, an electromechanical computer developed by Harvard University in 1945 and later taken over by the U.S. Navy. Its development was overseen by legendary computer scientists Grace Hopper and Howard Aitken. The machine used electromagnetic relays, making it 2.6 times faster than its predecessor, the Mark I, previously the fastest computer in the world. Searching high and low, the Mark II team could not find the cause of the malfunction. The normal teething problems were successively ruled out; this was a new culprit. After a thorough analysis of the machine's circuitry, they found a small moth had flown into a relay (Computerworld, 2011). Having removed the creature, they were able to start the machine up again. On a journal page logging that day's work the moth was stuck to the page with Sellotape, as physical evidence for what would become an apocryphal event in the history of computing: the apparent coining of the phrase 'computer bug' (Shapiro 1987, 376–378).

It is often suggested that it was from this point onwards that the term computer bug began to creep into common speech, referring to a 'fault,' 'defect' or 'error' in a computer system. In reality, the idea of a bug in the machine was nothing new. The term was in use from the Industrial Revolution onwards to describe any small, snagging malfunction in machinery. One of the first uses of 'bug' to designate a problem with machinery appears in a letter by Thomas Edison. *The Pall Mall Gazette* reported in 1889, 'Mr. Edison, I was informed, had been up the two previous nights discovering "a bug" in his phonograph — an expression for solving a difficulty, and implying that some imaginary insect has secreted itself inside and is causing all the trouble.' Some eleven years before its original appearance in print, Edison wrote an 1878 letter to Theodore Thuskas saying, 'this thing gives out and then that "Bugs" — as such little faults and difficulties are called' (cited in Computerworld, 2011). Edison's use of the word seems rooted in the medieval usage of bug, taken from the Anglo-Saxon bugge, which refers to a gremlin or monster, still present today in words like 'bugbear' or 'bugaboo.'

Despite this, Hopper's moth has become mythologised in the annals of computer history. Historian Peggy Kidwell notes that 'there is a widely propagated myth that this [moth] is the first use of the term "computer bug" and Grace Hopper was the one who discovered it.' Kidwell concludes that 'neither of those myths, although they are both very appealing, are

true' (Wayner 1997). On the topic, linguist Fred R. Shapiro cites ten books, journal and newspaper articles in the 1980s which ran with the story, including popular historical texts from the field of computer science including T. R. Reid's *The Chip* (1984) and Jack B. Rochester and John Gantz's book *The Naked Computer* (1983). Most of these etymological errors have been corrected today. However, even in the last few decades, the myth continues to be propagated. For example, in 2014 popular technology writer Walter Isaacson claimed that after the moth flew into Hopper's machine the team 'referred to ferreting out glitches as "debugging the machine,"' (2014, 94). Similarly, Doron Swade has suggested that moths were attracted to the light and warmth of vacuum tubes, which led to the use of the term 'debugging,' (2001, 291).

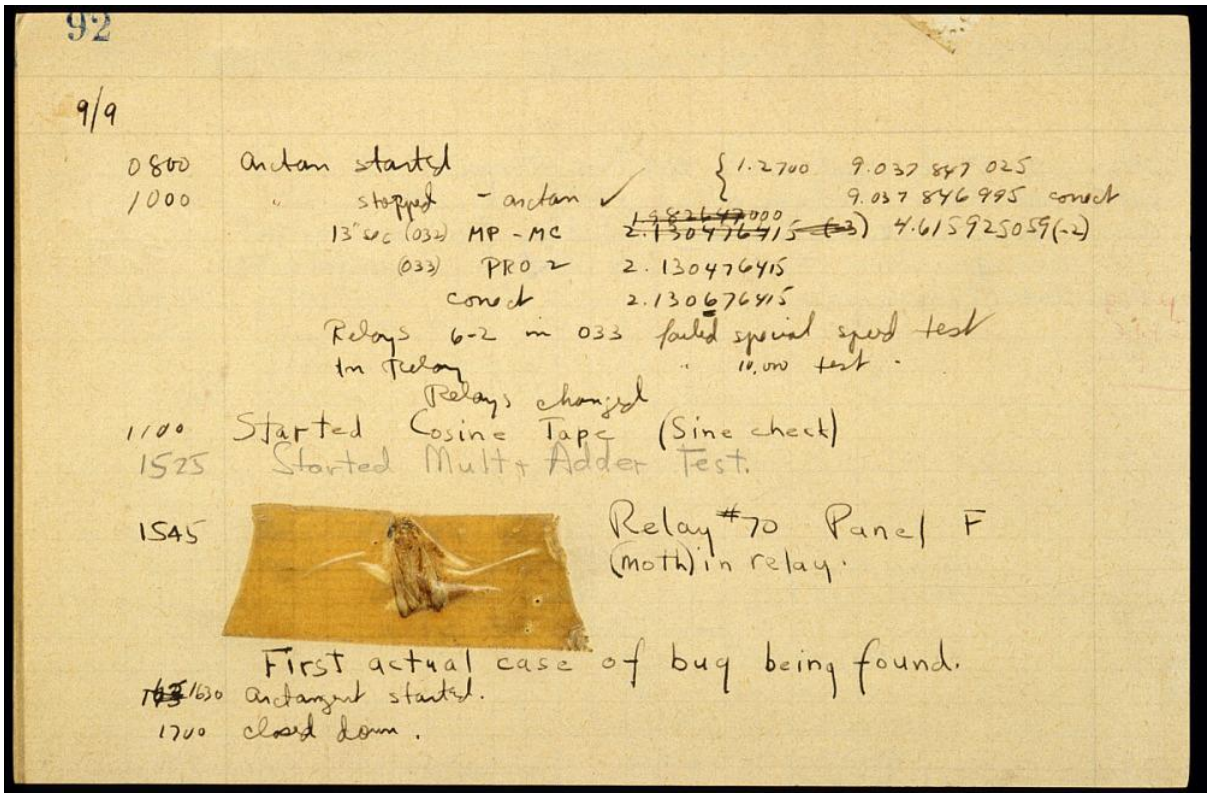

Figure 13 Harvard Mark II Logbook page, with a moth sellotaped to entry, 9 September 1947.

However, as Shapiro points out, Hopper and her team were excited by the moth flying into the machine because 'mechanical defects were ALREADY called bugs'. Moreover, the 'verb debug,' he suggests, appeared in engineering journal articles before the Mark II had been created, and consequently must have been in use a few years before that in 'engineering slang' (1987, 377). The Mark II's journal entry of the day (Figure 13) in fact makes clear that the term's earlier usage was the appeal of the story, as the sellotaped insect is annotated with the phrase 'first *actual* case of bug being found' (Hopper cited in Shapiro 1987, 377).

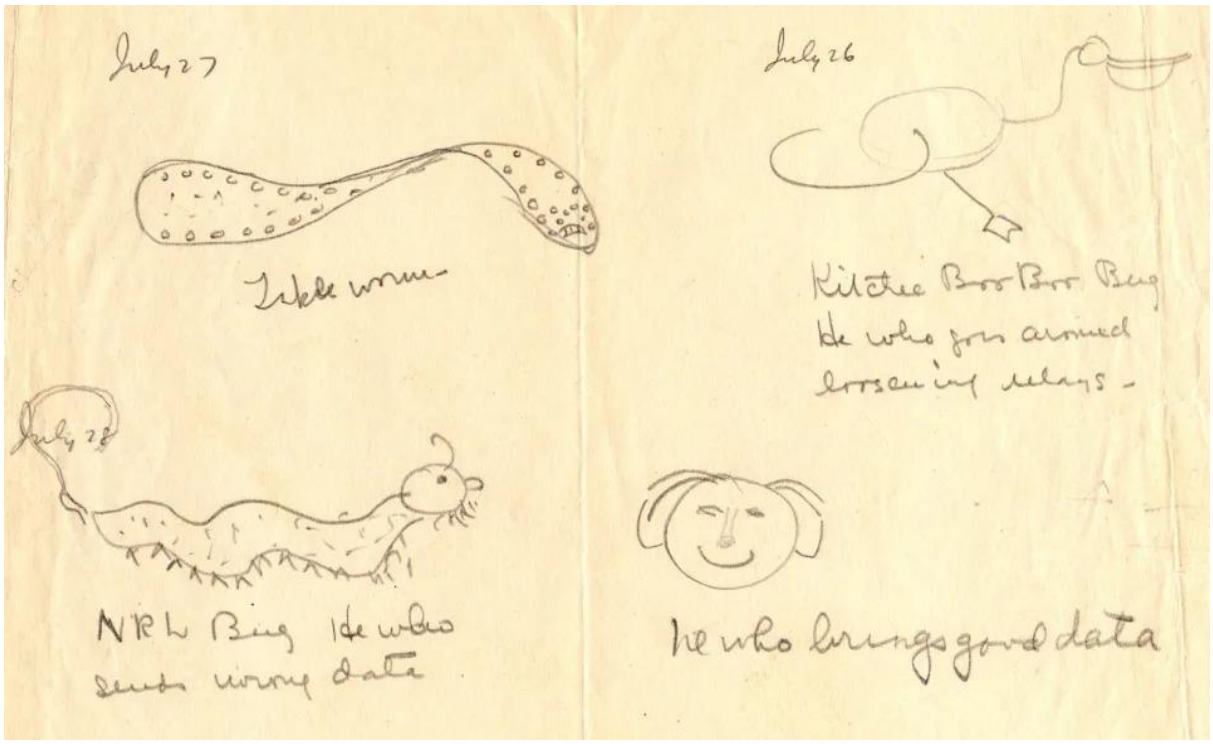

Figure 14 Grace Hopper, *Kitchie Boo Boo Bug*, 26 July 1944.

The use of the word ‘bug’ had migrated from engineering, but this is not to detract from Hopper’s role in popularising the term in the field of computer programming. Hopper herself had used the term ‘bug’ long before her team discovered a moth in September 1947. She drew cartoon illustrations of computer bugs (Figure 14) which were plaguing her machines including: the ‘table worm’ which caused errors in the paper tapes; the National Research Laboratory’s ‘NRL bug’ that mimicked a caterpillar that sent the wrong data; and the ‘kitchie boo boo bug,’ which was associated with loose relays. She made these humorous sketches in 1945 when working on the Mark I, two years before any real ‘bugs’ made their way into the mainframe of its successor (Kidwell 1998, 7). The subsequent mythologisation of this moment may be in part due to Hopper’s repetition of the story at numerous speaking events. She loved to tell the tale at lectures and dinners, despite the fact she was not actually present when the moth was found. The journal entry for that day does not feature her handwriting, and today the discovery is attributed to one of Hopper’s team, the programmer William Burke (Veldhuijzen van Zanten, 2013).

While real computer bugs, be they software defects or actual insects, were a problem, another type of insect also impacted the computer room. ‘Cable mites’ or ‘cable bugs’ were a phenomenon noticed by women who worked at telephone switchboards and with early

mainframe computers in the 1960s and 70s. Bruce Sterling writes ‘there are a lot of cords down there, and when a bunch of them are out at once they look like a nest of snakes. Some of the girls think there are bugs, living in those cable holes’ (1994, 29), Although eye-witness accounts suggest the insects were black or white, or even able to change colour, these bugs could not be found. That is not to say the women did not feel something real, as many suffered from itchiness and rashes, but mites were not the culprit. Some companies took measures to eradicate these problems with professional pesticide services, but despite their best efforts, they never discovered an infestation. Offices with new carpets, mounds of paper, and electromagnetic machinery all created environments where static electric shocks were common. It transpired that this invisible force biting the computer programmers was not an insect at all (Ebeling [1975] 2002).

Sabotage

> He lowered his voice. ‘Some claim sabotage! Do you know that French term, sabotage? Comes from “sabots,” the wooden shoes worn by French workers. They can kick an Engine half off its blocks!’ Tobias grinned at this prospect, with a glee that rather disquieted Mallory. ‘The French have Luddite troubles of a sort, you see, sir, much as we once did, years ago!’ (Gibson, Sterling 1992, 145).

So goes the etymological story of the word ‘sabotage.’ Bruce Sterling and William Gibson are here referring to the invention of mechanised looms and its impact on established forms of labour in the nineteenth century. Highly skilled weavers lost their jobs when the work of many could now be achieved by a single automated machine. These individuals reportedly threw wooden shoes, known as ‘sabots,’ into the looms as a form of protest. This is frequently how the narrative of sabotage is told, but much like the ‘computer bug,’ it is a false etymology. A more likely root for the phrase sabotage occurred much earlier, in sixteenth-century Holland, when the cities’ workforces went on strike and country labourers came into the towns to replace them. These replacement workers wore cheap, simple clogs, roughly carved from a single piece of wood. The earliest uses of the term sabotage did not describe machine breaking, but rather poor-quality workmanship associated with the footwear of this new influx of workers. This out-of-town workforce did not have the experience of the longstanding factory employees, and quite quickly the word ‘sabot’ was used to mean ‘walk noisily,’ becoming an indicator of poor workmanship and laziness. The English phrase ‘slipshod’ has a similar etymological root (Bell 2012).

The visual metaphor of sabotage has proved so durable that the image of a wooden shoe has been taken up by unions and workers' rights movements across the world as a symbol of industrial action. In a 1917 pamphlet for the *Industrial Workers of the World* (IWW)*,* feminist activist Elizabeth Gurley Flynn would extol the virtues of machine breaking and sabotage in the quest for workers' rights and class struggle. Emblazoned on the front page in red and black is a wooden clog beneath the title 'sabotage'. Inside she writes:

> I am not going to attempt to justify sabotage on any moral ground. If the workers consider that sabotage is necessary, that in itself makes sabotage moral. Its necessity is its excuse for existence. And for us to discuss the morality of sabotage would be as absurd as to discuss the morality of the strike or the morality of the class struggle itself (1917).

The 'sabot' continues to this day to be used as a symbol of class struggle on cartoons and membership pins for the Industrial Workers of the World and other union organisations (*Cultural Icons*).

Recently, the myths surrounding Luddism have taken on a specific set of connotations in the digital age, connotations quite disconnected from the plight of Yorkshire textile workers. As English scholar Steven E. Jones describes, even those who know about the Luddite riots are quick to 'extrapolate from [them] and eagerly express their agreement and solidarity with the Luddites' "philosophy," by which they meant that they often feel too dependent on their cars or enraged at their desktop computers' (2006, 5). Beyond this vague cultural kinship to the Luddites, during the early 1990s what was termed neo-Luddism appeared in response to the rapid spread of computer technologies at the height of the dot-com boom. Neo-Luddite thinking drew heavily upon Kirk Patrick Sale's *Rebels Against the Future* (1995), which traced the history of the Luddite struggle to the computer age. At speaking events, Sale would begin by taking a sledgehammer to a beige PC monitor, replicating Luddite machine-breaking practices as a contemporary gesture.

Like the mental image of a bug that proved so powerful as to make female office workers convinced they were being bitten, the conjoined images of sabotage and Luddite rebellion persist in the collective imagination. These symbols have morphed as time passes, and as technology evolves, adapting to articulate a feeling of unease around our place in relation to mechanised processes.

Managing like a man

When Hopper was asked by Aitken to join his advanced computing team, she appeared to be an anomaly. Although an exceptional mathematician Hopper had, like the majority of the population at this point, very little knowledge of computers. Somewhat bored with her university lecturing role however, she was intrigued by the offer and moved to IBM to work with Aitken and his team on the Mark I. Hopper described the Mark I in 1968 as a 'large mass of machinery …making a lot of racket… It was all bare, all open and very noisy' (cited in Isaacson 2014, 90). The task of programming the Mark I was hard both physically and cognitively. It required hours and at points even days of plugging and unplugging, connecting and reconnecting the '3500 multipole relays with 35000 contacts, 2,225 counters' and '500 miles of wires [with] three million connections' (IBM Archives).

In a sexual hierarchy that would be mirrored in the ENIAC some years later, Aitken was in charge of the mainframe's hardware, and Hopper became the guiding force of what we would now think of as software. Their joint achievements were remarkable, but the relationship could be fraught. As Hopper recounts:

> I wanted to keep my software and use it over again. I didn't want to keep reprogramming things. But unfortunately, every time I got a program running, he'd get in there at night and change the circuits in the computer and the next morning the program would not run. What's more, he was at home asleep and couldn't tell me what he had done (cited in Plant 1998, 152).

Despite exchanges between Hopper and Aitken often being difficult, they had mutual respect for one another. When other colleagues found Aitken hard to work with, Hopper noted, 'I would try to explain to [them] that Aiken was just like a computer. He's wired a certain way, and if you are going to work with him you must realise how he's wired.' Similarly, Aitken had reservations about Hopper, mainly based on her gender. He originally baulked at the idea of a woman on the team. However, her good work and stoic attitude eventually won him over. He recalled the times they worked together fondly, famously saying, 'Grace was a good man' (Aiken and Hopper cited in Isaacson 2014, 93).

In keeping with Aitken's characterisation, the fact Hopper won 'Man of the Year' in 1969 in the inaugural Data Processing and Management Associations prize might seem incomprehensible to us today. However, it highlights how masculinity functions within the field of computing, arguably both then and now. The small number of women who

succeeded were often figures, like Hopper, who took on masculine behavioural characteristics to survive. This is a well-documented phenomenon across all areas of professional employment but is particularly prevalent in the computer technology industry. As Wajcman argues, women take on conventional masculine traits because ‘women's presence in the world of men is conditional on them being willing to modify their behaviour to become more like men or to be perceived as more male than men’ (1998, 7–8). Although embracing stereotypical male characteristics may have been possible for some, it is a price many were either unwilling or unable to pay. For those of colour or queer, fitting in with the culture of engineering was much harder than for white middle-class women, such as Hopper, who could succeed.

Today, a few successful women in the history of computing might seem to disrupt the idea of masculine dominance in the field, but on closer inspection, their visibility can have the opposite effect. Computer scientist Ursula Martin has noted that by over-emphasising the work of specific female heroines of the industry and raising their contributions up to unattainable heights, we risk seeing the task of recognising the work and importance of women scientists as having been concluded. Martin’s research questions many claims surrounding the nineteenth-century mathematician Ada Lovelace. Lovelace’s work with Charles Babbage on the proto-computer the Analytical Engine has made her an emblem for women in science, and the patron saint of female programmers with celebrations such as Ada Lovelace Day held annually in her honour. In her co-written biography of Lovelace however, Martin has argued that descriptions of Lovelace have shifted dramatically from problematic disregard to awkward exaggeration (2019). Until relatively recently Lovelace’s mathematical work was thought to be quite poor and she was often cast as a hysterical socialite. Whereas today argues Martin, her actions are overly embellished, leaning towards hyperbole. Amongst other things that might prove difficult to verify, it has been claimed that without Lovelace the CD would not have been invented (Isaacson 2014, 33). Martin suggests that these overinflated assertions and celebration of individual achievements could be nearly as damaging as the earlier contempt with which Lovelace and other women in the industry were held. In a talk at Edinburgh University on Ada Lovelace Day in 2019, Martin showed several instances where photographs of women working in the field of computer science on the University’s website were anonymous, uncredited, or misattributed. She has found similar examples on the computer science section of virtually every institutional website she has spoken at when promoting her book. Over-emphasis on a few celebrity heroines, she argues, can lead to a disregard for the many. Building certain individuals up too much establishes a belief that a gender rebalance in the sector has been accomplished, and the sexism within the industry has been quashed.

The current popularity of Lovelace, and by extension Hopper, is implicated in this argument. Their existence seems to demonstrate that women could do the work of male mathematicians all along. Battling against the injustices of their time, these individuals are used to prove that women can reach the top levels of their professions. But these stories can obfuscate deeper cultural and societal dynamics. As computer historian Mar Hicks has argued, echoing Martin's sentiments:

> The few women who managed to break this mold … fill an important space in the cultural imaginary as heroes and role models. Yet, they also paradoxically contribute to the problem: by positioning exceptions to the rule as the way women succeed in computing, heroine narratives that focus on singular white women reproduce the problem of normalizing masculine stereotypes, male dominance, and existing patterns of privilege along lines of race and class (2017a).

To follow this argument, placing 'missing' women back into the history of technology without interrogating the societal and cultural factors that produced their exclusion is of limited value. Such an approach fails to recognise how existing structures of discrimination recur with the invention of new technologies. Focusing on individual female exceptionalism is a technique feminist theorists Charlotte Bunch and Mary Hunt pithily describe as the 'add women and stir' method of feminist history (Bunch 1987, 140). As we have already seen, women were far from a minority in the field of computing on the basis of their sex. At certain points, the number of women employed in the US and UK computer industries, particularly at its lowest grades, was often equal to, if not more than, the total men in the field (Abbate 2012, 41). The crucial distinction is that feminine stereotypes derived from domestic labour were applied to these new technologies, and were used to subordinate those women. Ironically, our contemporary celebration of female icons might risk having a similar effect. This calls for alternative narratives to be constructed, that can speak to the experiences of the majority of those who lacked the fortune of either Lovelace or Hopper.

A feature, not a bug

Figure 15 Anne Davis' Retirement Party, 1965.

How might the experiences of an anonymous majority be made intelligible, and through what means might we visually figure them? A photograph taken in 1965 (Figure 15) shows one such woman, named Anne Davis. A trained computer operator, she stands covered in punch tape and is pictured attending her retirement party at the age of twenty-one. Parties such as this were not uncommon in computing: a practice that not only promoted workplace heteronormativity but also kept the female workforce young and disposable. In a scenario like this, women were asked to 'retire' when they married and step down from these positions, as demonstrated in the well-documented Civil Service-wide policy known as the 'marriage bar' (Hicks 2017b, 45). The reasons women were encouraged to leave the workforce were based on gendered assumptions, as Hicks notes, 'defined by heterosexuality

…[making] work outside the home secondary to the dictates of marriage, procreation, and family' (2017b, 5). The cultural belief that women would rather be wives and mothers than have a career of their own, demonstrates how deeply cis the experience of female computer specialists was assumed to be. Hicks states: 'heteronormativity, as much as sexism, shaped their lives and work' (Hicks 2017b, 235). To summarise, domestic metaphors were used to tempt women into the field, when necessary, but equally domestic duties were used to dismiss skilled women when the industry desired.

The consequences of such practices to reduce the number of women in the computer industry would prove far-reaching and often detrimental. In *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing* (2017) Hicks has argued that the structural sexism performed by companies had a detrimental impact on the technologies they produced. Britain had been a leading force in technological development in the 1960s, but this edge, the so-called 'white heat of technology,' had all but disappeared a few years later. Hicks argues that the women who had made these technological developments possible were 'discarded.' When companies realised the importance of programming, they did not keep their experienced, mainly female employees. Instead, they appointed inexperienced men to these roles. In their research, Hicks found numerous examples where women would train their own managers or replacements, before losing their jobs or becoming subordinate to the person they had just inducted.

Focusing on the few, rather than the many, stops us from seeing the wider gender politics at play. This is a theme that can be taken up in the latter half of the twentieth century by looking at women who, unlike Hopper, took an explicitly feminist position on the subject of employment in the field of computing. Take, for example, the British software engineer Stephanie Shirley. Shirley was employed by ICL (International Computers Limited) and wanted to return to work part-time allowing her to look after her children. ICL were unable to accommodate her, and nor was she able to find other employment options. Consequently, she started Freelance Programmer Ltd in 1962 as its only employee. She quickly realised there were many women in her position, an expert technical workforce leaving the IT sector to marry or have children. In the early 1960s, she developed a 'panel' of employees, all women and all working from home. By the middle of the decade, she had 65 such employees, and 750 by 1984. Economic success was not the primary goal of the company. Instead, Shirley wanted to help women to continue their careers while they worked as carers. She encouraged part-time contracts and working from home. This practice is demonstrated in one photograph from 1966 (Figure 16), where programmer Anne Moffatt works on coding at her kitchen table while looking after her toddler. 'It was a crusade —

somebody called it a crusade, and that's about right…' Shirley said of her business, 'it became much more focused on women — opportunities for women to go on working in a professional level — and that was more important than the technology, more important than the money side' (cited in Abbate 2012, 129).

Figure 16 Ann Moffatt with her toddler. Moffatt is working on the Concorde computer code at home when employed by Freelance Programmer Ltd., 1966.

By encouraging working from home and providing part-time employment, the company not only supported mothers, but also queer and trans computer specialists who often faced discrimination in more conventional work environments (Hicks 2017b, 5). By choosing to employ a dispersed and part-time workforce, Shirley had to adopt a creative approach to her management style, at the same time as overcoming the sexism she and her employees faced. She concealed the way the business worked from prospective clients and concealed her identity by signing her name as 'Steve' on company letters. But despite these impediments, Shirley built a company of great power and influence based around highly skilled, yet disregarded women. Known as Freelance International (FI) from 1971, she was awarded major contracts, including the programme for Concorde's black box recorder. By

the mid-1990s, the company's annual turnover was over 450 million pounds. Shirley would be awarded a damehood in 2000.

One could tell Shirley's story in two very different ways. As an individual who saw something that others did not. As someone who built a company worth millions, overcame sexual discrimination and adversity, all the while influencing and innovating in the field. Alternatively, one could see her as an example of one of the many women who worked in a burgeoning industry and were rejected by it. In the former narrative, she becomes a heroine. In the latter, she becomes evidence of systemic sexism and proof of the myth of meritocracy in post-war computing. By examining how the oppression of the many might interact with the celebrated achievements of the few, this same story becomes compelling evidence of the gender discrimination that blankets that entire industry.

As has been outlined in relation to a wide range of examples here, legal means — ranging from contractual arrangements to changing job descriptions — were used to characterise female employees as something to be removed from the sterility of the technological environment male technologists were creating. Here, the reproductive capacity of those women interfered with the clean operations of corporations who relied on their labour, and treated them as replaceable components. On rare occasions, individuals, such as Shirley, saw opportunities for changing those institutional systems on a fundamental level, in effect feminising them. More often than not, however, women who excelled in this environment, such as Hopper, and to a certain extent 'Steve' Shirley, had to perform as if they were men, their status in turn coming to eclipse the stories of numerous others who worked in anonymity.

It is around such a question of performative roles that women's real position in the field of computing must be assessed. Faced with the challenges of speaking to a vast body of experience around which an insufficient amount of testimony exists, other strategies must be developed. The evolving metaphors traced above provide one such approach, as they afford a method through which the structural role played by anonymous female labour can be better apprehended. The metaphor of the 'bug in the machine' is a device that provides several ways to interpret these evolving labour conditions, and to reassess how we celebrate female achievements.

On one hand, a male interpretation of nature, in this instance the biological nature of womanhood, appears antithetical to the operational rationality of the technological apparatus women were employed to maintain. In such a scenario they constitute an infestation to be

managed. By comparison, in feminist accounts of singular figures who challenged these systems, we might envisage protagonists such as Lovelace, Hopper or Shirley as obstacles to the functioning of gendered hierarchy: creatures capable of momentarily bringing the machine to a standstill.

These are both interpretations that tally closely with our collective understanding of sabotage, symbolising as it does an impediment to operational stability and outrage on behalf of those dispossessed by technological forces. But, this is not the only way that the phrase can be approached. Another interpretation might contrastingly position the coordinated efforts of this female labour as swarm-like in its anonymised intelligence. Regarded in this way, such labour was in fact crucial to the computer industry's operational stability, an industrious core upon which the efforts of isolated geniuses rely. In this respect, it is ironic that by excluding women, and regarding them as a structural flaw to be excised from the system, the computer industry has at times effectively sabotaged itself, as would occur in the UK in the 1970s.

As Hicks has argued, women were no longer seen as a good fit for computer work which was, by the 1970s, recognised as important, professional and highly skilled, a role only culturally appropriate for men. This shift not only discarded years of real-world experience that female computer specialists held but set a pattern of gender discrimination that would continue uninterrupted to the accusations of racial and gendered inequality occurring in Silicon Valley in recent years. Recalling the narratives of the many women who were cast aside by the industry allows us to see these biased employment systems for what they were. Or, as Hicks put it simply when speaking of the history of computing, 'sexism is a feature, not a bug' (2021, 135).

microchips

Figure 17 *Hothouse* (installation view), 2019, Hospitalfield.

Staged in the pastoral setting of a former stately home in Hospitalfield, Arbroath, which now serves as the location for an artist's residency programme, event and exhibition space, *Hothouse* replicates the appearance of outhouses common in the grounds of grand houses of this period. The project consists of three large cuboid structures covered in digitally printed fabric, each containing a sculptural installation. This exterior fabric is covered in white lines that crisscross across a blue background, echoing the forms of circuit diagrams on microchips (Figure 17). These drawings were produced with Adobe Illustrator, using imagery of circuit diagrams and their transparencies as a template from which a pattern could be drawn. They were printed on a synthetic mesh material that is commonly used to shroud scaffolding towers, using a direct UV process designed to apply digital imagery to large-scale objects.

My rationale for using the microchip motif within this project was to reflect on the relationship between electronic circuitry and biological systems. The impetus for this was research carried out into the historical connection between cybernetics and ecology, and their joint influence on the history of computer design and the corporate ideology of contemporary

digital culture. ‘Microchip’ is a general term for any semiconductor component, the pieces of silicon on which electronic or integrated circuits (IC) are printed. They lie at the heart of computation and data storage and consequently have become one of the most omnipresent objects in the world. The enlargement of a circuitry pattern serves in part as a way of making these pervasive, ubiquitous, and minute objects physically imposing, foregrounding the role they play in our lives. Another factor that informed the design of these structures was research into the role of female labour, often in a non-Western context, has played in the manufacture of ICs. In focusing on the circuit as an object, this articulates, albeit abstractly, the degree to which we take for granted this labour.

Figure 18 Frank Lloyd Wright, *Design 105*, 1956.

Cara McCarty, curator of *Information Art: Diagramming Microchips* (1993) suggests that 'when we let our imaginations roam, the grid patterns of these [circuit] diagrams resemble the warp and weft structure of woven textiles,' or even the 'aerial views of cities, agricultural fields, paintings, calendars' (6) The open nature of its geometric imagery has led to parallels being made between microchip circuitry and textiles. Printed circuit boards became commonplace in consumer electronics during the 1950s and 1960s, and at the same time, many printed textiles appeared with the same stylised linearity (Figure 18).

The processes underpinning circuit production also present crucial technical parallels between digital and print culture. As art historian Jennifer Roberts' recent research has definitively shown, the relationship between print and the microchip is a symbiotic one. Each printed circuit board is, as the name suggests *printed*. Yet historically, the printed element of microelectronics has been overlooked. It almost goes unspoken that the ground-breaking technology that revolutionised electronics in the twentieth century utilised processes and techniques that had long been utilised by artists, illustrators and craftspeople (2023). As circuit designs have grown more sophisticated, the direct connections have become much less obvious. Two elements that these fields share are transfer processes that rely on either a water resist or chemical etching, and the use of transparent plastic materials as vehicles for that transfer. Another important aspect linking historic circuit design to printmaking is the degree of skilled manual labour it requires. Before the photo-mechanical age of circuitry production, early examples could not employ automated modes of production and required highly time-consuming and optically strenuous processes. Many of these techniques remain in use in print studios today, a link that I sought to highlight in both *Hothouse* and several other artworks through the use of print methods and microchip imagery. For instance, an integrated circuit relies on multiple strata drawn out in masks with corresponding diodes and transistors (Figure 19). The different layers of masks must be lined up precisely; the accuracy of the layering determines to the functionality of the final microchip. In its earliest days, a circuit could be designed and drawn up by one or two engineers equipped with a slide rule or calculator. Of this time, developers recount that:

> Schematic and layout for the first ten years of Intel [from 1968 to 1978] was done by hand. Engineers would produce draft schematics that a schematic designer would transfer onto D-sized vellum sheets. These would be hand-checked and signed off by the engineer (2001 as cited in Stine 2019, 774).

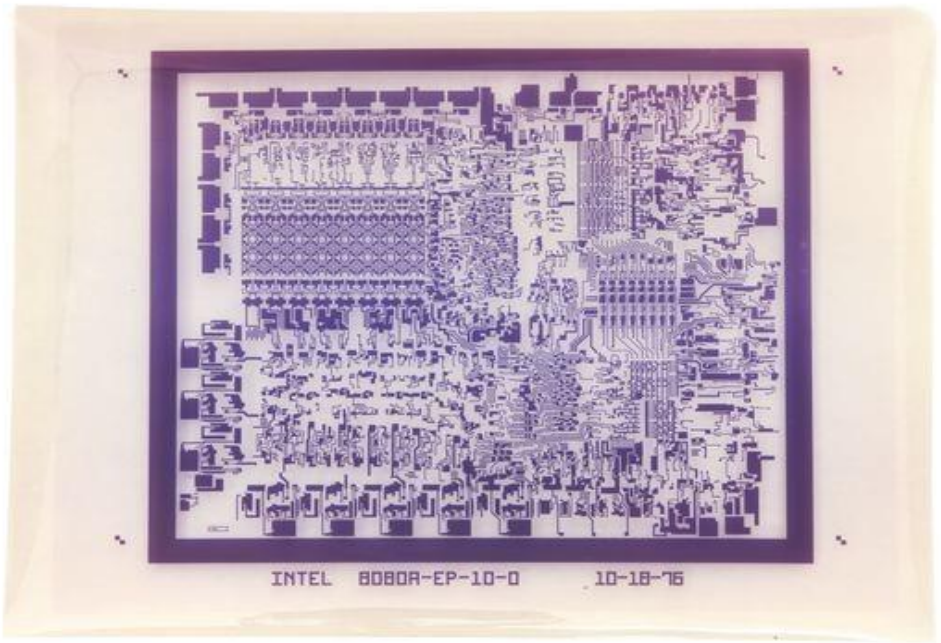

Figure 19 Intel 8080A microprocessor mask design transparency overlay, 1976.

Figure 20 Operators hand-cut IC designs onto Rubylith film, which was then optically reduced to create a photographic mask, ca 1970.

While today this process is digitally automated, these past designs were transformed into masks by hand, using a technique akin to cutting stencils. Documentation of the procedure depicts two women bent over a table, scalpels in hand, undertaking this task for one of Intel's circuits (Figure 20). Until the 1970s, these masks were cut from a red cellophane-like substance known by the trademark Rubylith. These masks were then photographed, minimised and re-photographed numerous times, to reduce these designs to the scale necessary for their application in circuit board manufacture. When photographed and scaled-down, the Rubylith masks were also multiplied to create a single mask, which was then used to produce hundreds or thousands of ICs at a time.

Significant to this project is the way in which circuit diagrams were applied to conductive metal sheets using similar kinds of synthetic film. Photoetching as a printmaking technique relies on this same innovation, a factor that led to its use in *My Monster*, a piece that reproduces an archival image of computer scientist Grace Hopper (Figure 9). Printed from a digital file onto a transparent film, this image was transferred to a copper plate covered with photo-emulsion by exposing it to light. The plate was then submerged in acid, with exposed elements of it etching the image into the plate, making a tooth capable of retaining printing ink. This is analogous to the way in which conductive channels are marked between connecting points on a printed circuit board.

Microchips and circuitry more generally are employed as metaphors in cyberfeminist practices, coming to symbolise the embeddedness of gendered assumptions in the very fabric of technology. Cyberfeminist collectives Old Boys' Network and VNS Matrix use the metaphor of the circuit to represent the interconnectedness of systems of oppression, suggesting that just as a circuit transmits electrical signals throughout a device, cultural norms and values are transmitted throughout society. The use of such metaphors is also tied to the idea of rewriting or hacking technology to serve feminist ends, reprogramming the "circuitry" of societal tech to be more inclusive, just as one might reprogram a microchip (Ackers et al, 1997; Barratt et al, 1991).

This metaphor of the circuit was based on the plight of women working in electronics manufacture; the chip factories themselves. Donna Haraway's influential concept of the 'women in the integrated circuit,' the original subtitle for 'A Cyborg Manifesto,' was taken directly from sociologist Rachael Grossman's harrowing report of a chip manufacture plant in Malaysia of the same name (1979), which will be detailed in the following chapter. Haraway used the image to 'name the situation of women in the world so intimately restructured through social relations of science and technology' (Haraway [1984] 2019, 25). Seeing both

the continued oppression and radical potential available for women within the integrated circuit she writes, ‘the nimble fingers of ‘Oriental’ women, the old fascination of little Anglo-Saxon Victorian girls with doll’s houses, women’s enforced attention to the small take on quite new dimensions in this world’ ([1984] 2019, 14). This emancipatory potential and space for reimagining emboldened later cyberfeminists to think through and reframe societal constructions.

Extending the microchip metaphor Haraway suggests that ‘writing is pre-eminently the technology of cyborgs, etched surfaces of the late twentieth century’ ([1984] 2019, 57). Yet the printed materiality of microchips is missing from the artistic and textual output of cyberfeminist and later technofeminist practices. Consequently, it was crucial to my project to emphasise and extend these metaphorical links. In *Hothouse*, the blue and white circuit board imagery used is digitally rendered on a knitted mesh used for industrial scaffolding, mixing the range of associations from the cyberfeminist legacy whilst extending the metaphor to emphasise the connection to print.

Just as this research unpicks the disputed origins of terms like computer bug and sabotage, the joint use of processes in circuit manufacture and printmaking reveals points of slippage that merit further scrutiny. What any enquiry into the subject exposes is how distinct technical processes are treated as interchangeable by electronics engineering, to support its cultural identity in a fast-moving and innovative field. A tendency to ignore the specifics of these material processes in favour of appearing cutting-edge is underscored by those who have worked in the IC industry itself. Jay W. Lathrop was a physicist who worked on several techniques that would influence the development of the integrated circuit. One major breakthrough he made was the introduction of a photoresist process to transfer the intricate circuit board designs onto the surface of the silicon chips. As Lathrop and his colleague recalled of the name:

> We coined the term photolithographic to describe our technique. The operation actually involved etching, not lithography. However, “photolithography” sounded “higher tech” to use than “photoetching.” This was the first published use of photolithography to describe semiconductor device patterning, and this misnomer has been used ever since (2013, 52).

Indeed, the term photolithography continues to be applied incorrectly throughout the entire computer industry, being given alternate names including ‘UV lithography’ and ‘optical lithography’. Lithography is a resist process that commonly relies on the insolubility of oil and water to control the transfer of information, as opposed to a chemical erosion of a substrate.

Interestingly, the more accurate term *photo* is frequently removed in favour of more technical sounding prefixes, while the inaccurate suffix ‘lithography’ remains. Following on from Lathrop’s remarks, these later approaches to naming can similarly be considered as celebrating a veneer of technocratic advancement over materially grounded accuracy.

Beyond connections presented between the histories of computing and printmaking, another key reason the motif of circuitry was employed in *Hothouse* was to speak to ecology, a discourse that only gains its contemporary dimensions following the introduction of cybernetic theories derived from the mathematical roots of computing. These mesh and scaffolding enclosures were paired with facsimiles of mushrooms as a way of articulating a connection between our conceptions of organic and inorganic systems. Circuitry, which maps the complex inter-relation of multiple elements, can be regarded as sharing much in common with the concept of an ecosystem: schematised visions of the natural world in which the change of any element exerts a cause and effect. Furthermore, fungi have become particularly associated with digital structures. Mycelium — the root-like system of fungus from which mushrooms grow — has been proven to be a communication structure for plant life; a network that has been colloquially described as the ‘Wood Wide Web’ (Macfarlane 2016). In this context, mushrooms can be seen as a fitting motif for the entanglement of ecology, digital technology and labour networks.

The theorisation of nature as a vast communications network was suggested by the outdoor placement of this exhibition, presenting these architectural structures as if they were connected underneath the earth. *Hothouse* serves as a point where the shared material histories of printmaking and circuitry converge. As a whole, the exhibition stands as a metaphorical ecosystem, highlighting the intricate connections between technological, craft-based and environmental narratives (see ‘Green Thumbs II’).

Nimble Fingers II: Weaving the Integrated Circuit

Indigenous circuits

Figure 21 Marilou Schultz, *Replica of a Chip*. 1994.

In 1994 the Intel Corporation commissioned Navajo weaver Marilou Schultz to produce a textile copy of one of their printed circuit boards. The resulting work was titled *Replica of a Chip* (Figure 21). The project was an acknowledgement by the company of the visual similarities between circuit board design and traditional Navajo weaving patterns. Taking Intel's own technology as her starting point, Schultz broke away from the symmetrical motifs common in her usual designs to embrace the irregularity of the circuit's operational linear structure. Fourteen years later, in 2008, the Nerman Museum of Contemporary Art would commission Schultz to produce a second woven chip (Figure 22).

Figure 22 Marilou Schultz, *Untitled*. 2008.

No one involved in either of Shultz's commissions referred to the surprisingly entangled history of Indigenous craft and integrated circuit manufacture that her works portrayed. This connection would only be brought to light by media historian Lisa Nakamura in her essay 'Indigenous Circuits: Navajo Women and the Racialization of Early Electronic Manufacture' (2014). Here, Nakamura describes how global technology company Fairchild Camera and Instrument Corporation, later Fairchild Semiconductor, instrumentalised weaving to create an argument for the employment of Navajo women for integrated circuit manufacture. Furthermore, facets of the argument Fairchild made for doing so would go on to influence a larger trend in electronics manufacturing across the world. In the 1970s and 80s women, often from Southeast Asia, were assumed to be 'naturally' suited to the industry. This assumption was dubbed by sociologists as the 'nimble-fingered thesis' (Elson and Pearson 1981, 93). As a succession of scholars have demonstrated, this thesis was not just applied to Asian women, but to women of colour more generally (Cowie, 1999; Hossfeld 2001). While 'Nimble Fingers I' explored the use of handicraft and domestic metaphors to frame computer work as suitable for women in Western offices, this chapter extends that analysis to factory settings, both in the U.S. on Navajo soil and in Southeast Asia. This analysis uncovers how the computer industry perpetuated gendered and racialised stereotypes, drawn from craft production, in the new field of circuit manufacture. By doing so the low

value labour status of women of colour was sustained. Furthermore, this chapter will trace the origins of the 'nimble-fingered' thesis to show how, with its conflicting dualistic mechanism of expression and exploitation, it contains the seeds of the contemporary creative economy.

Shiprock

Fairchild Semiconductor was a division of Fairchild Camera and Instrument, formed in San Jose, California in 1957, known today as Silicon Valley. In its early years, the company mainly supplied microchips to the US Military. Their chips controlled the Minuteman Missile, as well as the guidance system for the Apollo Missions (Nakamura 2014, 939). But company executives quickly realised that to become profitable they needed to expand their customer base to include the domestic market and dramatically reduce the cost of integrated circuit (IC) production. As a means of achieving that goal, they were one of the first US electronics companies to move their production facilities abroad. They took advantage of the cheap, flexible labour and lower overheads that other countries offered. Seen as a seismic event in computer history, other companies quickly followed suit, allowing ICs to become cheap and prevalent enough to play their part in the electronics revolution of the 1970s.

Less known is the fact that as Fairchild relocated much of their manufacturing to Asia, they also explored more economic means of production within the Americas. In addition to opening plants in Singapore and Hong Kong, Fairchild also launched facilities in Mexico, and on Native American land in the US. Akin to the deregulated legal frameworks offered by foreign countries, Native American Reservations were exempt from US Laws on minimum wages and, consequently, inexpensive domestic workers could rival the price and flexibility of offshore manufacture. Fairchild opened the Shiprock Semiconductor Plant in 1965 on the Shiprock Navajo reserve in New Mexico. Originally viewed as a pilot scheme, the plant began by tentatively employing 55 women from the local tribe. It then expanded quickly, employing hundreds of Navajo women and some men. At its peak Fairchild employed over 1000 Navajo tribespeople, making them the largest non-governmental employer of Native Americans in the USA (Nakamura 2014, 923).

Although it closed due to a hostile takeover by the American Indian Movement as part of a worker’s rights dispute in 1975, the plant was originally regarded positively by the Navajo people and the Fairchild Cooperation alike. To those running the plant, the Navajo people were model employees. As manager of the General Dynamics department at Shiprock C.J.

Jameson put it, '[Navajos] don't have the bad habits people have in more industrial areas' (as cited in Nakamura 2014 933.) This characterisation, Nakamura argues, is:

> An eloquent illustration of how racialization works; prior beliefs about Indians as unreliable workers unsuited for modern form of labor are transformed into assertions of the positive value of 'primitive' habits… Indians were described as careful, docile, and hardworking when it helped their managers to understand and explain productivity through an ethnic lens. (Nakamura 2014, 933)

But breaking the prevailing stereotype of Native Americans as technologically 'primitive' and incompetent was crucial to the chair of the Navajo council Raymond Nakai. These commonly held perceptions hampered their chances of employment, or what historian Philip Deloria argues was a 'racialized inability to advance' (2004, 145). In joining forces with Fairchild, Nakai thought the Navajo had established a 'partnership in progress,' which could shift the non-Indian perception of Native Americans as a primitive people culturally and spiritually tied to the past, and either uninterested or unable to use or comprehend technology ('Shiprock' 1969). As symbols of a futuristic modernity, integrated circuits seemed one of the best ways to break with these negative characterisations. Once employed in the electronics industry, their paradoxical position as producers of the most advanced technologies in the world, while simultaneously being perceived as hopelessly primitive was not lost on the workforce (Nakamura 2014, 924).

There is a long history of such situations in Native American history, where craft was used to unite contradictory positions of advancement and regression. During the nineteenth century, the range of commentators' opinions towards Native Americans was far from a simple binary of advocacy or malice. Adamson argues that 'in the politics of Indian reform, these malevolent strands intertwined with more charitable impulses, to the extent that it is impossible to pull them apart. And as the century progressed, craft increasingly acted as a binding agent between the two positions' (2013, 96). At this time there were many countervailing beliefs. Some held that Native Americans were incompetent, unable to free themselves from poverty through industry, or not to be trusted with new technologies (Adamson 2013, 93–8). Many desired to preserve Indigenous peoples in a kind of Arcadian paradise, where they were protected from the ills of the modern world. Others wanted to 'improve' the lives of Native Americans by education, teaching them new techniques and skills, or providing access to modern machinery. Although certain attitudes had changed, the dominant narrative remained the same well into the twentieth century. As Deloria suggests, even in the 1960s there was an underlying cultural view that 'primitive Native people had to

work their way, stage by stage by painful stage, through the developmental hierarchy of social evolution before they were allowed to enter modernity. At the same time, assimilationists insisted that any signifier of modernity was necessarily a sign of progress' (2004, 13).

A commemorative brochure

Fairchild similarly romanticised Native American culture by positioning Navajo women as innately suited to work on the semiconductor assembly line. Through their press and marketing materials, the corporation continually drew attention to the cultural heritage of Navajo craftmanship, admiring their 'natural' traits of patience and meticulous nature, as well as their 'innate' eye for detail. Furthermore, Fairchild attributed the Shiprock Plant's low chip failure rate to inherent Navajo skill. In 1970, an article in *Businessweek* praised plant manager Paul Driscoll for utilising the 'untapped wealth of natural characteristics of the Navajo… the inherent flexibility and dexterity of the Indians'(as cited in Nakamura 2014, 926). Fairchild perceived the weavers' design method as an innate ability rather than a learned skill.

In these marketing materials, jewellery and silver smithery are mentioned, but weaving, a technique closely associated with Indigenous female labour, was dwelt upon in much more detail. For example, in 1970, an article in *Businessweek* suggested that 'after years of rug weaving, Indians were able to visualize complicated patterns and could, therefore, memorize complex integrated circuit designs and make subjective decisions in sorting and quality control' (as cited in Nakamura 2014, 926).

Figure 23 Front cover showing Navajo Weaving, *Shiprock Dedication Commemorative Brochure*, 6 September 1969,

Figure 24 Navajo woman at a loom, *Shiprock Dedication Commemorative Brochure*, 6 September 1969.

The brochure commemorating the Shiprock plant in 1969 explicitly connects woven products with circuit design. Alongside products created in the plant, the brochure contains multiple images of Navajo weaving. The cover prominently features a woven Native American rug in brown, black and white (Figure 23). Elsewhere, there is a photograph of a woman at her loom (Figure 24) visible through the threads of the warp with accompanying text:

> The talents of the Navajo people extend beyond imagination. A Navajo woman weaves a perfectly patterned rug without ever seeing the whole design until the rug is completed. Weaving, like all Navajo arts, is done with unique imagination and craftsmanship, and it has been done that way for centuries (1969, n.p.).

Here, rather than displaying their own products, Fairchild relies on the visual similitude between the geometric Navajo design and the nodal lines of circuit board design. On another page another Navajo woman sits at a microscope, smiling and looking directly at the camera (Figure 25). The associated text doubles down on the implied connections between the craftmanship required for weaving and semiconductor production. 'Building electronic devices, transistors and integrated circuits, also requires this same *personal commitment to perfection*' and 'it was very natural for Fairchild… [to look] at an area of *highly skilled* people living in and around Shiprock...'

Throughout this brochure, Fairchild creates an ideological argument for the employment of Navajo women in their factory. The corporation continually praises the timelessness of Indigenous handcraft, which they see not as a learnt or taught method, but as an innate, natural condition. This serves to link Navajo women's craftsmanship with semiconductor production. Even when they do describe their own projects, a colour diagram of the 9040 integrated circuit, used in satellite communication, for example (Figure 26), quality and precision are dwelt upon, characteristics that are elsewhere in the brochure used to describe Indigenous craftsmanship. The accompanying caption reads, 'quality becomes a necessity in the semiconductor business…' and the 'transistors and integrated circuits, some of which before packing are no larger than the head of a pin, must perform to perfection in complex computers…'

Figure 25 Navajo Woman at a Microscope, *Shiprock Dedication Commemorative Brochure*, 6 September 1969.

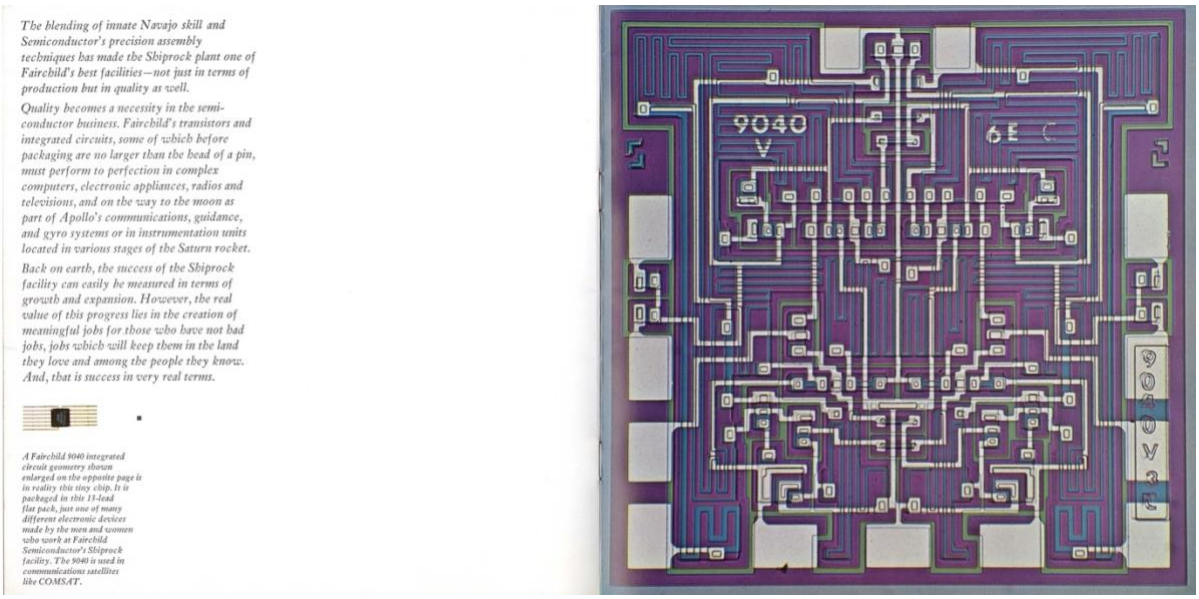

Figure 26 Diagram of the 9040 Integrated Circuit, *Shiprock Dedication Commemorative Brochure*, 6 September 1969.

One of the central tenets of Fairchild's argument is that the Navajo weavers are valid electronics workers because they are genuine craftspeople. The authenticity concept is complicated by Navajo weaving's origins in Pueblo cultural traditions, bestowing upon it what Navajo historian Jennifer Nez Denetdale has called a 'double status' (2007, 241). This not only points to the problematic concepts of authenticity employed by Fairchild but also highlights that cultural traditions are themselves continually changing and subject to movement between various communities.

Another factor Fairchild's highlighting of female employees neglected to acknowledge, just as in the history of European textiles, is that Navajo weaving has never been split directly, nor unchangingly, along gender lines. Despite being widely practised by women, some weavers are male. This somewhat discredits the assumptions that Fairchild made about the gender of their workers. Navajo communities have a more flexible relationship to gender roles across childcare, education and socialising than in Western cultures (Parezo 1982, 120). Although there are examples of gendering in Navajo textile mythology (the myth of Upward Reaching Way for example, in which the Spider Man taught men to construct looms and to spin thread while the Spider Woman taught the women to weave) in general gender has never been a main feature of craft production in Indigenous North American culture. As anthropologist Nancy J. Parezo stresses in her compelling description of Navajo sand paintings, 'economic necessity will continue to remain the predominant response for both sexes unless something dramatic happens to change the economic situation on the Navajo reservation; poverty does not recognize sexual differences' (1982,128–9).

Eyeballing

As Fairchild employed Navajo women at Shiprock, it and other electronics manufacturers opened semiconductor plants in the global South. Like Shiprock, handicraft was a fundamental component of these companies' rationale for employing a predominantly female workforce. As one source describes:

> The manual dexterity of the oriental female is famous the world over. Her hands are small and she works fast with extreme care. Who, therefore, could be better qualified by nature and inheritance to contribute to the efficiency of a bench-assembly production line than the oriental girl (as cited in Grossman 1980, 50–1).

This passage is an example of what would become known as the 'nimble-fingers thesis'. In the 1970s and 80s sociologists argued the thesis defined the problematic yet widespread

belief held by electronics companies and their managerial staff that their female employees had specific traits making them better suited to the work in their factories (Elson and Pearson 1981; Lim 1978). As the text above and the brochure at Shiprock reveal, women of colour were presumed to be particularly dextrous, patient, and meticulous, and thus able to deal with the precise and complicated work of computer chip manufacture.

Technology companies were able to make the connection between nimble fingers and electronics manufacture by noting the high number of women already employed by mass-manufacturing concerns to sew toys and clothes for a global market. The perception that these skills were transferable from domestic sewing projects to industrial sewing, and then in turn to electronics manufacture, was widespread, as this section from a 1976 Malaysian investment brochure demonstrates:

> …in Morocco, in six weeks, girls (who may not be literate) are taught the assembly under magnification of memory planes for computers — this is virtually darning with copper wires, and sewing is a traditional Moroccan skill. In the electrical field the equivalent of sewing is putting together wire harnesses; and in metal-working, one finds parallels in some forms of soldering and welding (Sharpston as cited in Elson and Pearson 1981, 93).

By assuming sewing skills were natural, as opposed to learnt traits, women were perceived as being ‘factory ready.’ This directly connected meticulous tasks required by factory labour to those required in domestic craft, while at the same time framing the work as ‘semi-skilled’ or ‘unskilled’ activity.

Yet this perceived skill had its limits. Studies from the 1970s onwards would reveal that when women are employed to do the same work as men, using similar skillsets or doing similar tasks, they are paid significantly less, even within the same industries (Phillips and Taylor 1980, 79–88). As Wajcman has described, ‘the classification of women’s jobs as unskilled and men’s jobs as skilled frequently bears little relation to the actual amount of training or ability required for them. Skill definitions are saturated with gender bias’ (1991b, 37–8).

From Shiprock to the globally popularised ‘nimble-fingered thesis,’ women were perceived as ideally suited to electronics manufacture through racialised and feminised characteristics such as dexterity and patience. But what did the women in these factories actually do, and is there, in fact, a way in which this labour pertained as much to the opticality of print culture as

it did to craft traditions? These are themes that become evident when examining in more detail the tasks that were involved in semiconductor manufacture.

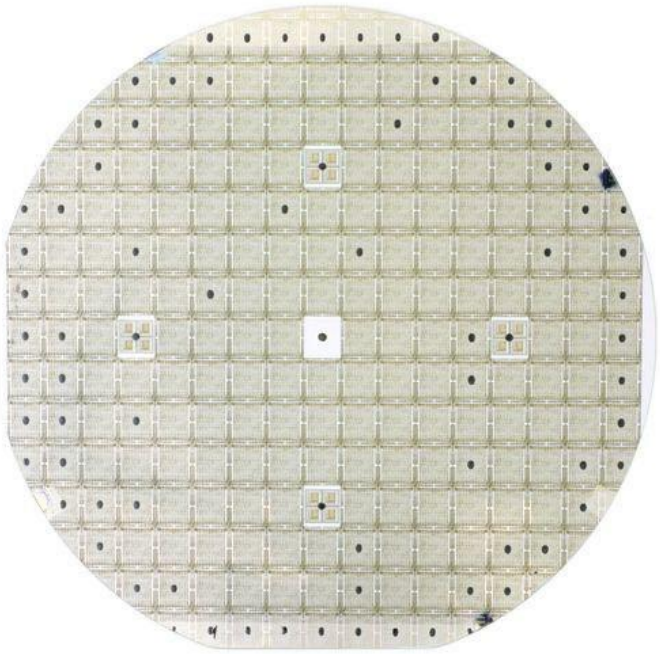

Figure 27 Tested Silicon Wafer, showing black dots on faulty die, n.d.

One of the main tasks Navajo women carried out at Shiprock was known as ‘eyeballing,’ a job that ascertained whether ICs produced in the plant were fit for market. Eyeballing was a difficult form of manual checking that was performed under a microscope. In this process, an entire silicon wafer, which contained hundreds of copies of the same integrated circuit or ‘die,’ was examined. A product engineer who worked at the plant described it as ‘tedious’ microscope work, adding ‘[the workers] couldn’t handle it, some of them, [because they had to spend] so many hours a day looking at it’ (Tutt, 2011 as cited in Nakamura, 925). Any errors in the ICs were marked with a dot (as demonstrated in Figure 27). Once the wafer was cut into individual die the faulty ones were discarded. Those in working order were packaged and joined together manually using tiny pins, a process again taking place under a microscope (Figure 28) (Stine 2019, 774). Although this process of joining IC to pins required manual dexterity, as is made clear in the documentation of semiconductor manufacture processes from the 1960s relatively few examples of skills akin to weaving were used (Fairchild Briefing 1967). Instead, what occupied most of the time of Indigenous women employed at Shiprock was intensive, sight-based activity, that could have a detrimental impact on their health.

Figure 28 Women working at a Fairchild Plant, 1963, in the packaging stage of die assembly connecting contact pads to fine gold wires.

Similarly, in factories being established in Malaysia the health issues experienced by workers predominately related to their eyes, rather than their hands. In her 1979 study of Southeast Asian electronics factories 'Women's Place in the Integrated Circuit,' Grossman reported that in just three years after the opening of an Intel plant in Penang, half the workers, 90% of whom were women, complained of frequent headaches and deteriorating eyesight. Meanwhile, eye infections such as conjunctivitis were rife and spread through the use of shared microscopes. Grossman points out the disparity between these real conditions and those that are depicted in company publications:

> A photograph of the interior of an electronics plant is striking for its sense of immaculate order: a spacious, well-lighted room in which rows of women dressed in white bend over gleaming microscopes. On an actual walk through a plant, however, the visitor often gags on the strong smell of chemicals and a trial look through a microscope quickly produces dizziness

> or a headache. Toxic fumes and eye ailments are the twin enemies of electronics workers. Yet the companies do not inform them of the health hazards their jobs entail (1980, 52–3).

20/20 vision was a prerequisite for being hired to carry out such a job. However, within a few years, the women who stay in the workforce show a dramatic deterioration in their eyesight. One worker from an Intel corporation plant in Penang recounted, 'after some time we can't see very clearly, it's blurred. We'll be looking into the microscope for over seven hours. We have to work with these gold wires, very thin like our hair…' (as cited in Grossman 1980, 53). For some, their eyesight declined to the point they could no longer carry out their job, resulting in a not-insignificant number of women being forced into sex work (1980, 55).

Paralleling such accounts, in 'Critical Hardware: The Circuit of Image and Data' (2019), Kyle Stine has argued that the whole production of microchips is linked to vision, suggesting that much of the critical engagement with computing relies heavily on a rejection of such visuality. He shows that important visual culture theorists, including Nicholas Mirzeoff, Jacob Gaboury and W. J. T. Mitchell, all downplay the visual elements of computer hardware, situating its optical properties within its screen display alone (2019, 73). According to Stine, the visual and material aspects of the computer are often delineated in such a way as to split the technology into two distinct parts: the *mechanical* and the *screen*, keeping hardware and software artificially separated (2019, 762–4). While advocates of posthumanism, including Katherine Hayles, endeavoured to materialise the digital information and structures by looking at IC manufacture, Stine stresses that it is crucial not to get swept up in 'pure materialism', but instead to focus on clarifying optical aspects of hardware (767). For Stine, this is nowhere more obvious than in the production of integrated circuits where several optical technologies — diagrammatical, microscopic and photomechanical processes — are required.

While the connections between weaving and computing have proven persuasive for feminist artists and scholars, as much as they have for corporations like Fairchild Semiconductor, what this exposes is the potential limits of such associations. Challenging these dominant tropes requires looking closely at various eras of manufacturing and identifying the complex and often paradoxical points of crossover with other fields. In fact, there are several comparisons that could prove just as persuasive, in other processes such as silversmithing and printmaking. The first circuitry was made up of point-contact transistors and used no photo-mechanical processes, instead relying on contacts to be individually placed by hand. This comparatively large-scale manipulation of contacts was more equivalent to the task

carried out by a jeweller than someone involved in managing the warp and weft of a loom. Nor was it so technical as to necessitate any innate skill on the part of the worker. ‘In the good old days,’ observes Friedrich Kittler, ‘when microprocessor pins were still big enough for simple soldering irons, even literary critics could do whatever they wished with Intel’s 8086 Processor’ (1997, 156). Later, the decreasing size of ICs would require the use of photographic apparatus, as they became too small to manipulate manually. This would create the demand for scalable processes that bore considerable similarity to those used in print, both in the domain of fine art and more broadly.

Labour of love

What this perceived interface of craft and technology prefigures is a set of distinctly contemporary discussions around how we might attribute value to work, discussions that extend far beyond the community at Shiprock. In recent years, the contemporary economy has been described as an arena in which creativity, cultural value and free labour have flourished. This results from the transformation of what we might normatively expect our working lives to consist of: from a factory job for life to a piecemeal gig economy that blurs the distinctions between remunerated labour and life that takes place around it. In digital networks, earlier conceptions of the nature of work, such as manual labour, servitude, and monotony, have been recast as a creative field of expression. Or, put another way, our working lives are euphemistically presented to us as having transformed from ‘factory to playground’ (Scholz 2013). As this type of creative digital work has increased, a consideration of ‘free labour’ has become increasingly important. ‘Free labour,’ theorist Tiziana Terranova argues, ‘is the moment where this knowledgeable conception of culture is translated into excess productive activities that are pleasurably embraced and at the same time often shamelessly exploited’ (2000, 37). Facebook, Instagram and Twitter are reliant on the astonishing amounts of labour performed by its users, providing these companies with both content and information for free. It is in this online environment, she suggests, that the users become the source of economic value, or as cultural critic Mackenzie Wark has memorably put it, ‘if you are getting your media for free, this usually means that you are the product’ (2019, 1). It is in this digital realm, Terranova suggests, that there is an ‘increasingly blurred territory between production and consumption, work and cultural expression’ (2000; 35).

Beyond the role that this type of free, creative activity plays in social media, the blurring of waged and unwaged labour has an equally significant bearing on contemporary concepts of

the creative economy, or cultural industries. As cultural theorists Glen Fuller, Caroline Hamilton and Kirsten Seale note, '"Creativity", once associated with the "natural" or "acquired" fits of the artist, has expanded to include virtually all the performative labours producing the information economy, from computer coding to legal research' (2013, 144). This classification is now used to describe a wide range of roles in our current economic structure. The model for this worker is, as Angela McRobbie argues in 'Artists as New Economy Pioneers?' (2001), that of the artist. Artists are often self-employed freelancers, who find themselves with flexible working schedules and a precarious relationship to both employment and payment structures. This fragmented experience mirrors the position that most find themselves in the wider creative economy. As McRobbie suggests, individuals in casualised jobs, who find themselves increasingly responsible for their own time, 'are less like CEOs, and more like conventional artists trying hard to make a living on a DIY or cottage-industry basis, constantly looking for small amounts of investment and haunted by the fear of having to give up their own work' (2011, 74).

Extending McRobbie's concept, we see that factors heralded as part of today's digital and creative economies are in fact repeating structures historically present in craft traditions broadly, and in twenty-first-century Navajo weaving culture specifically. This parallel is explicitly demonstrated by the plight of contemporary Navajo craftspeople in the documentary directed by Bennie Klain, *Weaving Worlds* (2008). At first, the women of the Navajo Black Mesa reserve appear as idealised artisanal craftspeople. They work the land, wool is spun from the fleece of their herd, and dyed with local plants. Producers answer only to themselves, working when and how they please. In one scene, a weaver laments her administrative day job, time she would much rather spend at her loom. Yet the weavers earn a meagre income from their work, and the sales of rugs cover little but the essentials. Their labour-intensive work yields insufficient income, contrasting sharply with the high resale values of their rugs. White traders, who act as intermediary merchants between weaver and customer, tend to resell the rugs at sums far greater than the Navajo could achieve. Faced with few alternatives, these weavers are caught in a persistent cycle, by being undervalued in the quest for creative fulfilment. This echoes the conflicting position of crafts described by Parker for women more generally as both a 'source of pleasurable creativity and oppression' (Harris 1988, 5).

For these Navajo weavers, the nature of their access to buyers has begun to change with digital platforms such as Etsy, the online marketplace for handmade items, making trading directly with customers a possibility (Klain 2008). But in turn, Etsy itself acts as a vehicle for both self-expression and exploitation, in which most of the sellers are barely able to make

enough to get by (Luckman 2013, 249–70). Although the form of mistreatment may not appear as visceral as that exerted on this community by the traders, there is still an extractive process at work. Here, the mercantile middleman has been replaced with what might be termed a platform economy, one that derives its profit from giving its users access to the digital vectors along which contemporary capital flows (Wark 2019). The situation faced by Navajo weavers today, one in which the products of their Indigenous labour are made globally available through such online marketplaces, demonstrates considerable parallels to the experience of their forebears who were employed in IC production by Fairchild Semiconductor. In both instances, ancient craft techniques act in a hybrid manner, in concert with visions of technological freedom that seem antithetical to them.

Returning to Shiprock, it can be argued that these contradictory positions were formulated into a blueprint for the digital age. Indeed, Nakamura suggests that Fairchild was one of the first to equate creative craft labour with digital labour as a method of exploitation. Building on urban theorist Richard Florida's influential conception of a 'creative class,' she suggests that the mechanisms at Shiprock are the 'first iterations of an exceptionally effective argument to justify digital labor exploitation by depicting it as an outlet for the expression of cultural and racial identity' (Nakamura 2014, 932). Individuals in this creative class not only get paid, but they achieve some creative fulfilment through their work and are also afforded a comparative level of personal freedom (Florida [2002] 2019). Nakamura suggests that in Fairchild's racialisation of Indigenous weaving we see the 'seeds of this argument'. She argues this was used to transform semiconductor factory work into a form of creative labour:

> By representing the labor of semiconductor manufacture as a 'labor of love' or, more accurately, as agentive or creative race-labor rather than as alienated labor. Like weaving blankets, semiconductor production is posited as an intrinsic part of the Indian psyche, an expression of cultural essence imperilled, yet ultimately enabled, by the 'modern" world (2014, 938).

Just as at the Shiprock Plant the aesthetics of craftwork masks the underlying dynamics of power and labour. Contemporary Navajo weavers are driven by a love of their craft and a desire to continue cultural traditions while being trapped by the systems of value attached to their identities. By interpreting this weaving tradition as 'women's work', Fairchild Semiconductor was able to harness this same duality and would in turn introduce a system that would have far-reaching consequences for employment in the worldwide semiconductor industry. The narrative that the assembly of chips was a creative and pleasurable job, which was far from the realities of the menial, optically demanding labour it required, would be applied to women in the global South. Its success was achieved through a celebration of

natural aptitude that seemed to destine individuals to this kind of work. These are narratives that exert a continued effect on the position people of colour occupy in the hierarchy of electronics manufacturing. In turn, however, this narrative would also prove pivotal in the way contemporary Western subjects conceive of their labour in a digital economy. In this instance, creative freedom is something to be maintained and celebrated, even as it necessitates interacting with systems that purposefully exploit it. It is paradoxically by engaging with an image of autonomy rooted in pre-industrial activity that individuals are enlisted in these new systems of exploitation.

tie dye, patchwork and macramé

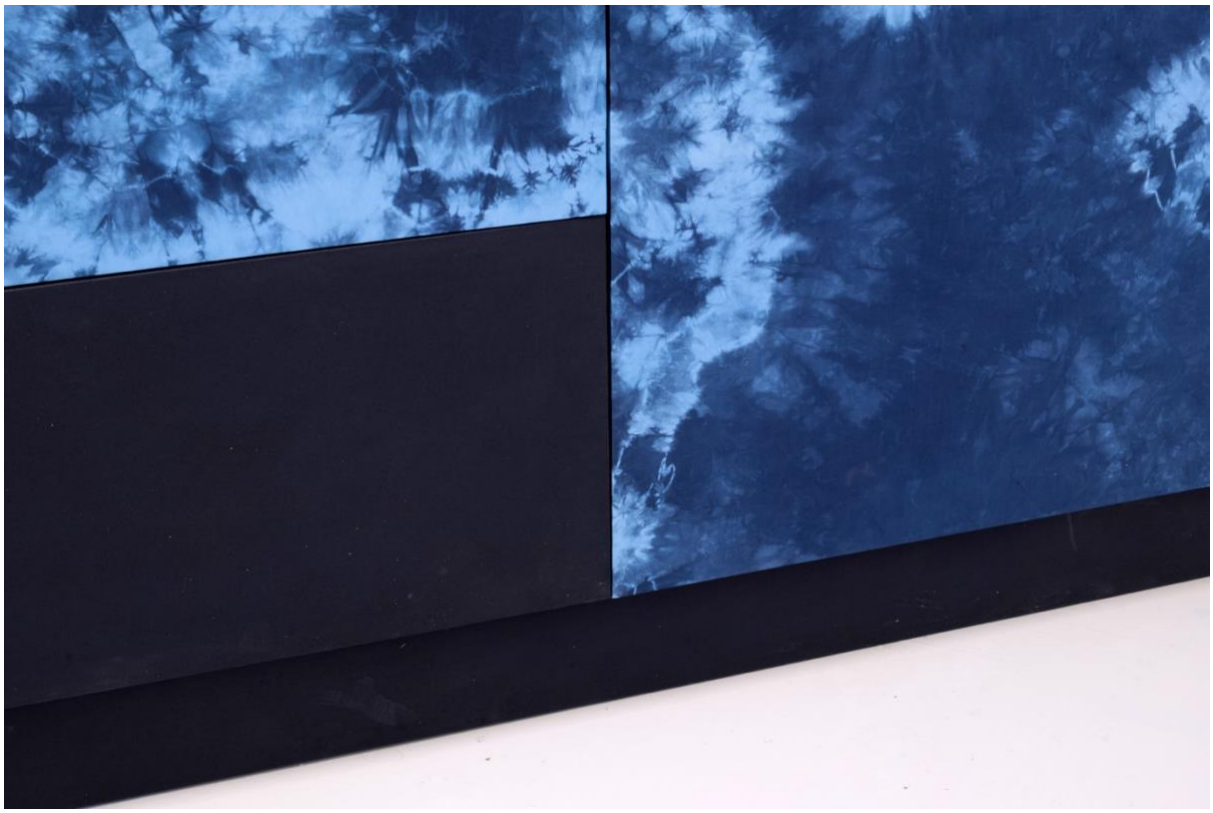

Figure 29 *Irrational Cabinet II* (detail), 2018. Exhibited in *Lowlight*.

Figure 30 *Hidden Hardware*, 2018. Exhibited in *Lowlight*.

Throughout this project, I have utilised tie-dye, patchwork, and macramé techniques to produce sculptural objects. These techniques are featured in the series *Irrational Cabinet* (Figure 29) and an accompanying work, *Hidden Hardware* (Figure 30). These works incorporate a variety of DIY textile craft techniques to create forms typically associated with 1960s formal abstraction, or the 'industrial aesthetic' (Jones 1996, 2). As explored in **mainframes**, these forms are connected to a form of worldmaking that resonates with the ethos of the West Coast movement. DIYism, craft and particularly textiles remain a potent foil for this exploration. I assert that craft serves not only as a counter-narrative to art, but also as a counter-narrative to technology. Therefore, in this project, handicraft has been strategically utilised to engage with both domains as a method of examining the role of feminised labour in digital history.

Hidden Hardware is a raised platform covered with a patchwork fabric, into which a sequence of grates has been inserted. This irregular assemblage is made up of numerous pieces of fabric that have been screenprinted with an illustrational wood effect, to replicate the appearance of a piecemeal timber floor with metal grates, through which liquid can pass. Exhibiting an area of flooring was a method of hinting at the importance of the infrastructural support beneath our feet. Where elsewhere in these exhibitions the wires, cables and pipes are made visible, this work aims to materialise the concealment of these structures. Exhibited in *Lowlight,* alongside the cabbage lighting system, *Hidden Hardware* aims to evoke the image of how resources such as electricity, water and information travel to the consumer. Or as media theorist Lisa Parks writes, 'though we live in a digital age and processes are increasingly technologised, not all infrastructures are fully automated and not all labour is immaterial' (Parks 2015, 370). In producing this work with a range of methods including laser cutting, digital vector illustration, screenprinting and patchwork a plethora of creative labour forms are emphasised. Moreover, it was crucial that printmaking was not only employed in the vegetal and horticultural sculptures (see **vegetal matter**) but was also present in other configurations. As I have already noted, to ghettoise any materials, processes of techniques would be against the ideological premise of this project. By foregrounding the printmaking processes within this crafted textile, *Hidden Hardware* not only highlights the slippages between these production forms, it also hints at their role in shaping our perception of the digital and physical worlds.

Figure 31 Example of server cable management.

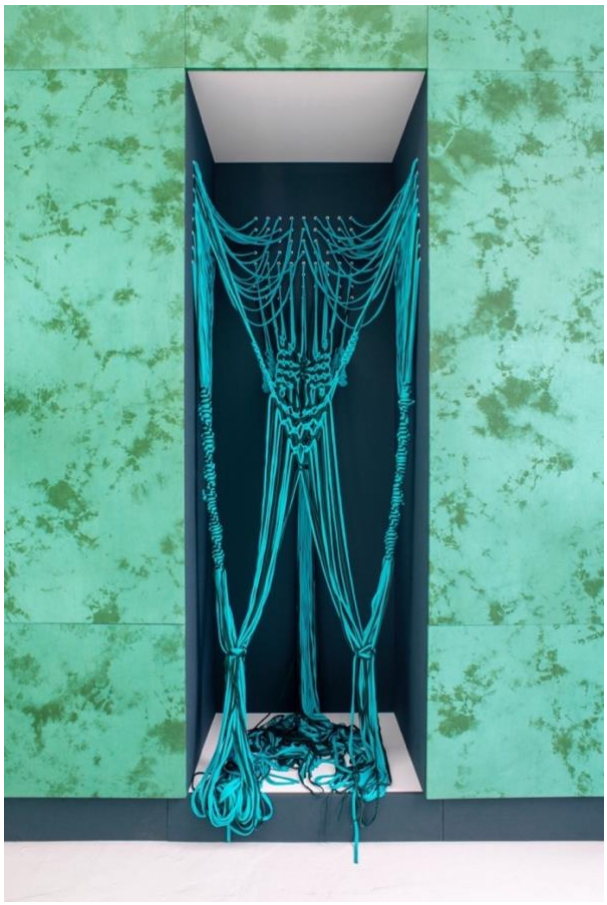

Figure 32 *Irrational Cabinet I* (detail), 2018. Exhibited in *Noon*.

The use of tie-dye and macramé in *Irrational Cabinet I* points to two narratives simultaneously, that of 1960s and 1970s counterculture, and a longer history of female craft labour. It does so to detail the considerable contextual overlaps that can be traced between them. At the back of this sculptural representation of a computer mainframe is a mass of dark green and turquoise macramé, replicating the complex arrangements of cabling that controlled machines of this kind. This sculptural representation of a mainframe creates a clear link between the threading and knotwork of handicraft labour and cable management; the neat arrangement and securing of the various cables that connect servers, routers, and other network devices within a rack (Figure 31). As discussed in 'Nimble Fingers I' the initial comparison between these two forms of labour was made in relation to early computers such as the ENIAC. But my use of macramé here was a method exploring the connotations between amateurism and professionalism evoked by either form of activity. The combination of materials (yarn made from fashion waste) and design (symmetrical knot-work which spills into disordered tassel forms) situated the frame of reference between well-ordered, immaculate cabling and the unruly, disobedient, hippie forms (Figure 32). *Irrational Cabinet I* not only juxtaposes historical and contemporary forms of labour but also embodies the flexibility and tension between the associations of disciplined precision in technology and expressive, organic forms of traditional craft, challenging our perceptions of value and expertise in both spheres.

This knotted arrangement signals clear affiliations with a longer history of feminist art practice. In such a lineage, textiles and other craft techniques were employed to position an artwork as explicitly or implicitly political, often questioning the hierarchical relationship between the fine and decorative arts. An important early example of this approach is Faith Wilding's 'Womb Room', or *Crochet Environment*, which was created for the influential feminist exhibition *Womanhouse* (1972), organised by Judy Chicago and Miriam Shapiro in California. In this work, crocheted yarn and sisal rope cover the interior walls, making a weblike structure which, with its tightly knotted threads and gaping holes, draws out a form reminiscent of a precarious shelter. Wilding was not only a critical player in the fiber arts community, but years later became a leading figure in the cyberfeminist collective subROSA (Fernandez, Wilding, Wright 2003). Acting in this capacity, she and the rest of the collective actively took up the subject of how technology was changing conversations around gender equality. In many ways, Wilding's life has played out many of the themes present in Plant's proposition of a model of feminist practice blending craft and the digital, moving as she has through different stages of political organising and maintaining an artistic practice at the same time.

Macramé is a type of patterned knot work, Arabic in origin, that came to prominence in the West during the 1960s. Like tie-dye and crochet, macramé increased in popularity as part of a move in the post-war period where women entered professional employment while paradoxically turning to previous chores such as knitting and needlecraft for pleasure (Bryan-Wilson 2017, 93–6). In time, many of these same craft processes became linked with the DIY aesthetic of the hippie movement, becoming a way to demonstrably lead a 'handmade life' (Williams 2002). Tie-dye, like macramé, has historic origins in a non-western context, with examples from both South America and Asia being over a millennium old. Produced using different techniques of folding and bunching as a way of controlling how much and where dye enters the fabric, it has become synonymous with a psychedelic aesthetic. Parting with the convention of displaying the outcomes of this process on loose wall hangings and articles of clothing, I have pasted this fabric onto rigid supports. Presented in this way, their effect is more akin to the decorative quality of a natural material like marble. In *Irrational Cabinet I*, this illusionism imbues the structure with a greater degree of monolithic solidity, while still hinting at the countercultural ideologies that would intertwine with the computer industry. I have deliberately placed these discourses together as a way of creating a counternarrative, one that purposefully seeks to overlay a sequence of cultural reference points on top of one another.

Making something by hand was a rejection of consumerism, positioning yourself within an alternative lifestyle or even economy (Farber 2016, 409). A range of kits and books provided step-by-step instructions and designs to follow. This allowed the at-home-crafter to develop a new skill and to showcase their creativity. Instructional books, including Anne Maile's *Tie Dye as a Present Day Craft* (1963) and Dona Z. Meilach's *Macramé: Creative Design in Knotting* (1971) were extremely popular, often selling copies in the hundreds of thousands. These books helped to promote low-cost craft processes as an easy and fun way to make and individualise clothes and household items. Beyond those publications aimed at a younger audience in that period is a broader range of guides revolving around patchwork and quilting, techniques central to the aesthetic of frontier-dwelling Americana from which the countercultural spirit developed. The processes of dyeing the fabric attached to *Irrational Cabinets I* and *II* and the methods of joining fabric in *Hidden Hardware* partly derive from these instructional books. The graphic design of such manuals, and the documentation of projects they contain, have been a longstanding inspiration and inform the appearance of sculptural installations I have produced.

While it is straightforward to conceptualise the distinction between store-bought and hand-crafted items, even during the countercultural movement the lines were blurred. As art

historian Julia Bryan-Wilson describes, during the 1970s craftspeople saw handmade DIYism as sitting next to consumer culture rather standing for a rejection of it (2018, 67). Contemporary accounts describe how 'housewives' could gain almost all they needed to create a product line of tie-dyed clothing items from the instructional book and bottle of dye that came with it. But this standard knowledge could easily be made bespoke through personal interaction with fellow craft practitioners, or finding innovations through other books on the subject (2018, 67). At popular craft markets vendors could sell hand- and mass-produced crafted items from their home, or gathered from across the globe. So, as Bryan-Wilson writes:

> Rather than being regarded as a space apart from consumerism, these [craft] markets were understood as models of neoliberal capitalism, which was then taking hold as a dominant economic and ideological system with its emphasis on individual marketing, business savvy, the monetization of social transactions, and self-promotion (2018, 66).

Although batik, tie-dye, macramé and other DIY crafts appear to be a reaction against consumerism, they were, quickly co-opted by consumerism, if they ever stood counter to it.

The idea of a democratic form of creative expression that these forms of craft production portray is of particular interest, especially as it can be seen as at odds with the use of the very same techniques within fine art. Rather than constituting a dualistic opposition, what is instead encountered is a layered sequence of hierarchical distinctions that exist in competition with one another. Writing on the subject, art historian Elissa Auther has noted that sculptural arrangements made from woven material by male artists were regarded as extensions of a postminimal tendency, whereas similar efforts by female practitioners were more often than not categorised in pejorative terms as 'fiber art' (2010, 21–5). In turn, equally evident is a distinction between artists who adopted these craft techniques in service of a feminist agenda, and the large number of women who employed them with less ambitious goals in mind. As Auther highlights, many craftspeople wanted to emphasise the hierarchy separating those with a critical agenda from the activities of the amateur. Identifying with DIYIsm as a home craft as much as with the various strands of established lineages of feminist art practice, these are multivalent interpretations that my artistic practice intends to bring into dialogue with one another. Auther reflects that:

> Feminists conceived of amateurism as a strategy that held both the traditional home and the mainstream art world at arm's length. Craft was the most material expression of that strategy. It served double duty as a symbol

> of unjustly quashed creativity, and a token of the Feminist desire to break out of the stultification of domesticity (2006, 151).

Hence, the subordinate status of amateur craft has long been a potent vehicle for critique. This project harnesses tie-dye, patchwork, and macramé to craft sculptural forms, challenging historical sculptural ideologies and creating a counter-narrative through craft. While critique and counter-narrative differ subtly — the former assesses the dominant narrative, the latter offers an alternate line of inquiry or fictioning — craft serves both functions, critiquing established hierarchies and generating new possibilities. Craft, a field both interconnected and distinct, often deliberately segues into other material discourses. If art represents the prevailing narrative, then craft is its natural antithesis. In this regard project not only applies craft as a critical tool but also as a means of fictioning.

As Bryan-Wilson has recently noted, the relationship between craft and fictioning or worldmaking is particularly strong. Drawing on philosophers Nelson Goodman and Hannah Arendt, Bryan-Wilson constructs a conceptual framework for understanding craft as a form of worldmaking (Bryan-Wilson 2018, 45). As Goodman notes, ‘worldmaking as we know it always starts from worlds already on hand; the making is a remaking’ (1978, as cited in Bryan-Wilson 2018, 45). Bryan-Wilson describes Goodman’s perspective as emphasising the repurposing of existing elements, restating 1970s ecological calls for a more sustainable consumer culture and the adoption of recycling. Goodman underlines that creating worlds is essentially a process of remaking the worlds we already have; an ethos paralleled the *Whole Earth Catalog* the subject of the next chapter. Bryan-Wilson argues for positioning Goodman alongside Arendt’s worldmaking concepts, which are based on labour and its material and political conditions (2018, 45). This form of worldmaking has clear parallels with the practice-based application of fictioning this project is engaged with.

Green Thumbs II: Cybernetic Fields

Whole Earth

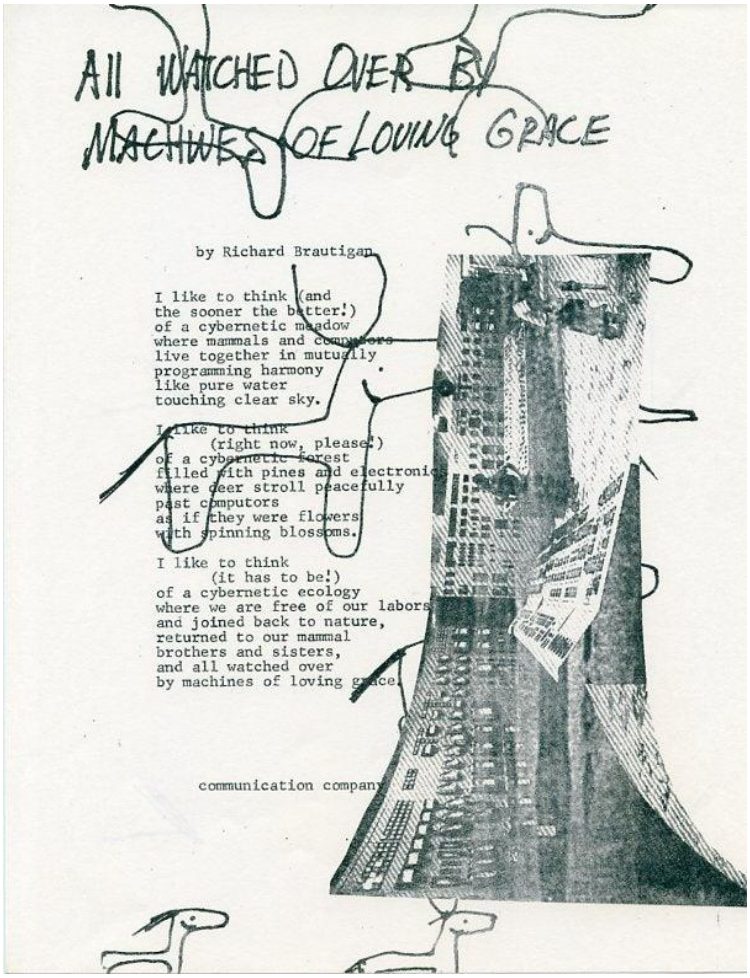

Figure 33 Original mimeograph of Richard Brautigan's self-published poem *All Watched Over by Machines of Love and Grace*, 1969.

During the 1960s and 70s, citizens fled American cities for a more nature-centric lifestyle, primarily on the US West Coast, and particularly in San Francisco. This countercultural movement initiated a significant rise in anti-establishment values. The 'back-to-the-land' movement rejected consumerism, capitalism and urban life, in search of deeper meaning in an ill-defined but powerful image of 'nature'.

While this turn to nature of the 1960s does not at first appear to have much to do with information technologies, historian Fred Turner has analysed how key players in the countercultural movement and the values they espoused were crucial in later conceptions of the computer as a device usable by all. By the late 1960s, at least some members of the back-to-the-land movement had come to terms with technology-based systems thinking

which was developed during the Cold War. The beginning of this juxtaposed relationship lies in San Francisco's history, where bohemian culture intersected with the emerging technological hub that would become Silicon Valley.

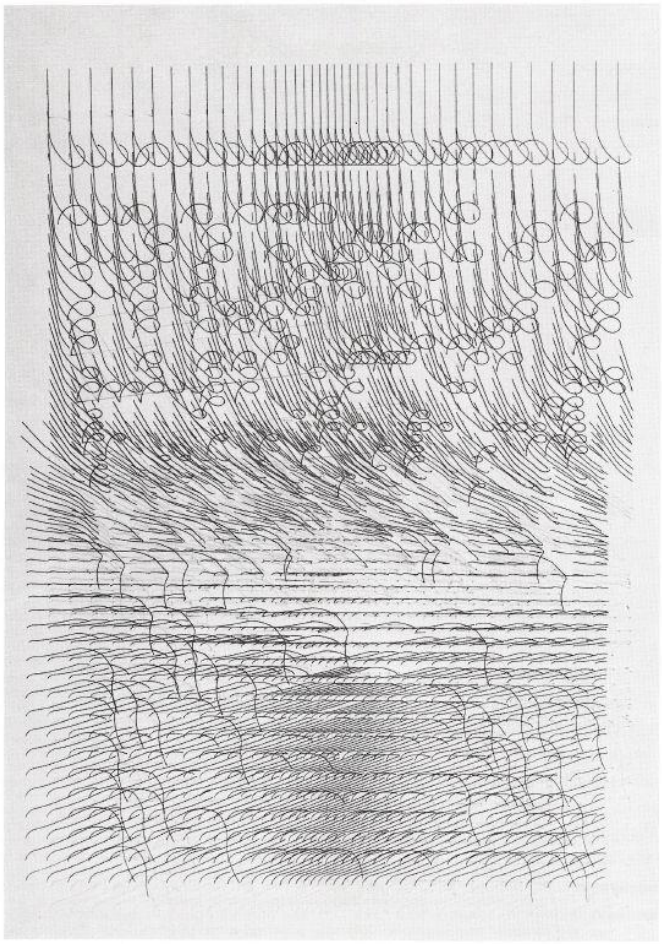

Figure 34 Colette-Charles Bangert, *Large Landscape: Ochre and Black,* 1970.

This hybrid attitude is perhaps best summed up in the poetry of the so-called ‘hippie laureate’ Richard Brautigan whose prose, such as *All Watched Over by Machines of Love and Grace* (1969) is full of complex combinations of pastoral imagery and computational metaphor. Brautigan's writing encompasses the principles of countercultural ideology — environmentalism and anti-establishment sentiment — intertwined with a techno-utopianism that was pivotal in transforming the computer's cultural imaginary. The significance of this poem within both countercultural and technological discourse is well known, perhaps most memorably lending its name to a BBC documentary on the history of computerised systems (Curtis 2011). However, the part that printed matter played in this exchange is seldom acknowledged. This poem was originally published as a single-leaf handout where lyrical text combined with images of mainframes and Neolithic cave paintings (Figure 33). Created using a mimeograph, an early stencil duplicator akin to today's Risograph, the print was

handed out on the streets of San Francisco in 1969 (Jones 2006, 190–2). Contemporaneous computer art, often machine-made imagery plotted on paper, embodied similar contradictions. Artist collaborators Colette and Charles J. Bangert's works, such as *Large Landscape: Ochre and Black* (1970), demonstrate how print combined hippie ideology with a technical aesthetic (Figure 34). This is encapsulated in their 1975 statement, 'grass is also random and random is a natural computer facility. Computer grass is natural grass'. Yet, as this work and others, plotted by a computer-driven, mechanically operated arm, were materialised as works on paper, they were ultimately perceived as relatively traditional in the lineage of editioned prints and drawings. (Taylor 2014, 46). These examples underscore the underacknowledged part printed matter plays in bridging the gap between computing and ecological metaphors.

The following chapter will examine a particular printed work that arguably, more than any other document, shaped the cultural identity of computing. As detailed in Turner's *Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (2006), Stewart Brand, the creator of the Whole Earth Catalog (*WEC*), and his network were instrumental in this cultural shift. First issued in 1968, the *WEC* was a publication that combined philosophy, how-to guides, and products for self-sufficient living. It defies simple categorisation, being neither a guidebook nor an academic treatise, neither newspaper nor magazine. The *WEC* was an eclectic mix of interconnected ideas, encompassing horticulture, engineering, book reviews, and instructional documents. As Fred Turner writes:

> At one level, the *WEC* was a 'Whole Earth' in its own right. That is, it was a seemingly comprehensive informational system, an encyclopaedia, a map. …At another level, the reader could order the 'tools' on display and so help to create a realm of 'intimate, personal power' in her or his own life (albeit by entering the commercial sphere first) (2006, 83).

Its content wove together a complex network of sources grounded in cybernetic theory, leading to a new form of individualistic DIY ethos emblematic of the techno-utopian vision. It was within these pages that the seemingly opposing concepts of military technology and anti-establishmentarianism were reconciled, fostering the emergence of ecological metaphors and DIYism within computer ideology that coined the 'Californian Ideology' (1996). As this chapter will show, ironically, the computer, often described as the harbinger of the end of printed matter, has its roots in the very medium it was presumed to replace.

Appropriate technologies

The *WEC* began as the Whole Earth Truck Store, where tools and books were loaned to new communes from the back of Brand and his wife Lois' 1963 Dodge (Kirk 2007, 48). Despite arguments that counterculturalists were generally anti-technology, they embraced tools necessary for a self-sufficient lifestyle. Later described as 'appropriate technologies' (Kirk 2001; Pursell 1993) or 'soft technologies', these tools considered need and locality, using knowledge and technological innovations to provide new solutions. This included solar panels, heat pumps, and bicycle-powered water filtration systems, as well as pre-industrial farming techniques and Indigenous knowledge. As environmental historian Andrew Kirk writes, appropriate technologies included a 'wide spectrum of activities involving research into older technologies that had been lost after the Industrial Revolution and the development of new high- and low-tech small-scale innovations' (2001, 381). The *Truck Store* provided a range of publications which helped the free-wheeling hippie to survive outside the system. As Kevin Kelly, later an editor of the *WEC* described: '"here's a tool that will make drilling a well, or grinding flour, easier," Brand would [say] pointing it out in his catalog of recommended tools. But his best-selling tool was the catalog itself, annotated by him, featuring tools that didn't fit into his truck' (2003, loc. 406). That annotated tool catalogue would provide the blueprint for the first *WEC*, published later that year.

Despite the radical politics of the time, patriarchal family structures remained relatively unchanged in the communes. As Gretchen Lemke-Santangelo argues, even as feminist politics swept through the hippie movement, women often 'seized on difference to claim authority,' doubling down on 'natural' roles of nurturing and motherhood (2009 160). This double-bind both permitted and required women to continue with under-acknowledged reproductive labour which sustained the communes. Their roles were often highly gendered. These were packaged via a return to 'tribal' values popular in the back-to-the-land movement, where child rearing and other domestic duties were left to women, while men took on leadership roles (Turner 2006, 76–7).

This was also true in the *WEC*'s organizational structure. Lois Brand was crucial in keeping the *WEC* afloat, doing the 'hardcore work of business' in a subordinate clerical role, allowing Stewart Brand, the 'idea man', to focus on concepts. Brand acknowledged this reality, stating, 'in my experience every working organization has one overworked and underpaid woman in the middle of things carrying most of the load' (Kirk 2007, 50). Lois described how the gender roles in communes mirrored those in suburbia. Men typically did construction

work, while women handled tasks such as adding Clorox to the water to prevent sickness (Tuner 2006, 76). Historian David Farber agrees with Brand's claim, suggesting, that 'many hippie women accepted and promulgated the gender-normed ideal. They embraced the role of ''earth mothers,'' whose primary calling was to nurture, cook, weave, garden, and pursue other traditional feminine roles' (2016, 436).

Making the Book

This book was conceived, researched, written, photographed, designed, typeset, pasted-up by six women in a little over five months.

April—Kirsten and Susan do preliminary research.

May 13—Kirsten and Susan begin a 12,000 mile trip around the country to report on projects and groups first-hand. Fanette and Ruth join, continue research and get in touch with women Kirsten and Susan will not be able to visit.

July 13—Kirsten and Susan return, and sorting of the material begins.

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Figure 35 'Making the Book', New Woman's Survival Guide, p. 216. 1972.

Despite the replication of normative gender roles, women in the counter-cultural movement saw the *WEC* as a new way of thinking about tools and what a tool could be. As one commune dweller put it:

> Walking to the bathhouse today, holding my new twenty-ounce hammer, I suddenly understood the Whole Earth Catalogue meaning of 'tool.' I always thought tools were objects, things: screwdrivers, wrenches, axes, hoes. Now I realize that tools are a process: using the right-sized and shaped object in the most effective way to get a job done. It's having a well-balanced hammer and knowing how to hold and swing it that makes it a tool; changes the whole work process from a struggle to a pleasure (Jeanne Tetrault and Sherry Thomas 1976 as cited in Binkley 2007, 125).

It is hardly surprising that one of the many spin-off versions of the *WEC* was *The New Woman's Survival Catalog* (1973), which outlined the network of alternative feminist printing presses, health centres and bookstores available across the West Coast, and described the process of making the publication with photographs and instructions (Figure 35). The change described here was in many ways the greatest achievement of Brand's project. With the *WEC*, tools were transformed from mundane objects to forms of information technologies. It was in this space that an argument could be made that advanced technologies were a viable asset within the hippie ideology, but such a relationship relied on print technology to be feasible.

Over the print run of the *WEC*, this argument would be solidified. Rather than embodying the anti-technology hippie stereotype, tools were radically reimagined to include complex technological devices. In complete contradiction to the anti-technological position he outlined in *The Making of a Counter Culture* (1969), cultural thinker Theodore Roszak would later note the hybrid position of the *WEC* in *From Satori to Silicon Valley* (1986). He states:

> Alongside the rustic skills and tools, we discover high industrial techniques and instruments: stereo systems, cameras, cinematography, and, of course, computers. On one page the 'Manifesto of the Mad Farmer Liberation Front' … on the next, Norbert Wiener's cybernetics ([1986] 2000).

The *WEC* is perhaps the most pronounced example of how the countercultural movement re-thought the preservationist views of earlier, environmentally inclined movements. As Kirk describes:

> Counterculture environmental politics embraced the seemingly contradictory notion that the antimodernist desire to return to a simpler time when humans were more closely tied to nature could be achieved through technological progress. Counterculture environmentalism simultaneously

> encompassed both antimodernism and modernism. Nowhere is this apparent contradiction more visible than in the pages of the *Whole Earth Catalog* … where primitive wood stoves and survivalist supplies for counterculture neo-Luddites share the page with personal computers, geodesic domes, and oscilloscopes (2001, 385).

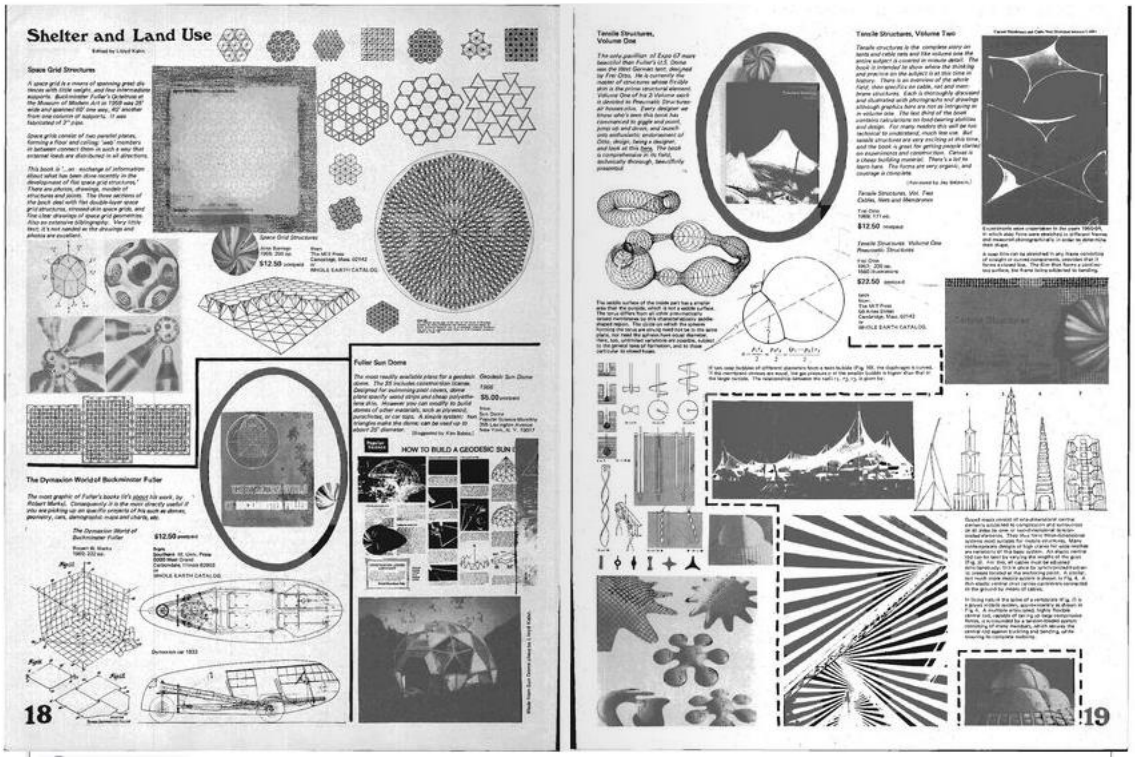

Figure 36 'Shelter and Land Use' double page spread from *Whole Earth Catalog*, fall 1968.

In the first issue of the *WEC*, the relationship between DIYism, a back-to-the-land mentality and techno-utopianism is demonstrated through the range of subjects covered. It features sections entitled 'Industry and Craft', 'Shelter and Land Use', 'Nomadism', 'Learning' and 'Community', in which practical guides to each subject are given (see Figure 36). Although these headings could be generally viewed as facilitating forms of preservation key to an anti-urban movement, they were counterbalanced with an introductory section titled 'Understanding Whole Systems', which includes the theories of technologists such as Buckminster Fuller, Marshall McLuhan and Norbert Wiener. Throughout, the cybernetic influence is in evidence. In the layout of the *WEC*, what could appear as a disregard for individual sections, where the theories of technologists spill across multiple pages, echoed the networked subject matter of Fuller and Wiener's writing and refused to acknowledge distinctions between discourses, instead seeing them as structurally connected (2006, 52).

The influence of Fuller and McLuhan on Brand was significant. Brand and others advocated viewing technologies as part of the hippie cause rather than against it. McLuhan's work was crucial in developing this position. In both *Gutenberg Galaxy* (1962) and *Understanding New Media* (1964), McLuhan argued that new media connectivity was 'retribalizing' society, signalling a shift from a typographic society to an electronic age, linking individuals as part of the 'global village' (1962, 31). As he wrote, 'print is the technology of individualism. If men decided to modify this visual technology by an electric technology, individualism will also be modified' (1962, 158). For the countercultural movement, this logic reconciled the relationship between localism and global mass media, creating a path for the communalists to enjoy the pleasures of a consumerist society without giving up their political beliefs. The effect of this reconciliation of nature and technology on the *Whole Earth* community was great. As Turner notes, 'McLuhan's simultaneous celebration of new media and tribal social forms allowed people like Stewart Brand to imagine technology itself as a tool with which to resolve the twin cold war dilemmas of humanity's fate and their own trajectory into adulthood' (2006, 54).

Figure 37 Building and repair of geodesic domes at Drop City ca 1960.

Just as McLuhan promoted an electronic 'retribalism', Fuller's futuristic theories helped to reconcile aspects of environmentalism and cutting-edge scientific theory. Brand's 'pragmatic environmentalism' was indebted to Fuller's concept of *dymaxion*, a theory of scientifically

driven design processes based on an economy of means. This is what Fuller described as ‘doing the most with the least’, a principle epitomised by the famous ‘Bucky ball’ or geodesic dome. The geodesic dome was based on sophisticated design principles and high-level mathematics but could be applied to a host of architectural applications. These geodesic domes became a staple of commune shelter design, becoming synonymous with projects such as Drop City in Colorado (Figure 37) that claimed to be building their community from ‘the garbage of America’ (Senior, 2011). This approach and the materiality of these sustainable structures mimicked the make-do and mend characteristics of patchwork quilting. On the popularity of such structures Kirk has noted, ‘no other aspect of the counterculture, in fact, captured the spirit of the age better than the simple desire to strike out to a new frontier and provide one’s own shelter’ (2007, 83). Aspects of frontierism did not stop there. For both Fuller and the counterculturalists, space exploration was a logical continuation of these ideas. Fuller’s *Operating Manual For Spaceship Earth* (1969) continued this thinking on a grand scale, proposing that the Earth was itself a form of sophisticated, self-sustaining spacecraft. With its focus on tools and systems theory, ‘spaceship earth’ was a powerful metaphor that permeated the *WEC.*

Cybernetics, ecosystems and computer design

A notable visual example of this stance was the image emblazoned on the cover of its first issue. While on an LSD trip in 1966 Brand would conclude that ‘people perceived the Earth as flat and infinite, and that that was the root of all their misbehavior…’ Sitting on his roof, Brand noted that ‘I could see that it was curved, think it, and finally feel it. But how to broadcast it?’ (as cited in Kabil 2018). He began an earnest campaign selling pins on college campuses with the slogan ‘Why Haven’t We Seen a Photograph of the Whole Earth?’ written on them. In 1967, he received his answer when the satellite ATS-3 captured the first colour photograph of the Earth from space. Appearing as a perfect metaphor, Brand used this extraordinary photograph for the first cover of *WEC* (Figure 38), whose contents exhorted the reader to understand the planet as an interconnected whole, operating in ecological equilibrium. The striking image echoed the theoretical position of the world as a self-regulating system which would come to dominate the period such as the Gaia hypothesis (Lovelock, 1979). For many in the countercultural movement, this image also ushered in a new chapter of human existence that unified the previously contradictory relationship between technological advancement and environmentalism. It permitted a way, according to James J. Farrell, to criticise ‘the depersonalised life of mainstream culture and offered

alternatives that promised to create a new world in the shell of the old' (as cited in Kirk 2007, 51).

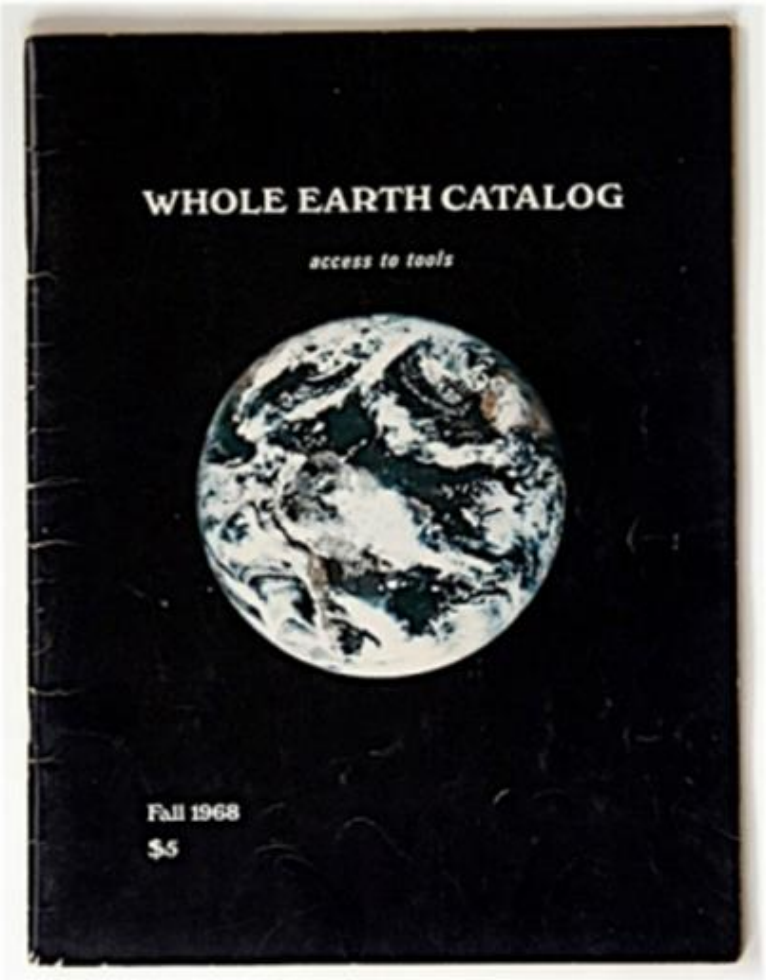

Figure 38 Cover of the first *Whole Earth Catalog,* Fall 1968.

Although emerging from countercultural politics, Brand's 'Whole Earth' ideology heavily relied on systems derived from militarised cybernetic theory (Turner 2006, 39). In *Cybernetics: Or Control and Communication in the Animal and the Machine* (1948) and *The Human Use of Human Beings* (1950), Norbert Wiener developed the concept of cybernetics, described by Charlie Gere as 'information and feedback as a paradigm for understanding biological, machinic, and social processes' (2008, 56). Weiner's vision for cybernetics was truly interdisciplinary in its outlook and his assertion that any system could be controlled and observed would influence a range of fields including computer science, sociology, philosophy and biology. With cybernetics, previous boundaries between different spheres are no longer relevant, as everything can become part of a balanced system of control. What cybernetics proposes is a speculative organising principle which can be applied to almost any system, variously capable of describing insect metabolisms, the human brain, robotics, and the operations of government.

Figure 39 Operator uses a printer from the IBM System/360 Model 40 and the central interface in the background ca 1965.

Cybernetics would not just influence post-war military projects. Its popularity would extend to the design and architecture of digital computing systems used in business. During the 1960s the demand for computer mainframes for commercial use was growing, and IBM was at the forefront of this trend. In 1964 they launched the IBM System/360, which was a modular office system with changeable desks, operational interfaces, and mainframes. Whereas computer systems of the 1940s and 50s, such as the ENIAC or Colossus, had been the preserve of the military and major governmental agencies, IBM's System/360 was a relatively affordable product which companies of any size could employ. The system synthesised the operational duties of different computers into a single user-focused mainframe machine, in an attempt to streamline the human-machine relationship (Figure 39). With the IBM System/360, the computer was reimagined as part of an environment where man and machine worked in harmony. This was a reformulation of the office environment as a space in which humans and computers coexisted as equals.

The System/360 was designed under the leadership of Eliot Noyes, who took over as IBM's Consultant Director of Design in 1956, and was given the task of redesigning its identity as a corporation. Before Noyes took this position, IBM accounting machines were placed in

ornate cabinets, which, according to him, ‘had cast iron cabriole legs in the manner, I believe, of Queen Anne furniture’ (as cited in Harwood 2011, 4). In fact, computers had up until that point been imagined as a form of heavy domestic furniture, hiding their modernity under a decorative skin (Harwood 2011, 72). Noyes had a very different vision for the future of the company. In his role as Design Director, he supervised the production of everything from the architecture of IBM’s buildings to its graphic identity. The visual aesthetic of the company’s products was seamlessly integrated into this overarching vision. Guided by Bauhaus design principles, Noyes envisioned his mainframe systems as being able to create an efficient, controlled environment based on cybernetic principles.

These mainframes were sited within what was referred to as the ‘white room’, a sanitised space with blank walls, floor and ceiling, in which idealised configurations of computers and operators might be imagined. This is what architectural historian John Harwood has described as a ‘“counterenvironment,” an enclosure organised over and against the surround, disorganized environment’ (2011, 13). In ‘the System/360 white room,’ Harwood argues, ‘many of the modules seem to have neither front nor back, and the singular surfaces with which the human components of the man-machine system work may be oriented in any direction — 360 degrees, as it were’ (2011, 157). This harmonious ‘man-machine’ system exerted a level of control over the environment. By removing personal items and streamlining and regulating workers’ movements, it also controlled the workers operating within it. The goal of this new arrangement was to increase productivity, by optimising the workers’ interactions with the machines they used. This was a central ideology for Noyes, who would state ‘if you get to the very heart of the matter, *what IBM really does is to help man extend his control over his environment*… I think that’s the meaning of the company’ (as cited in Harwood 2011, 5).

Figure 40 EAI 640 Digital Computing System Marketing Brochure. 1966.

Perhaps the clearest example of the way in which an environmental metaphor was employed by computer companies was through the marketing imagery for the 1966 Electronic Associates, Inc. (EAI) 640 Digital computing system. The EAI 640, like the IBM 360, featured distinct components designated for specific functions, such as desk control, line printer, card reader, storage rack, magnetic tape, and card punch. Throughout its promotional brochure, the EAI 640 is displayed in a modernist courtyard (Figure 40). Components are strategically arranged across an architectural quadrangle placed between meticulously pruned hedges and trees. Adjacent to the mainframes, a woman lounges in a white mini dress, as though one of the computer operators has left her post to enjoy the sun.

The brochure proclaims, ‘the 640 is the balanced computer’, a notion mirrored by the orderly and precise garden landscape, where every element is in its proper place. The woman,

lounging as if an ornamental statue, serves to accentuate the modern technological aesthetic, perpetuating Enlightenment-era binary notions of control of masculinity over femininity, and culture over nature. While the brochure's depiction may appear as a representation of literary critic Leo Marx's 'machine in the garden' metaphor, it omits the essential element of psychological tension that Marx posited as vital to his conceptual framework. For Marx, the machine in the garden is an abrupt intrusion into the pastoral idyll (such as a train's whistle), which symbolises industrial society's invasion into a romantic reverie for an untainted natural world (Marx 1964, 19-24). The intrusion outlined by Marx was not merely a meeting of technology and nature but represented a stark rupture that highlighted the dissonance between the age of industry and the preceding age of pastoral tranquillity. Instead, EAI portrays a new vision, more akin to Weiner's cybernetics, in which computer systems create harmony between technology, man, and the natural world.

While early cybernetic concepts were used by companies like IBM and EAI, 'second-order cybernetic theory' was more popular in the *WEC* network. Unlike first-order cyberneticists who believed systems could be controlled by an outside observer, second-order cyberneticists saw the observer as part of the system. Influential figures Gregory Bateson and Margaret Mead transformed cybernetics from a field of 'engineering metaphors' to one of 'biological metaphors' (Kirk 2007 165). 'What is the pattern,' Bateson would ask in *Steps to an Ecological Mind* (1972) 'that connects the crab to the lobster and the orchid to the primrose, and all four of them to me? And me to you?' ([1972] 1987, 236). Their work made biology and ecology central to cybernetic 'whole systems' thinking, viewing humans as part of a global system of interactions. These ideas significantly influenced Brand, who noted in 1970, 'if you get into cybernetics and your head is just a minute ago full of organic gardening and ecology, then cybernetics starts to come alive for you in a different way' (cited in Turner, 2006, 84).

Today, this metaphorical way of thinking is deeply embedded in a host of digital systems, particularly the internet. By the late 1990s, the ecosystem became a central allegory for the complex network of interactions created in cyberspace. In 1999, Dr Bernardo Humberman, already describing himself as an Internet Ecologist, wrote the web 'grows on its own like an ecosystem.' 'The sheer reach and structural complexity of the Web,' Humberman would remark, is what 'makes it an ecology of knowledge, with relationships, information "food chains," and dynamic interactions that could soon become as rich as, if not richer than, many natural ecosystems' (as cited in Johnson 1999). In our era of networked social media, however, the optimistic connectivity proposed by the model of an ecosystem has been brought into question. Some have argued that ecosystems are one of the most useful

metaphors in communicating how the internet functions to the public, while others have argued that presenting the internet as an ecosystem is a form of 'greenwashing.' Speaking on the subject, cyber-security specialist Adriane Lapointe has pointed out that the symbolism of ecosystems creates the impression that the internet is a safe space, one where everyone is welcome and takes responsibility for their own actions when this is quite obviously far from the case. As the internet developed from cyberspace to the primary site of our social interactions, it has become more and more evident that this image of tranquillity and balance conjured in the word 'ecosystem' is a false descriptor (Lapointe 2011). As scholar Sue Thomas writes, 'in reality, the organic, holistic, evolving eco-system of Web 2.0 connectedness is less like a prettied-up travel brochure and more akin to a messy brackish swamp seething with mutations' (2013, 114).

The Californian Ideology

Returning to the *WEC*, Turner has demonstrated how Brand's thinking would extend far beyond the short-lived communes project, to play a pivotal role in how information technology was envisaged as a tool with which to re-design society. This is echoed in Roszak's *From Satori to Silicon Valley* (1986) and John Markoff's *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry* (2006) which also demonstrate the importance of countercultural thinking on network and computer technologies. While the *WEC* was only regularly published for four years, with a few special editions in its wake, its and Brand's continued influence on culture was significant. Over the subsequent thirty years, Brand brought together individuals from two sides of the 1960s San Francisco scene: Silicon Valley's burgeoning technology industry and its alternative bohemianism. Brand saw the personal computer, as well as a range of other media, as full of 'subversive possibilities' (Kirk 2007, 106). He was a hippie who had a profound respect for the work of innovative technologists including Apple founders Steve Jobs and Steve Wozniak (Kirk 20017, 106). Indeed, Jobs once described *WEC* as 'Google in paperback form' (2005). The cross-fertilisation of these two fields was made possible by the way in which computers such as Apple were positioned as part of the hippie movement. As Kirk writes, 'the very naming of these products suggested that these machines were somehow more natural than the computers of old' (2007, 106).

Although Brand had very little direct contact with computers until this point, as Turner argued, it was during the late 1980s and early 1990s, Brand would become an influential spokesperson for a vision of the internet in which countercultural values were embedded. In

the 1970s and 80s spin-offs of the *Whole Earth* were produced by Brand's *Point Foundation* including the short-lived *Whole Earth Software Review* (1984–5). This publication was aimed at the computer literate, and like the *WEC* before it provided a guide to the best tools available (Turner 2006, 128). In 1985, he, along with a group of colleagues, would establish the 'Whole Earth 'Lectronic Link', or WELL, one of the first and most influential virtual communities. Along with John Perry Barlow, Esther Dyson, Kevin Kelly, and Howard Rheingold, Brand was a driving force behind the launch of *Wired* magazine in 1993. It has been argued that *Wired* moulded digital culture and became 'the monthly bible of the "virtual class."' (Barbrook and Cameron 1995). Turner points out that for the founders of *Wired*, networked technologies and the personal computer not only provided a technological revolution but would transform work as a whole. 'The suddenly public Internet appeared,' he says, 'to be both the infrastructure and the symbol of the new economic era' (2006, 1).

This new economic era, or 'New Economy', emerged in the mid-1990s during the dot-com boom, describing the shift from a manufacturing to a more service-based economy based on digital systems. While there is some debate as to this economy's precise modus, at least one characteristic of its culture is clear. Ideologically, the New Economy conflates the seemingly contradictory ideals of countercultural dropout with techno-utopian capitalism. Although the full extent of this history was researched and demonstrated by Turner, this form of cultural entanglement was first outlined by Barbrook and Cameron in their essay 'The Californian Ideology' (1996). Here, they discussed how the roots of Silicon Valley's belief structure were embedded in a strand of counterculture that embraced both technology-driven environmentalism and anti-establishment individualism. This belief system does not run down traditional political lines but instead incorporates aspects of left- and right-wing dogma to construct a new ideological structure for the 'dotcom era.' On this note, they observe:

> At this crucial juncture, a loose alliance of writers, hackers, capitalists and artists from the West Coast of the USA have succeeded in defining a heterogeneous orthodoxy for the coming information age: the Californian Ideology. This new faith has emerged from a bizarre fusion of the cultural bohemianism of San Francisco with the hi-tech industries of Silicon Valley. Promoted in magazines, books, tv programmes, Web sites, newsgroups and Net conferences, the Californian Ideology promiscuously combines the free-wheeling spirit of the hippies and the entrepreneurial zeal of the yuppies (1996).

According to Barbrook and Cameron, the Californian Ideology combines individual entrepreneurism and radical community-based politics, but rather than individual replacing

communal belief structures, the two are entangled in a contradictory knot of social action and individual gain. Despite community being a key concept for Brand and other technologically inclined hippies, in this new era the individual becomes paramount. As Marxist historian David Harvey suggests, 'the worldwide political upheavals of 1968… were strongly inflected with the desire for greater personal freedoms… But the '68 movement also had social justice as a primary political objective. Values of individual freedom and social justice are not, however, necessarily compatible' (2005, 41). The political and social action that was paramount to the collectivism of counterculture has waned, becoming eclipsed by the pursuit of individual freedom.

Perhaps more than others, Barbrook and Cameron concentrate on how craft is employed in this discourse. They use the term 'hi-tech artisans' — referring to middle-class workers within the new economy — to demonstrate how the DIY hippie culture has been adopted by new media technologies. They propose that:

> The Californian Ideology offers a way of understanding the lived reality of these hi-tech artisans. On the one hand, these core workers are a privileged part of the labour force. On the other hand, they are the heirs of the radical ideas of the community media activists. The Californian Ideology, therefore, simultaneously reflects the disciplines of market economics and the freedoms of hippie artisanship (1996).

Of course, art, artisanship and creativity were all important parts of commune culture. Brand, for example, was part of the USCO media art collective, and several prominent West Coast artists of the period were embedded in the *Whole Earth* community. These affinities are reflected in Barbrook and Cameron's term 'hi-tech artisan.' In turn, they define the Californian Ideology as a 'mixed economy, the creative and antagonistic mix of state, corporate and DIY initiatives' (1996). We can see this idea continue to proliferate today in the way creativity is discussed across the digital economy.

As discussed in 'Nimble Fingers II', Richard Florida's concept of the 'creative class' has become central concept of the New Economy. However, what Florida forgets, but Barbrook and Cameron do not, is that there are winners and losers in the New Economy. Many in the Californian virtual class, the latter argue, fail to notice their reliance on the menial work that keeps their lives frictionless. As they point out, it is often people of colour who carry out this low-valued, manual labour, who 'work in their factories, pick their crops, look after their children and tend their gardens.' Barbrook and Cameron argue that many who have adopted the values of the Californian Ideology do not recognise their lifestyle is built on the labour of

others of differing gender, race and class. The split between the virtual labour of the professional classes and the non-digital labouring workers is a clear example of how technologies extend socio-economic inequalities, which could be described as one facet of the ‘digital divide’ (Chow-White and Nakamura, 2012; Servon; 2002; Van Dijk; 2005).

This chapter considers how the *WEC* and the countercultural movement redefined the intersection of technology, ecology, and personal agency. Spearheaded by Stewart Brand, the *WEC* emerged not just as a compendium of tools and ideas for self-sufficiency, but as a ground-breaking document that reimagined the computer and other advanced technologies as integral to a sustainable, self-sufficient lifestyle. What it also demonstrates are the contradictions at the heart of counterculture and how a movement that often eschewed mainstream technological advancement inadvertently laid the groundwork for a new paradigm in digital technology.

In this account, I have highlighted how craft plays an important role in resolving the conflicting principles of militarism and anti-establishment values in computing more broadly, which in turn impact our shifting relationship to work and technology today. From a contemporary perspective, where computer technology is perceived to have eclipsed printed matter, it is equally important to remember the part publications and other print processes played in a new ideology based on, individualism, environmentalism and cybernetics. Be it marketing imagery, mimeographic or computer plotter prints juxtaposing pastoral and computational imagery, or the *WEC* itself — print played a crucial role in shaping this new ideology.

vegetal matter

Figure 41 *Ponics*, 2018. Exhibited in *Noon*.

The exhibitions featured in *Nimble Fingers and Green Thumbs* consider the gallery as a site for reimagining concepts of gendered digital labour. Each one presents itself as a fictional farm, garden and allotment, overlaid with technological imagery. In *Noon* and *Lowlight*, cabbages and moths are positioned around pseudo-mainframe sculptures either through cabbage patch-like sculptures (*Ponics*, Figure 41) while in *Hothouse,* temporary farming structures akin to soft fruit cages are covered with microchip diagrams and filled with synthetic mushroom farms and palm fronds. In this section, I will discuss the specific theoretical underpinnings for positioning vegetal motifs within this project. My decision to do so draws on the history of gender in the botanical sciences and feminist and materialist theory. Following this overview, I will explore the technical and contextual rationale for the specific vegetal motifs employed for the artworks produced.

Historically, botany was one of the few scientific fields that women were able to take part in. In many instances botanical studies were even encouraged and several women made significant contributions to the field. Anna Atkins, for example, published the first book of

photography in 1843, which documented varieties of algae in the British Isles using an early cyanotype method. Similarly, Anna Maria Sibylla Merian was a seventeenth-century entomologist and botanical illustrator whose scientific observation of caterpillars was instrumental in developing the concept of ecology. In her work, Sibylla Merian wanted to counter the commonly held belief that insects were 'born of mud' by demonstrating how their lifecycles, or development from larvae to adult, were dependent on their environment and food. By doing so, she became an early exponent of the now widespread opinion that these elements should all be viewed as part of a single interconnected system (Etheridge 2011). The botanist Jeanne Baret became the first woman to circle the globe in 1769 collecting over 6000 plant specimens, all the while disguised as a man, rather contradicting the assertion that botany was an area where women were welcomed and encouraged. In the twentieth century, Janaki Ammal, Katherine Esau, and Ynés Mexía all made significant contributions to botany through cytology, plant anatomy and the retrospective collection of botanical specimens (Oak Spring Foundation 2020).

The legacy of female herbalists and gardeners and the floral and garden imagery in myths and literature in Western culture had, by the eighteenth century, meant that 'botanical work was considered to be very much imbued with feminine attributes' (Howard-Borjas 2001, 3). So-called feminine attributes such as 'patience' and 'passivity' were perceived as necessary in the study of the natural world. Comparisons to embroidery and needlework were developed, making botany and entomology 'appropriate' for women.

Such associations have posed problems for twenty-first-century feminists. Much like handicrafts, the associations between femininity and nature are not only characterised as cliché but frame how we naturalise and envisage gender categories. As feminist theorist Stacey Alaimo writes: 'the dual meanings of nature converge at the site of woman, fixing her in a vortex of circular arguments: woman is closer to nature and is thus inferior; woman is inferior because nature has made her so' (2000, 3). As feminist discourse developed in the twentieth century, these associations would result in a 'flight from Nature', with particular groups of feminists rejecting the essentialist associations between nature and women. However, as Alaimo argues, this had a contradictory effect. Describing this, she writes that 'by attempting to disentangle "woman" from the web of associations that bind her to "nature"; … nature is kept at bay — repelled rather than redefined…' (2000, 4).

Nonetheless, there are other ways that this relationship might be pictured. By comparison, new materialist and posthuman thinking affords a way to reimagine nature through an alternative ecological lens. In the work of thinkers including Braidotti and Haraway, the

falsehood of an ontological split between nature and culture, as exemplified by Haraway's portmanteau 'naturecultures', is recognised as gendered, racialised and colonial in its effect (Braidotti 2011; Haraway 2016; Plumwood 1993). Instead, in these theories the entanglement between these forces is formed anew. Remarking on the same desire to regard these forces as intermeshed in one another, Alaimo has stated 'nature is agentic — it acts, and those actions have consequences for both the human and nonhuman world' (Alaimo and Hekman 2008, 5).

As media theorist Sean Cubitt and others have made clear, a historical perception of the environment and technological media as separate or antithetical to one another is an ideological construction. Cubitt highlights that there is a lingering tendency to split these categories, saying 'the dominant utopian mechanism today is technology, and its counterfaith is Gaia.' By contrast, what an investigation into the materials or fabricating systems employed in the production of digital technologies exposes, he writes, is a 'mutual dependence of human, natural, and [the] technological.' It is in this intermeshed relationship that 'there is a utopian orientation toward a future overcoming of their tripartite separation' (2017, 6; Ensmenger 2018). Just as this project employs ecological imagery to undermine the persistent perception of a split between technology and the natural world, it in turn brings into question the implicit gendering of this binary. To see the way in which new material thinking can reimagine the cultural constructs of nature and gender is a core principle around which this research project has been constructed.

Figure 42 *Ponics* (detail), 2018. *Noon,* David Dale Gallery & Studio.

Figure 43 *Lowlight (pink)* 2018. Exhibited in *Lowlight*.

In this project, I used a range of motifs based on vegetal and plant life as a means of reflecting on such concerns. In *Noon* and *Lowlight*, I employed the image of a cabbage as a stand-in for bodily agency in technological systems. In the sculpture *Ponics* (Figures 41, 42, and 43) they are displayed on a grid of white pipes, assembled to follow the logic of contemporary farming hydroponic structures. A series of lampshades, also titled *Lowlight,* exhibited in both exhibitions, were based on the same motif. These lamps hung from electrical cables in an outdoor space in *Noon*, and from the gallery ceiling in *Lowlight*. To expand this repertoire of organic forms, in *Hothouse* I employed imagery of mushrooms and palms inside the three mesh-covered cuboid structures built for the exhibition (Figures 44 and 45). All the works featuring vegetal motifs were produced using a specialised technique I developed while working at DCA Print Studio. These works employed acrylic plastic, undermining the ecological connotations of the forms depicted. Using plastic was a deliberate decision not only to draw out the false binarisation of mass-production and handmade items in global production but also the blurred relationship categories had in countercultural crafts (discussed in **tie-dye, patchwork and macramé).** Making replicas of real-world objects through a variety of digital capture and print technologies became akin to a feedback loop, in which an original was dismantled and subsequently reformed through reproductive means.

To create a facsimile of these vegetables I used screenprinted and laser-cut plastic. Prior to commencing this process, the chosen subject was placed on a flatbed scanner to generate an image to be printed. For the works based on mushrooms, this procedure was relatively straightforward, but for the works that reproduced cabbages, this required scanning and fabricating each leaf individually, before recombining them as a nest of forms. From each of the scanned images, I created two file types. One of these was used to print the image (a raster file), and the other was used to cut the outline of the leaves (a vector file). The laser cutter followed the vector file to cut out each silhouette individually. The raster file of the same vegetable was then screenprinted onto plastic sheeting. This flat version of the vegetable was given three-dimensionality by heat-forming the plastic, producing a more faithful rendering of its original form. For the works depicting cabbages, these clusters of leaves were then mounted onto the pipe armature to create *Ponics,* or fastened onto a lampshade ring in the case of *Lowlight*. Utilising a similar gesture of framing these printed motifs, in *Hothouse* the formed mushrooms were secured to a bundled wood pile, or into the bark floor of the cage-like structures. One of the key aspects of the impact of this mode of presentation lies in how jarring a synthetic material like plastic, printed with photographic approximations of organic forms, appears when placed directly in contrast with the natural environment it is attempting to depict.

I chose to employ this production method across several works, as it succinctly mirrored the theoretical aims of the project as a whole. As a method it incorporated a range of print technologies, from analogue screen-printing to hand-forming, and digital scanning and cutting enabled by computer software and advanced hardware. These are processes that contain a range of both amateur and professional significations demonstrating the overlapping and variable relationships between these forms of production. My approach runs parallel to remarks made by the craft historian Stephen Knott, who has argued that we must question established categories of professionalisation, suggesting that 'the characteristics of amateur labour … are inherently elusive and complex,' and within making there can be an 'oscillation between "amateur" and "professional" at any given time' (2015, xiv-v). The technique used to produce these vegetal forms does not attempt to juxtapose the processes involved but rather aims to combine them seamlessly as a single procedure.

The specific choice of the vegetables displayed across these exhibitions was based on their symbolic relationship to feminised labour and digital culture. Mushrooms, for instance, have been suggested to signify a moment of collapse between professional and amateurism in global capitalism. Reflecting on the subject, social anthropologist Anna Lowenhaupt Tsing has argued that the international matsutake mushroom market exemplifies the precarious employment structure of late capitalism more broadly (2015, 4). Tsing suggests that, as matsutake mushrooms are unable to be commercially farmed, those who harvest them are forced into labour types which range from supplementary or hobby income to poverty-inducing, precarious working conditions. Moreover, rather than succumbing to clichéd ideas of 'nature' and 'femininity', mushrooms provide a means with which to picture forms of existence outside these simplistic essentialisms. As the curator Francesca Gavin highlights, 'mushrooms are not just beyond the gender binary: they have 36,000 sexes' (2021).

Figure 44 *Hothouse* (detail), 2019. Hospitalfield.

Figure 45 *Hothouse* (detail), 2019. Hospitalfield.

Figure 46 Constance Spry, *Chard Arrangement in Vase*, ca 1935.

Cabbages, on the other hand, were employed in these artworks for their simultaneously lowly and decorative connotations. The flamboyant ornamental qualities of the vegetable can be detected in seventeenth-century paintings celebrating the lives of working people. For example, Sir Nathanial Bacon's *Cook Maid with Still Life* (1620) and Tommaso Salini's *Young Peasant with a Flask* (1610) both focus on the extravagant potential of the leafy green. The ornate qualities of the cabbage however are perhaps nowhere better demonstrated than in florist Constance Spry's vase arrangement of chard. Here, the vegetable appears elevated to the realm of the decorative, just as vibrant as any rose (Figure 46). Organic and botanical forms have long been a mainstay of the decorative arts, and the cabbage motif has been specifically utilised since the eighteenth century in ceramic bowls, plates and dinnerware by companies such as Bordallo Pinheiro and Majolicaware (Online Store). Art historian Alexandra Harris writes that across culture 'the cabbage has been variously conceived as extravagant, magical, curative, plain, pure, noxious, smelly, sublime and ridiculous' (2010). These varied associations are something that I have sought to exploit, as they parallel one of the central assertions of this thesis: that the value of objects and individuals is contingent on the context they occupy.

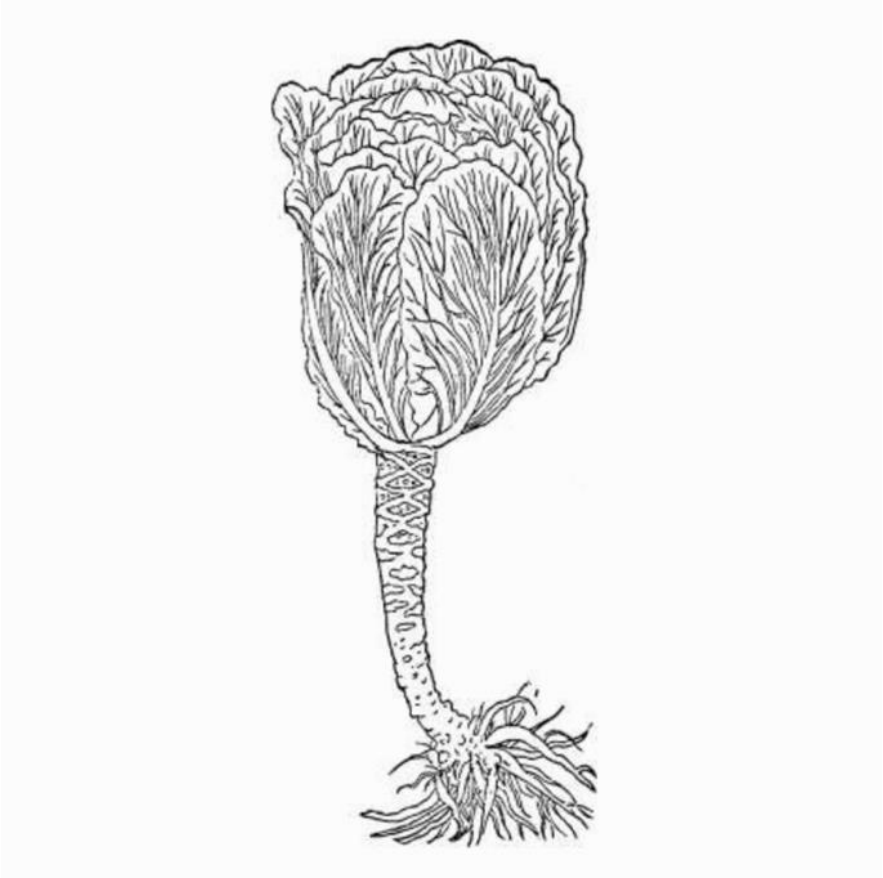

Figure 47 Woodcut from Leonhart Fuchs, *De Historia Stirpium*, ca 1545.

Another reason that vegetal forms appeared to be a fitting subject to explore arose from the longstanding role they play in the history of printmaking and, by extension, the print studio. In the classic text *Prints and Visual Communication* (1953), William Ivins catalogues the relationship between image production and technology as it unfolds through the ages, by tracing its depiction of organic imagery. Ivins's account outlines the development of sixteenth-century 'herbals' in which he claims the standards of botanical illustration were set. Such illustrational standards, Ivins argues, are based on a complex interaction of visual syntax and technology at this time. Early printed images of vegetal forms were often symmetrical, thick-lined woodcuts. Such oversimplification of subject matter can be observed in plates of violets as reproduced in the *Grete Herbal* (1525). However, as print technology rapidly improved these illustrations would feature more delicate lines, which artists used to capture what has been called 'portraits' of individual plants. Features of these illustrations included individually wilted leaves or damaged stems, as seen in Otto Brunfels' *Herbarum vivae eicones* (1530). The image with which Ivins concludes his argument depicts a cabbage taken from Fuchs' *Herbal* (Figure 47). This celebrated volume is important in the history of

print as it includes three portraits of those responsible for the work: the artist who made drawings from the plant specimens, Albert Mayer; the artist who transferred these drawings to the blocks, Heinrich Fulmaurer; and the woodcutter himself, Hans Rudolph Speckle. For Ivins and others, the importance of this book is crucial in the development of European scientific illustrations, not only because it was the first time the different artists were individually recognised, but due to its creation of a standard production method for illustrations to follow: the drawing of an image, its faithful transfer, and finally its incision into a wooden panel. As Ivins states, 'it was a deliberate step away from the particular to the generalised, and as such is of the greatest importance in view of the subsequent history of visual information and the thought based on it' (1953, 46–7) In effect, the development of botanical illustration shaped the way in which visual information, more broadly, could be disseminated.

Across the three exhibitions presented in this project, the farm motif was employed as a container that both confirmed and rejected the gendered associations. Agriculture is often associated with control and masculinity, while domestic food production is just as likely associated with femininity and the home. Indeed, it is considered a determining factor in historically established gender relations. For example, according to sociologists, the widespread adoption of the plough is one of the greatest indicators of societal beliefs in gender inequality (Alesina, Giuliano, and Nunn 2012). While there are obvious links between labour and farming, its use as a metaphor for digital technologies may seem more oblique. However, it bears remembering that language from agricultural practices is used across our contemporary digital economy. Companies that employ freelance workers to create text-based web content are known as 'content farms' and social media platforms, such as Instagram and Facebook, are described as 'walled gardens' (Kinsey, 2022).

The term *Hothouse*, the title of the exhibition at Hospitalfield, is a colloquial term for greenhouse. On entering one of the larger structures presented in this exhibition, plastic palm leaves seem to grow from metal pipes overhead. This environment poses as a surreal version of a nineteenth-century glasshouse, at a point when a trend for raising rare, exotic, and tropical plants indoors in Victorian Britain reflected the Empire's considerable colonial reach (Heichelbech 2018). Rather than stemming from trailing vines, the palms branch at regular intervals, appearing from the metal framework of the enclosure itself. Steel rods hold up the plastic leaves, combining technically rendered, faux plant life with real grass and weeds growing below it.

Hothouse referenced ideas of mycelial and root connectivity seen in Brian Aldiss's 1962 science fiction novel of the same name. Here, Aldiss describes a future Earth in which humans are no longer the apex predator, and the globe has been overrun by vegetation and plant life. In this account, Aldiss creates a dystopian vision in which climate change has forced humans to succumb to the power of the natural world. This early example of 'eco-sci-fi' paints a picture of a world of connectivity, imagined through jungle root systems and advanced fungal life forms. The works in *Hothouse, Noon* and *Lowlight* combine to function like these ecological structures or even cybernetic systems. Simon O'Sullivan observes that an important aspect of fictioning is the relationship between the accumulation of motifs, which 'itself becomes a material insofar as the accretion happens through time…across a work, or across multiple work.' The result, he suggests, is a 'kind of aesthetic ecology… which means the practice has more in common with a series, or again, a scene, than with an object per se' (2015, 84). The individual artworks in these projects can function discretely but, I would argue, through their specific deployment of motifs, processes and materials interact with one another to build a unified whole. It is through this practice, that my organic forms fabricated from non-organic material are speculative devices, much like Aldiss's, through which alternative realities might be imagined. It is here that my approach to exhibition-making aligns most with evolving discussions of fictioning as a method.

In this section, I have traced the rationale for employing vegetal motifs and plant life forms in the exhibitions included in this project. Although the relationship between nature and feminism is vexed, it is precisely because of this contentious connection that they have been employed. Developments in posthuman and material feminist theory have generated space for a dissolution of the nature-culture binary and instead opened new ways of conceptualising ecology. By focusing on specific motifs discussed above for their conceptual, material and contextual connotations, the vegetal motifs stands here with one foot in feminism's past and one in its future. Links to domesticity, decoration and women's history are clear while creating new associations with complex ecological thinking. Print plays a crucial role as a method of joining the technical, synthetic and organic, allowing the forms to cross a range of working methods.

Conclusion: I Never Promised You a Rose Garden

Summary

When considering what *Nimble Fingers and Green Thumbs* proposes, I am reminded of Ada Lovelace. Although I have argued elsewhere in this thesis for decentralising the importance of celebrated individuals, Lovelace's proposition made in 1843 remains relevant. In 'Note A' of her remarks on the Analytical Engine, she writes, 'we may say most aptly that the Analytical Engine weaves algebraical patterns just as the Jacquard loom weaves flowers and leaves' (2012). This comment is typically used to demonstrate Lovelace's visionary understanding of what computer programming could eventually become. However, for me, it evokes the restraints placed upon Victorian women's labour and creativity, and its symbolic containment within botanical and ornamental imagery. Such considerations have become a central tenet of this thesis, which asserts that women's work remains a relevant lens through which to examine digital labour.

For this project, I developed a material feminist methodology based on exhibition-making, fictioning and interdisciplinary research. The written element of my thesis includes case study chapters which draw on research from computer history, feminist theory, Science and Technology Studies (STS) and sociology. By overlapping narratives of women's early involvement in the computer industry with the evolution of countercultural thinking, what is demonstrated is that the computer industry has long relied upon the metaphor of craft to perpetuate gendered forms of exploitation. The varied instances in which this has occurred, however, show anything but a consistent approach. What becomes most clear when analysing several case studies in conjunction with one another, and the principal reason for doing so, is to expose the inherent mutability of these conditions.

'Nimble Fingers I', emphasises how domestic handicrafts such as knitting and needlework naturalised computer operating work for women, associating it with secretarial and administrative labour. However, as computer work became more desirable, the reverse situation occurred: the language of the artist and craftsperson was used to form the stereotype of the masculine software engineer or hacker. In 'Green Thumbs I', the complex situation faced by women who innovated computing in the military and business sectors was analysed. This enquiry demonstrates how women had to conform to masculine stereotypes to bypass the systemic discrimination they faced in the field. This chapter charted the development of the 'bug' as a metaphor, shifting the focus of attention from a few individual

innovators to many unseen female computer workers who have gone unrecorded. ‘Nimble Fingers II’ explored women’s roles in integrated circuit manufacturing in the US and Southeast Asia. Echoing ‘Nimble Fingers I’, this chapter recounts how during the 1960s Navajo women and other women of colour were naturalised as electronics factory workers through associations with handicraft, particularly indigenous weaving. Finally, ‘Green Thumbs II’ focussed on how printed matter employed handicraft terminology to shift the cultural identity of the computer. The *Whole Earth Catalog* used DIYism to demilitarise the computer's image, reforming it as a tool akin to a hammer, axe, or publication. While *WEC* was not a computer industry publication, it was perhaps the most successful document in marketing the machine and transforming its image. This chapter highlights how ecosystems and environmentalism became part of a new image of technology, one that associated the computer with forms of individual creativity. Together, these chapters show how metaphors from craft, ecology and environmentalism have been used to naturalise the computer, resulting in gendered labour hierarchies which continue into our digital age.

Situated between these case studies are accompanying sections which reflect on how the specific materials and motifs from the ‘nimble fingers’ of handicraft and the ‘green thumbs’ of horticulture are employed across the exhibitions I have produced as part of this project. These sections examine how the visual metaphors used in my artistic practice are rooted in and expand upon the histories I am outlining in the case studies, and serve to materialise those same concerns by other means. In each section, I reflect on the aesthetic routes and historical influences that led to the production of these artworks, acting to foreground contextual aspects that are otherwise tacit.

Across the exhibitions, *Noon, Lowlight* and *Hothouse* mainframe computers were a central motif. In **mainframes**, I outline the rationale for materialising digital labour through handicraft processes and make comparisons between minimal sculpture and the visual appearance of early computers. With **moths**, I discuss the development of the horticultural motifs within the project. I show how the motif of the moth in the work *Saboteur* intersects with other works in the exhibitions *Noon* and *Lowlight*, as a way of imagining the gallery as an ecosystem. The section **microchips** outlines the importance of print techniques in chip manufacture and the rationale for the blue and white geometric pattern employed across the surface of the cuboid structure in *Hothouse*. The motif of the circuit links together cyberfeminist histories, women’s work with microchips and textiles, as well as ecology and whole-systems thinking employed in computing. In **tie-dye, patchwork, and macramé**, I explored how craft techniques form a bridge between feminised handicraft and DIY or countercultural crafts within the works *Irrational Cabinet I, II*, and *Hidden Hardware*. Here, I propose the potential for these

techniques as unique fictioning or worldmaking devices, with which counternarratives can be formed. Similarly, **vegetal matter** unpacks the specific motifs of the cabbage and mushroom used in *Ponics, Lowlight*, and *Hothouse*. This is to show how they connect to the idea of a garden, allotment, or farm, as a place in which gendered associations with technology can be renegotiated.

In the exhibitions *Noon, Lowlight*, and *Hothouse*, which comprise the Portfolio section of this project, these elements and narratives coalesce and build to create what I have described as 'counterenvironments.' Counterenvironments are fictionalised versions of the exhibition space, which integrate historical research and socio-cultural narratives through a specific combination of metaphorical figuration. This approach envisages the exhibition space as a dynamic setting for critically examining the intersections of gender, labour, and technology. By drawing from interdisciplinary research, alongside existing metaphors from craft and feminist art, these exhibitions challenge conventional narratives, to create spaces which encourage the imagining of alternative pasts and different futures. It is my claim that this practice-based research contributes to a greater understanding of the subjects it addresses, as it serves as a space, quite unlike that created in conventional scholarship, in which these might be productively brought together. In turn, this project adds to an ongoing discussion around methods such as fictioning and exhibition-making within contemporary art, incorporating a set of concerns that have not been present in those until this point.

Key Findings and Contribution to Knowledge

As argued in my introduction, I consider a definition of craft to be under-developed in post-cyberfeminist discourse. I believe this shortcoming stems from a contemporary desire to evade charges of gendered essentialism levelled at figures such as Plant. My initial impulse to reconsider craft was in response to a feminist critique of digital labour as a presumptively 'immaterial' form. Here, craft was an effective method with which to 'rematerialise' this supposedly immaterial labour. Overall, computing is often cast as either a tool of liberation or exploitation within cyberfeminist discourse. Yet, my research has shown that the digital labour we carry out today does not occupy a singular position. Instead, its characteristics closely mirror the specific duality of handicrafts, cited earlier by Rozsika Parker as, 'a source of pleasurable creativity and oppression.'

Following and expanding upon technofeminist discourse, this project consciously engaged with tracing the links between the history of women's work and computation. However, the

important role that various, often competing conceptions of craft played in the construction of the computer only became apparent as the research progressed. A central aim was to highlight recent historical research that extended Plant's entanglement of computers and women's work. Although I understood craft to have contributed to the development of computation, I did not expect its role to be so integral. By looking at the work of scholars included here, such as Janet Abbate, Nathan Ensmenger, Mar Hicks, Lisa Nakamura, Andrew Kirk, and Fred Turner, I have shown how imagery and language from the world of craft were used to shape information technology. It was through this research that the metaphors for digital labour of *Nimble Fingers and Green Thumbs* were formed.

The case studies in this thesis detail how employment for women in computing during the twentieth century was a double-edged prospect. Opportunities in the military, offices and factories were not only welcomed but often presented as creative. New roles working with computers, from their production and programming to operation, were marketed to women through an association with domestic tasks, and handicrafts such as needlework, knitting, and weaving. This cast their employment as akin to a leisure activity — framing their work as variously empowering, deskilled, and amateurish whenever it proved most convenient. Historical examples demonstrating how craft has been employed to both devalue and praise labour in the computer industry show how, as scholar and activist Trebor Scholz puts it, with innovative technologies 'there are new forms of labour but old forms of exploitation' (2013, 2).

At the same time as this was taking place, ideas drawn from the field of cybernetics were conditioning an understanding of how the natural environment might function as a balanced ecosystem. While at first glance technology is easily positioned in opposition to nature, across these case studies we find that, in the development of computing, ecology was a crucial component with which to naturalise the computer. With ideas popularised from cybernetics, the boundaries between animal and machine were dissolved and comparisons between natural and mechanical systems were drawn. These ideas, alongside the shift to environmentalism and DIYism in countercultural politics, altered the image of a computer from a symbol of the industrial complex into a tool for individual creativity and social expression.

These conditions serve as the underlying basis for my approach to the practice-based research presented here. Seeking to depart from what I consider to be a technofeminist over-reliance on textiles as a metaphor to speak to the gendering of computing, this project

intertwines a deliberately heterogeneous range of methods from the domains of print, handicrafts, and digital technologies.

One of the main priorities of this project was a practical engagement with more traditional print techniques and the innovative processes available at DCA Print Studio. DCA Print Studio has pioneered post-digital print practices, incorporating CNC machines, laser cutters, and 3D printers alongside their traditional presses. However, few artists have yet had the opportunity to fully engage with the technical and conceptual potential that this new combination of machines affords. A narrow critical framework in which printmaking is often situated can all too easily ignore print's fertile associations with digital culture. Print processes are used in the production of computer technologies, and prints are often the product of computer software. This dialectical relationship between print and the computer is useful as both can be considered lenses through which to apprehend the other. Although Sadie Plant hinted at the potential of printmaking nearly 30 years ago, its value as a technofeminist technique has been largely overlooked.

I would argue that this project is significant in its employment of analogue and digital print techniques, as a means to pull together craft and technology discourses, but also to raise issues of their gendered connotations. In doing so, my approach reframes printmaking as a method of introducing ambiguity and complexity into a pre-existing framework of feminist practice. This is something that I have argued to be implicit in the history of fine art printmaking and in need of further foregrounding. In my practice, I have emphasised print's inherent utility for approaching the question of gender, something that I have at points explored through the use of vegetal imagery. Artworks such as *Ponics*, *Lowlight*, *Hothouse*, and *Saboteur* use horticultural motifs to speak directly and indirectly to the machines that made them. Combining plant imagery with specific material processes speaks in a less literal manner to the history of women in botanical science and the ecological roots of computer technologies. Early botanical illustrations highlight the importance of print as a medium that intersects with broader socio-economic and cultural factors. Moreover, this points towards the importance of seeing print as a site of cross-pollination. Or, as Luce Irigaray once noted, 'no system is closed. The outside always seeps in...' (1985, 116).

Accordingly, this thesis is marked by a desire to balance detailed descriptions with the broader conceptual aims of the project. To maintain a focus on the social potential of print I have not included overtly detailed descriptions of technical processes. Instead, it deliberately focuses on how processes like laser-cutting, heat-forming and screenprinting are tied to specific social factors. For example, the techniques discussed in **vegetal matter** reflect the professional-amateur readings of the work, mimicking the social dynamics they critique. In

doing so, I have explored the social potential of print through its unique metaphorical and material qualities. This approach actively challenges the existing discourse on print technologies taking it beyond its often-ghettoised state as a technical discipline, and positioning it within broader conversations such as feminist technology studies.

Recognised literature on the computer industry tends to compartmentalise types of employment. One of the goals of my research was to traverse the field, analysing how craft was instrumentalised across different types of work in the computer industry. Echoing craft historian Glen Adamson's invitation, cited earlier, to look 'not just in studios, but in factories as well,' my analysis spans various sites of labour, including military complexes, offices, factories, and domestic space. Building on this research, my approach to exhibition-making in this project has been to blur the boundaries between different sites of work as a way to question labour within the art system. As artist Andrea Fraser has written, within the current hegemony of the art world, it is hard to envision what alternative structures or models could be. Fraser asks, 'can we imagine, much less accomplish, a critique of art institutions when museum and market have grown into an all-encompassing apparatus of cultural reification?' (2005, 278). Staging computer rooms and farming structures within the art venue creates space with which to compare these labour sites. Drawing out their similarities and differences, these arrangements create a system which can reflect upon them, and offer a model of critical engagement by acknowledging that the art venue is itself also a site of labour.

Overall, this project points towards a more integrated field of exhibition-making that not only involves the physical arrangement of artworks, but also a conceptual and thematic position that interweaves historical, social, and cultural narratives. These combined methods allow for a different engagement with the artworks presented, prompting viewers to consider broader social and cultural contexts. Despite the relevance and growing popularity of exhibition-making in contemporary art circles, there is still limited academic discussion on the subject. This project highlights the need for more research in this area, suggesting a gap in the literature that presents an opportunity for further investigation. Key areas for future research could include establishing definitions of exhibition-making, tracing its historical origins, critical reception and analysing its impact on art-viewing audiences. The methodological approach adopted by this project uses the speculative properties of artistic research to visually articulate how these issues interrelate. Across this project, artworks are considered as distinct, individual objects that gain increasing complexity when put into relation to others that form part of the same exhibition. Here, an exhibition is conceived of as a system of interaction where meaning is formed, and narrative is created through the

dialogue between these various sculptural propositions. Consequently, works such as *Ponics* – the synthetic cabbage patch – or *Irrational Cabinet* – the tie-dyed mainframe – can be regarded as both stand-alone gestures and constituent parts of an overall whole. The juxtapositions and underlying affinities that such collisions of artworks produce are the points at which I consider the work to actively embody fictioning as a method.

I have used the term counterenvironment to describe my specific approach to exhibition-making in this thesis. For my purposes, the term comes from computer history, but it is useful also as it implies 'counter' from counternarrative and 'environment' to emphasise a site. This acknowledges and responds to the context of the exhibition while simultaneously presenting an alternative, fictionalised version of that space grounded in historical information. In his argument for fictioning practices Simon O'Sullivan writes, 'the more engaged [art] is, the more it must mirror, however critically (or negatively), its object. Such critique… is trapped by its target, which it must, to some extent, adjust itself in order to engage' (2019, 81). Through the combination of site, linked historical narrative and the deployment of metaphors, I would argue that my approach goes beyond the narrow form of critical engagement that O'Sullivan raises. For example, in *Noon* and *Lowlight*, marketing imagery from 1960s computer rooms is contaminated by countercultural crafts and horticultural imagery. *Hothouse* reverses the process, placing a series of microchip-covered mainframes within a pastoral landscape that the audience can walk inside, encountering farming and botanical imagery.

Reflections and Future Research

As I noted in my introduction, the structure of the thesis essay is unconventional, forming a type of scaffolding or container around the artwork, rather than a traditional linear argument. This reflects the understanding of practice-based research, as outlined by artist and academic Elizabeth Price, in which the thesis must place the artwork at the centre of the project, and aim to reflect the position of what the artwork does in its manifestation (2021). Each distinct element of narrative analysis within the case studies and reflection on the motifs and materials in the intervening sections works in tandem, to create dialogue between the scholarly research and practice as they evolve in tandem with one another. The argument built throughout this thesis is that interdisciplinary research can create new metaphors and material engagements for contemporary art practice.

While I would not claim this thesis makes a direct contribution to the field of computer history, these findings suggest a need for further research. As a long-term resident of Scotland, of particular interest is whether comparable gender relations between craft and computation as those described in the preceding text can be observed in the companies of Silicon Glen (the colloquial term for Scotland's high-tech industry) or more specifically semiconductor factories established in the Inverclyde area. The methodology developed in this thesis, in which historical research fuels an exhibition-making practice, would be further enhanced with original archival-based scholarship, as there is presently limited scholarly research in this area (McCourt 2006).

An engagement with the concept of the computer as a site also pointed out certain limits of my investigation. While gender was a primary concern in this project, the entangled relationship between race and women's work in the factories of the global South appeared in part as a response to the criticisms of white essentialist cyberfeminism discourse. This only made the American and Eurocentric nature of the other case studies I have employed more obvious. Although it remains beyond the scope of this project, there is a clear need for historical and archival investigations to address this imbalance. This points to the importance of Latinx cyberfeminist projects and recent scholarship such as Ruha Benjamin's *Race After Technology: Abolitionist Tools for the New Jim Code* (2019) and Safiya Umoja Noble's *Algorithms of Oppression: How Search Engines Reinforce Racism* (2018), which demonstrate how forms of oppression from the past are being built into contemporary technologies.

One of the major challenges encountered during the research process was determining how much information from the original academic source material I consulted could be incorporated into the final artworks and exhibitions. From the outset, the project aimed to use historical scholarship as a starting point for art objects. Although I am satisfied with the approach developed here, how much of the underlying research can be intuited from the resulting artworks remains an issue for consideration. This issue, I believe, extends beyond my own practice, as is reflective of a broader operative issue within contemporary art. In recent years, the increased emphasis on research within art circles has had profound and multifaceted effects. As artists become more focussed on research, as a form of practical groundwork, it becomes virtually impossible to extricate their research interests from the artworks they produce. For instance, artist's talks, press releases, and other supporting textual materials reveal a wealth of knowledge otherwise not directly visible in artworks. While I would not categorise this either positively or negatively, we must recognise this gap between modes of interpretation that outline artistic research and its outcomes, so as to

accurately gauge its impact. Questions about the significance of this fissure, how much audiences can infer narratives and intent, or whether new techniques are needed to bridge the gap remain open for future research. Specifically, further study is required to determine if this issue is more pronounced in visual art practice-based PhD research, due to its embeddedness in academic research culture and a requirement that such practice be explicitly presented as a form of knowledge production.

Beyond the portfolio of exhibitions presented here, I have continued to explore the themes raised by this thesis in my artistic practice. Experiments with materials and processes conducted in DCA Print Studio over the last few years have come to fruition in several ways. Amongst the most successful of these is the series *Eyeballing* (2020), in which slices of agate are laser-cut with circuit diagrams (Figure 48). These pieces extend upon the deep and often multivalent connections between new age thinking and computing that have preoccupied me in this text. Here, the silicon wafers upon which integrated circuits are etched are replaced with glass-like rock formations, made from volcanic reactions: a material switch that ties geological systems to technological ones. In another body of work, the history of machine breaking and its connection to a gendered history of computing forms the basis for *Shirley* (2019). Consisting of an axe handle mounted to a polyester resin copy of a women's shoe last, this paired the ergonomic design of a functional item with gendered office wear. Elsewhere, the motif of fungi has occupied an important position in several exhibitions that have been realised in the wake of those presented here. One such example produced during lockdown, *Home Grown*, was mounted at Yoshimi Arts Osaka in January 2021 and consisted of mushroom forms each sprouting from the pages of interior design magazines to which I subscribe.

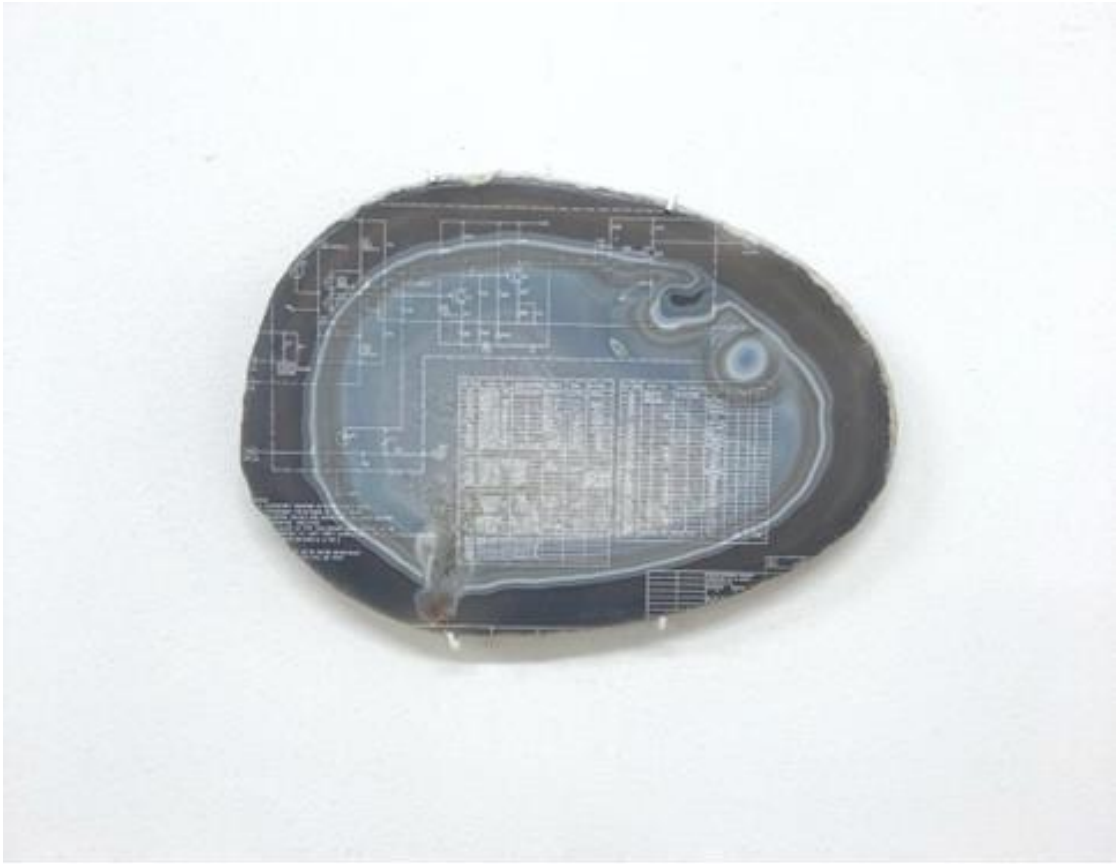

Figure 48 *Eyeballing*, 2020. Laser engraved agate.

Digital labour inaugurates a new epoch of employment. In *Be Creative* (2016), sociologist Angela McRobbie suggests that creativity is one of the key forces driving exploitation in the digital economy. She argues that the 'artist-precariat,' who continues their studio practice with the support of another job because they believe that one day their creativity will pay the bills, is the blueprint for the contemporary worker. These themes of craft and digital labour are woven throughout the exhibitions that are part of this project. As noted, there are limits to how much of a detailed history I have presented here is intelligible in them. However, with the continued importance of personal expression in a post-Fordist economy, drawing links between the arts, both visual and applied, can allow the viewer to consider how ideas of creative autonomy are intricately linked to the digital economies in which they circulate. At first glance, the art gallery might not be the most obvious place to explore contemporary labour conditions. Yet, as someone who archetypically embodies the 'do-what-you-love' worker, I consider art venues a highly suitable location to question such structures. As I have demonstrated in this thesis, the exhibitions *Noon, Lowlight,* and *Hothouse* draw out the ways in which art can be utilised to examine these themes, and to imagine how these systems could be rebuilt.

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NIMBLE FINGERS AND GREEN THUMBS

Appendix

Contents

Motherboard

by Stephanie Straine

Accompanying text to *Noon*

Motherboard
Stephanie Straine

Rachel Adams
Noon
David Dale Gallery, Glasgow
15.09 - 20.10.18

(1) OPERATIONAL LOGIC
In 1941 Grace Hopper (1906–1992) relinquished her tenured mathematics professorship at Vassar College to sign up to the war effort. By 1944 she had graduated first in her Naval class and was awarded the rank of Lieutenant. She was assigned to a computer project, now commandeered by the Navy, led by Howard Aiken at Harvard University.[1]

1 Hopper continued for decades to work as both a naval officer and a pioneering computer programmer. She was one of the oldest active service personnel in the Navy when she retired (for the second time), at the rank of Rear Admiral.

(2) Until 1945, the term 'computer' was 'a job description for a person who performed mathematical operations for large-scale projects.[2] In a February 1945 US defence report, George Stibitz signalled a shift in the terminology's definition, a transposition from human to machine: 'By "computer" we shall mean a machine capable of carrying out automatically a succession of operations of this kind and of storing the necessary intermediate results ... Human agents will be referred to as "operators" to distinguish them from "computers" (machines).'[3]

(3) 'FIRST ACTUAL CASE OF BUG BEING FOUND'
On 9 September 1947, Hopper and her team working on the Mark II computer 'helped to popularize the terms bug and debugging. The Mark II version of the Harvard computer was in a building without window screens. One night the machine conked out, and the crew began looking for the problem. They found a moth [...] that had gotten smashed in one of the electromechanical relays. It was retrieved and pasted into the logbook with Scotch tape. "Panel F (moth) in relay," the entry noted. "First actual case of bug being found." From then on, they referred to ferreting out glitches as "debugging the machine."'[4] This account

2 'About Mark I', accessed 01/09/18: http://sites.harvard.edu/~chsi/markone/about.html

3 George Stibitz, 'Report for the National Defense Research Committee on Relay Computers (February 1945)', quoted in 'About Mark I', accessed 01/09/18: http://sites.harvard.edu/~chsi/markone/about.html

4 Walter Isaacson, *The Innovators: How a Group of Hackers, Geniuses and Geeks Created the Digital Revolution*, New York, 2014,

in itself edges towards the mythical: the term 'bug' had been used since the nineteenth century in relation to engineering glitches; Thomas Edison used it in an 1878 letter to mean 'technical error.'

(4) This incident, however, lodged firmly in the collective imagination. The remains of the moth in question have been preserved, first in the group's logbook at Harvard, and subsequently with the document's transfer to the Smithsonian's National Museum of American History in Washington, D.C. Its tiny form, trapped against ever-yellowing adhesive tape, appears now as if preserved in a sliver of amber.

(5) Rachel Adams started using moths in her work because of Grace Hopper, drawn to the bodily potency of the moth 'computer bug' anecdote. While it has assumed the character of an origin story for this now common terminology, the events merely literalised a figure of speech already in use. As the logbook records, this particular moth actualised the metaphor to enact a physical, concrete disruption ('first actual'). The moth inside the Mark II computer stopping it from working, but here – in this room – this quasi-apocryphal tale is reinvented. What is synthesised in this new account of bug and machine, comprised not of words but instead a collection of objects made and assembled for one space? Rachel Adams has envisaged this exhibition space as a total environment, comprised of three fundamentals: craft (and those processes and materials associated with it, such as fabric, dyes and macramé); industrial technology; and finally nature. How these three elements interact with each other is the subject of this space, and its history.

(6) In 1947 Grace Hopper witnessed the assimilation of nature and technology that produced an unexpected rearrangement of power relations, summarised by Adams with the phrase: 'Nature is the saboteur.' Nature holds the power; it has its own strategies of action and counter-action. Let us remember that, as Bruno Latour once said, 'An object that is merely technological is a utopia...'[5] Correspondingly, an object that is brought to the condition of nature, while remaining a material and technical hybrid, offers a glimpse of production that is equally hand- and machine-made, both and neither, evading binary constructs.

(7) TECHNOLOGY'S GENDER
Commander Howard Aiken, director of the Mark I and Mark II computer projects at Harvard, many years later would describe Lt. Hopper as a 'good man.' The highest compliment he could give Grace Hopper was to erase her gender, or rather, to reallocate it.

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excerpt accessed 01/09/18: https://news.harvard.edu/gazette/story/2014/12/grace-hopper-computing-pioneer/

5 Bruno Latour, *Aramis or the Love of Technology*, Cambridge, Mass., and London, 1996, p.viii.

(8) DEGREE OF DISORDER
Is this installation environment a closed system, and therefore one which invites entropy? Entropy is the tendency of all closed systems to become inert, having lost the ability to uphold a particular state. The computer in this room is both an ordered, rigid and geometrically coherent structure, and a mess of cables, an entanglement that resists order and lurches toward decay. It is both a technological entity and its apparent opposite, a rich, plush furnishing – something luxuriant and tactile, offering us macramé, the craft of knot tying, one other form of connective circuitry. (And a leisure pursuit shared by sailors and housewives alike.) It demands to be touched, to relate to the body, while also resisting the human realm. The computer is a machine, but we cannot know what it really does; what function it performs. It is – in effect – subject to what Robert Smithson would call, embracing the vocabulary of entropy, 'monumental inaction.'[6] The messy, fibre-based innards reassert its handmadeness as if challenging the assumption that computers must be sleek, cool and elevated beyond the human touch, while still engineered to tap into the human desire for acquisition (of soon-to-be consumer products) on the basest bodily level.

(9) THE MOTH BREAKS THE SYSTEM
In this room, the moths' wings appear like a Rorschach test. Randomly generated digital splatter is produced using Photoshop, then the pattern is flipped, traced and cut into vinyl stickers. Resembling both the cabbage moth and the pepper moth this new species is born in code. Memorably, industrialisation in northern Europe caused the pepper moth to invert its features, from white with black smudges to become black with white smudges, so that it could blend in with newly sooty trees. The adaptation of this reversal speaks to the technology-like 'updates' of nature: the evolutionary impulse to survive under new conditions by upgrading your hardware, be that IBM computer cabinetry or the pattern of a moth's wings.

(10) INSERT ONE: 'RAVENOUS INVADERS'
The 1974 film *Phase IV,* directed by graphic designer Saul Bass in his only feature, unfolds a scenario in which nature – ants, specifically – controls, disrupts and co-opts humanity and technology in equal measure. Turning the tables on our assumed hierarchies, the tiny insects (terrifying en masse) assume a dominant position in the Arizona desert's ecosystem. The film shows us the ants' newfound ability to communicate with each other, across species. There is a corresponding 'biological imbalance' – the ants' predators are dying out. What remains, in this place, of the unbuilt and abandoned 'Paradise

6 Robert Smithson, 'Entropy and the New Monuments,' in *Artforum* (June 1966), reprinted in *Robert Smithson: The Collected Writings*, ed. Jack Flam, Berkeley, Los Angeles and London, 1996, p.12.

City' housing development, is just a parched grid. It is the apocalyptic American Dream, charred and desolate like a nuclear test site. The film's score is atonal, abstract and suggestive of computer beeps, with squeaking, high-pitched sounds for the ants' collective workforce.

Anthills assume the proportions of monolithic towers – like oversize CPUs, controlled not by a circuit board but by the hive mind and its queen: a literal motherboard. The film's camerawork consistently elides the ants and the humans; their bodies are given an equivalency. The ants are described by one of the film's human protagonists as 'individual cells, tiny functioning parts' – like the components of a technology they are here to study. The ants are framed technologically as much as the computers are, and they take over the scientists' field lab with apparent ease: chewing through a cable to disconnect their essential air conditioning system, upon which both man and their machines rely.

With this act of sabotage, the insects occupy machinic territory. Of the two scientists, James starts to 'decipher the ant language' from the sounds recorded, attempting to communicate with them, while Ernest believes that he can 'educate this power'; an almost colonial attitude of assured domination over the ants. In reality, it is the humans who are the bugs in the ants' social and environmental machine; it is humanity that needs to be 'debugged.' The film ends with the humans becoming host bodies for the ant colony, James uttering the words: 'We were being changed and made part of their world. We didn't know for what purpose. But we knew we would be told.'[7]

(11) Rachel Adam's single-room installation fails to confirm what purpose it serves. Its components allude to productive systems of business and farming, but without clear articulation of an ultimate objective. From the lamps to the desk to the low structural field harbouring cabbages, it presents a concept of labour lacking confirmation or fixity. Some elements appear recognisably office-based, while others gesture towards industry outdoors. This room's machine hub is a green-on-green tie dye fabric, panelled in reference to IBM's design shift of the mid-sixties, when computers stopped looking like domestic appliances and began to take design cues from Cadillacs, which is to say, the ultimate object of consumer desire. In 1964 IBM launched their System/360 model, a room-sized computer mainframe available commercially in five standard colours.[8]

(12) The welcome desk of this space is a custom-built construction of Formica on plywood. It has a precise,

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7 James R. Lesko (Michael Murphy), in *Phase IV,* directed by Saul Bass, Los Angeles: Paramount Pictures, 1974.

8 See IBM's history of the System/360, accessed 09/09/18: http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/system360/impacts/

factory-built finish. If its labour isn't visible, is it still quantifiable as such? The desk is home to a series of holes drilled by CNC – computer numerical control – that appear like a punch-hole or ticker-tape pattern, suggestive of clocking in and clocking out, a visual manifestation of our physical labours as marshalled by working time. It's also a reminder of the electro-mechanical punch tape operations of the Mark I computer. This trail is an absence that stands in for the hours worked, the labour given up or rendered whole, a transfer of time, energy and matter from individual to a collective, corporate or otherwise variously productive end point. Looking around the room we might also read these incongruous holes as evidence of caterpillar consumption. The holes indicate a lack, a loss that is also indicative of sustenance achieved by the insect on its way to becoming a cabbage moth. All that energy has to go somewhere.

(13) HEAT DEATH
'The Heat Death of the Universe' is a short story by Pamela Zoline, first published in 1967 and widely considered to be one of the most innovative (and genre-defying) contributions to the sci-fi genre at this time. It locates the disorienting effects of system breakdown in the family home, and in the personhood of one Californian housewife, Sarah Boyle.[9] As Esther Leslie notes, Zoline's text 'visioned the entropic decay present in the seemingly perfect world of convenience consumer products and chemically based substitutes.'[10] Sarah Boyle's worries about sugar in particular seem startlingly prescient. Long before our uncertain obsession over what is safe and healthy to feed children today, Sarah Boyle's concerns about her children's day-glo packaged breakfast cereal have a visceral, pulsing power. The artificiality of foodstuffs is an abiding theme – the extremity of their processing which leads to an unnatural state of consumption and absorption; a union of nature and artifice.

(14) In the words of Mary E. Papke, Zoline's short story 'marries science to fiction, all for the purpose of detailing one day in the life of Sarah Boyle and her mental disintegration. It effects this marriage through the inclusion of scientific explanations but also in its presentation of all information through a series of axioms, hypotheses, definitions, narrative fragments and summaries that instantiate the scientific principles inserted into the story.'[11]

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9 Pamela Zoline, 'The Heat Death of the Universe' first published in *New Worlds*, No. 173, July 1973. Reprinted in *Busy About the Tree of Life and Other Stories*, London, 1988, pp.50–65.

10 Esther Leslie, *Synthetic Worlds: Nature, Art and the Chemical Industry*, London, 2005, p.236.

11 Mary E. Papke, 'A Space of Her Own: Pamela Zoline's "The Heat Death of the Universe"', in *Daughters of the Earth: Feminist Science Fiction in the Twentieth Century*, ed. Justine Larbalestier, Middletown, Conn., 2006, pp.144–159,

The story is recorded in short, numbered paragraphs to reinforce 'the "experiment" of our observing Sarah Boyle,' creating an effect similar to the ants' detached, experimental treatment of the humans in *Phase IV*.[12]

(15) FORCED GROWING
The plants need watering in Sarah Boyle's house. A hydroponic field in this space ensures the automated growth of crops without soil; the efficient delivery of water above ground, via mechanical delivery system. Again we witness a transformation of states within a closed system. If this white plastic floor-based structure is based on a hydroponic growing field, it adopts its feedback loop mechanisms while diverging significantly from the real. These cabbages are made rather than grown. This is a system that is not functional: the hydroponic field alludes to forced crop growth, but without the elements required for such a function. It's an operational feint; a gesture towards a field of production that remains unfulfilled, unprocessed and uninitiated. The cabbages hang on as if for dear life. It is not at all clear whether this gridded system is indeed their life support, or that which inflicts their decay and death. Is the system sustaining the cabbages or are the cabbages sustaining the system?

(16) These various elements within the installation together instigate a conversation: in cybernetics, the term 'conversational' 'refers to a feedback loop between a command and its activator.'[13]

(17) THE GARDEN
Outside this gallery space there are two dark green cabbage lamps. Sarah Doyle's suburban California is summed up by two 'natural' colours ('cunt pink and avocado green') but amongst this ecological harmony is a seeping toxic presence, 'fumey ammoniac despair,' from which the home offers no refuge. Cabbage moths are an utter blight: their caterpillars eat brassicas especially, as their name suggests. As with Sarah Boyle's home so too in this space there is growth and blight, renewal and destruction. The hole punches on the cabbage leaves and on the desk also appear on the leaves of the green lightshades, and are indicative of this blight – they trace the pattern of crop consumption and devastation, marking the ability of something tiny to wreak havoc on vast swathes of farming land.

(18) HEAT FORMATION
László Maholy-Nagy and Naum Gabo began working with heat-formed plastic in the 1920s and early 1930s, attracted to these newly available materials and their potential for transformation. Moholy even heated and warped sheets of Plexiglas in his kitchen oven, in a beautiful blend of domesticity and cutting-edge artistic practice. The new acrylic options in the

accessed 01/09/18: https://justinelarbalestier.com/books/daughters-of-earth/excerpts/papke/

12 Ibid.

13 Latour, 1996, op. cit., p.306.

1960s caused this earlier technique to slip into obsolescence. What does this old technology of heat-formation allow the object to do? As well as contorting or curving a flat surface to oscillate between two- and three-dimensions, it also retains a sensation of malleability; an awareness of its change of state, from solid to near-liquid, from firmness and resistance to a state of pliability – a potential for slippage between different states, between different categories and cartographies. It is a permissible form.

(19) LOOSE HEADS
These cabbage leaves were scanned and then screen printed onto laser-cut acrylic, finally heat-formed to various three-dimensional shapes.[14] The Savoy cabbage, Brassica oleracea L. var. sabauda, is a medieval variety with a loose 'head' originating in Western Europe, probably Germany, which gained its name in the sixteenth century from an association with the Italian Savoy province in France.

(20) A 1967 essay by E. P. Thompson examines how technology re-shaped the working day in the late eighteenth century, away from an agrarian community model and towards the industrial capitalist system. He charts technology's impact on our bodily rhythms, focusing on the imposition of clock time. As Thompson remarks: 'Those who are employed experience a distinction between their employer's time and their "own" time […] Time is now currency: it is not passed but spent.'[15] His concern is 'simultaneously with time-sense in its technological conditioning, and with time-measurement as a means of labour exploitation.'[16]

(21) Our contemporary attitudes towards work's definition and our labour's boundaries have become more diffuse, less concrete, more confused. Many of us lack the ability to determine our working hours or agree those hours contractually. The blur between work and leisure time, in this freelance, gig economy labour market, has become an absolute. If we have lost the solid, irrefutable certainty (with an exploitative tinge) of the punch in, punch out clock-based mentality, then what have we gained in return? If we choose to stream TV shows instead of working, that is our choice, in a sense, but we suffer in some way – one less task complete,

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14 For an account of the historical use of cabbages as stand-ins for human heads, see Rachel Adams and Nicolas Helm-Grovas, 'Theses on Restaurants (A Discontinuous Perambulation on Time, the Guillotine, Gastronomy and the French Revolution),' accessed 02/09/18: http://www.jerwoodvisualarts.org/writing-and-media/theses-on-restaurants-a-discontinuous-perambulation-on-time-the-guillotine-gastronomy-and-the-french-revolution/#_ednref15

15 E. P. Thompson, 'Time, Work-Discipline and Industrial Capitalism,' in *Past and Present*, No. 38 (December 1967), p.61.

16 Ibid., p.80.

one less shift clocked. If there is no real end (and no real beginning) to work, if we work without temporal and spatial restriction, how do we measure anything? Our output, our productivity, our improvements? Or do we resist the capitalist logic of this continuous cycle of self-assessment and self-negation, and choose instead to stop marking time, to return to a pre-industrial, task-based delineation of the working day? We still have deadlines to meet, meetings to attend, and many other markers of our labour's delineation. Britain's productivity is statistically considered to be one of the lowest in Europe, so perhaps this warm embrace of inefficiency is merely inevitable. How much disorder can we allow into the system, before it can no longer constitute itself as a system? Is it perpetually noon here, just shy of lunch, the day stretching ahead of us?

Stephanie Straine is the Curator, Exhibitions and Projects at Modern Art Oxford.

Rachel Adams (b. Newcastle upon Tyne, 1985) lives and work in Glasgow. Adams recently completed an MFA at the Ruskin School of Art, University of Oxford. Recent exhibitions include, *Right Twice a Day*, Jerwood Visual Arts Project Space, London (2018); *Insight 20*, Yoshimi Arts, Osaka, Japan (2018); *Mostra*, British School at Rome, Rome, Italy (2016); *How to Live in a Flat*, The Tetley, Leeds (2014); *Long Reach*, domobaal, London (2014); *Mood is Made/Temperature is Taken*, Glasgow Sculpture Studios, Glasgow (2014).

This exhibition has been produced in partnership with Bloc Projects, Sheffield. Rachel Adams will present *Lowlight*, a solo exhibition at Bloc Projects from the 5th - 22nd October 2018

Hiding the Hardware

by David McLeavy

Accompanying text to *Lowlight*

Hiding the Hardware

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A text by David McLeavy for *Lowlight* by Rachel Adams

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We are not the first generation to wonder at the rapid and extraordinary shifts in the dimension of the world and human relationships it contains as a result of new forms of communication, or to be surprised by the changes those shifts occasion in the regular pattern of our lives.

Carolyn Marvin, *When Old Technologies Were New: Thinking About Electronic Communication in the Late Nineteenth Century*, 1988

Day in, day out, we are in physical dialogue with mechanisms that we do not fully understand. Our dependence on these systems is enormous, and we are moving further and further away from understanding the ever-increasing technological innovations as the days go by. The internal workings of the modern computer system are hidden from view, behind the sleek and minimal design of the aluminium outer casing. Images appear on our screens and cursers dart from corner to corner as we caress the recessed panel discreetly positioned in the centre of the device. We are under the impression of being in control, the paradox however is that we are never fully able to be in complete control if we no longer understand the system that we are trying to tame.

Our slow separation from understanding the systems that we are dependent upon, at least the mechanical systems are inevitable. As technology lurches forward into new realms, we are forgiven for being nudged into the passenger seat, aware that we are travelling, but with limited control over the journey.

The introduction of the seemingly intangible cloud storage systems has accelerated this ever more, highlighting quite how little most of us know about the devices that ourselves and large portions of the industrialised world rely upon. The cloud defies material comprehension. How can information be stored in the immaterial realm and how are we to ever comprehend the amount of information it would take to fill a Exabyte, Zettabyte or Yottabyte of storage. The reality is that this information does have to find a physical space to be stored. In vast warehouses, giant hard

drives are processing all that we are saving and storing via shared, seemingly invisible, hard drives.

This hiding of the 'hardware' means that we no longer have the same relationship with much of the technology that we use. It is worth noting that this is not unique to computer systems. Bicycles for example now have optional electronic gear systems, removing the need to understand how incremental pulley wheels and adjustable cable tension systems can move the chain from one sprocket to the next. We are also well aware of the complex web of drainage systems and sewage canals that lay beneath our feet, but how informed are we of how they function and the processes needed to maintain this serpentine network.

With this rapid technological development the question may have shifted from whether this direction has wider sociological implication to investigating how we deal with the new dynamics of the relationships we now have with systems and devices of unknown complexity.

Is it important for us to see the working organs of the systems we are dependent on in order to re establish a working understanding?

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Rachel Adams (b. Newcastle upon Tyne, 1985) lives and works in Glasgow. Adams recently completed an MFA at the Ruskin School of Art, University of Oxford. Recent exhibitions include, Right Twice a Day, Jerwood Visual Arts Project Space, London (2018); Insight 20, Yoshimi Arts, Osaka, Japan (2018); Mostra, British School at Rome, Rome, Italy (2016); How to Live in a Flat, The Tetley, Leeds (2014); Long Reach, domobaal, London (2014); Mood is Made/Temperature is Taken, Glasgow Sculpture Studios, Glasgow (2014).

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Lowlight by Rachel Adams runs between 6th – 27th October at Bloc Projects, Sheffield.

The exhibition has been produced in partnership with David Dale Gallery, Glasgow, who are currently hosting an exhibition by Rachel Adams titled *Noon.*

Lowlight has kindly been supported by Arts Council England.

Hothouse

by Cicely Farrer

Accompanying text to *Hothouse*

Hothouse
Cicely Farrer

2019 Sculpture Commission for Hospitalfiel by RACHEL ADAMS

Every year, we invite an artist to create an outdoor sculpture which appears in dialogue with the history, grounds and surroundings of Hospitalfield For 2019 we have invited artist Rachel Adams to create a sculpture commission specificall for the Paddock, a beautiful grassy meadow just outside the walled garden with a clear view to the sea.

Hothouse is a blue intrusion to the surrounding pastoral and residential landscape. The work is sited until the end of the year and we are excited to see the buoyant Paddock grow up around the art work as the seasons change.
Hothouse builds an unfamiliar and dystopic vision of nature, farming, the garden and the machine. The art work plays with expectations of the things around us, natural or artificial how they are used, constructed or appear. Within the sculpture the artist references the productive labours that are associated with her constructed vision of leisure and industry.

Three large cubic structures are encased in digitally-printed building mesh. The design is based on circuit board diagrams; part of the physical materials that support the digitised world. The whispery movement of the fabric in the wind echoes the unreliable sense of translucency in the idea of 'digital'. The digital infrastructures that hold together contemporary life are rarely made visible. This intangibility is emphasised by language of technology frequently borrowed from the language of nature and food production– for example saving your file in 'the cloud' or content farms where huge numbers of freelance writers provide cheap copy for thousands of websites.
The shape and scale of the sculptures recall polytunnels fille with berries that occupy the field of Angus and Tayside as well as the fruit cages used to protect personal allotments and hobby gardens. Adams repurposes structures which support daily life to consider where labour and hobbies begin distinctly yet come to overlap.

The interior of the 'houses' reveals an image of a surreal colonial garden. Towering palms lose their softness in favour of rigid translucency. Blue screen-printed mushrooms pop up out of logs and mulch. This botanical garden is unsettled by the replacement of collected flor and fauna with beautiful, and desirable, plastic replicas. The project takes its title from Brian Aldiss's 1962 science fictio novel where a future

earth has been overrun by vegetation and plant life, and humans, literally shrinking to fi their new world, must figh for survival.

Rachel Adams was born in Newcastle upon Tyne and now lives and work in Glasgow. Adams' work considers the linked systems that govern the world. She observes these incomprehensible networks that detail the shifts in society and technology, in dialogue with the environment and the natural world. Using sculpture, printmaking and textiles, Adams' work uses the collapsing boundaries between natural and synthetic, hand-produced and machine-made, to consider the entangled relations of technology, labour and nature.

She has recently had exhibitions at David Dale Gallery, Glasgow; Bloc Projects, Sheffiel and Jerwood Visual Arts Project Space, London (all 2018). Adams was the Sainsbury's Scholar at the British School at Rome 2015-16 and is a current AHRC Doctoral Researcher at the University of Edinburgh and Dundee Contemporary Arts. This year she will be exhibiting at Design Exhibition Scotland in Edinburgh in June and House for an Art Lover's Studio Pavilion in *Stoop Stooping is Stoopid* with Tessa Lynch in July.