ANGLIA RUSKIN UNIVERSITY

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ATTRIBUTE CLASH:

AN ARCHAEOLOGY OF THE ZX SPECTRUM

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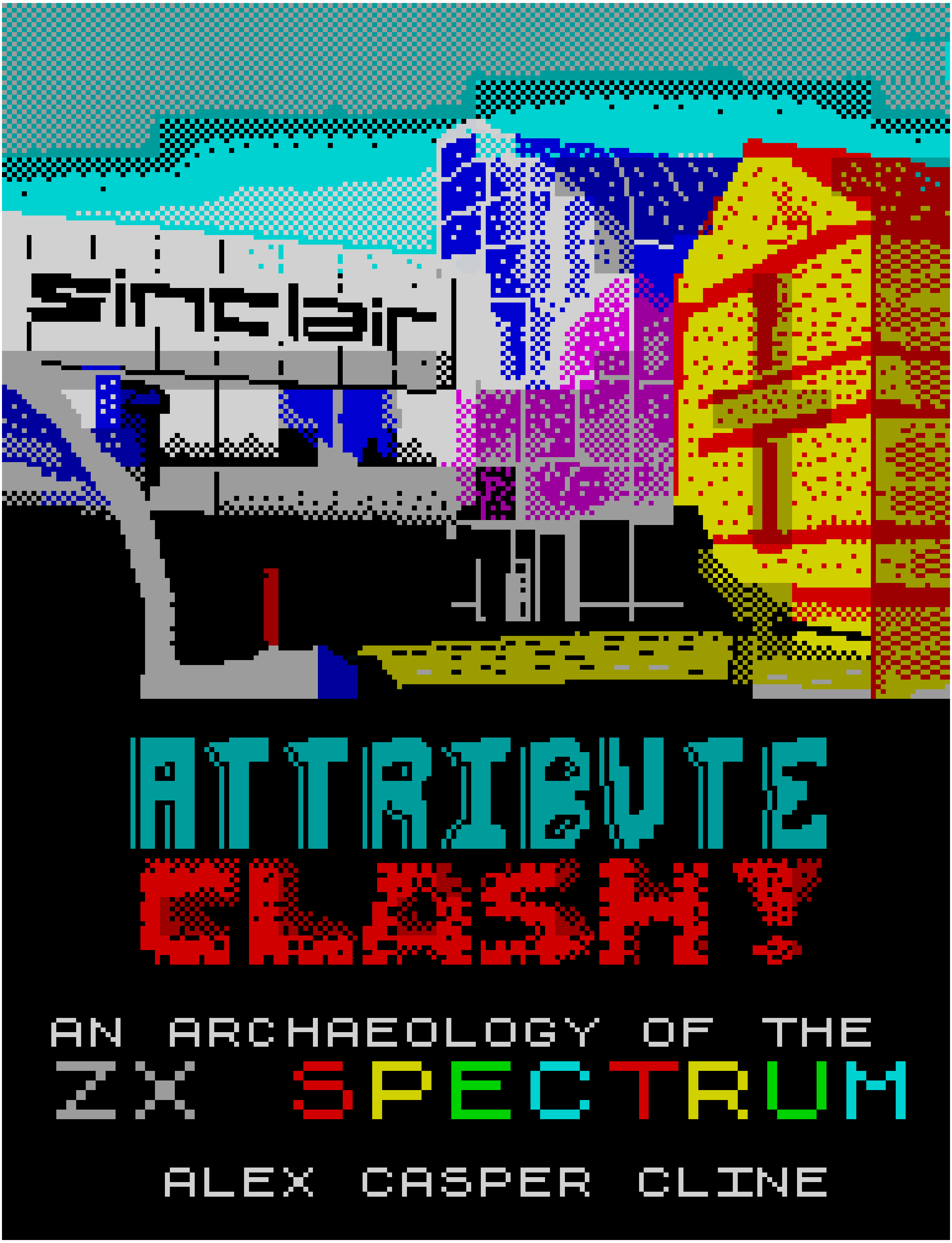
Abstract

This thesis investigates the Sinclair Research ZX Spectrum, an early microcomputer released in 1982. The system belongs to the first accessible generation of home computers in the United Kingdom and had a lasting influence on the development of digital culture there. At the same time, it has had a global impact, leading to the embrace of computing in several different contexts. Despite its rapid obsolescence in the face of technological change, it has remained a powerful object. A community organised conference in 2012 brought together enthusiasts and students of technical history. In Cambridge, a museum opened in 2013 has progressed both preservation and community engagement. In London, a gallery devoted to the Information Age opened in 2014, putting on display objects forgotten by many for three decades.

At the same time, several new subdisciplines began to develop. Platform studies has attempted to blend technical and cultural research, creating a synthetic approach. Media archaeology has proposed unconventional ways of investigating media and their archives. Contemporary archaeology has engaged with the contemporary world, looking at our relationship with objects and technologies through techniques once reserved for classical civilizations. This thesis has been as much an attempt to bring these approaches together as to study the ZX Spectrum itself. Further, other approaches are intertwined.

Important concepts for this study have included convergence and diffusion. In the first, different components and infrastructures are brought together, clashing with one another, collaborating only in a temperamental fashion. In the second, artefacts cross spatial, temporal, and cultural borders, emerging in strange places and situations. Emergence and variation involve the creation of complex systems from simple fragments. A single object was chosen in the hopes of isolating it for discrete and thorough analysis.

The ZX Spectrum, however, resisted simplification. Instead, it has refracted analysis in a range of different directions. This thesis is similar; like the Spectrum, it has provided a means to train an experimental creativity for a digital world.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The author’s mother and uncles, 198?

Table of Contents

A variation of a small section of this thesis (pp16-17) was submitted for an Undergraduate Diploma II in Archaeology at the University of Cambridge Institute of Continuing Education

The second section of the final chapter, Documentary as Documentation, was published as Cline, A.C. 2015. Documentary film and the (re)production of the 1980s UK game industry. GAME Italian Journal of Game Studies. 4

Introduction

The central research question relates to the identity of the ZX Spectrum - a British computer from the 1980's - as a computational device, as a creative tool, and as a memento. How does the ZX Spectrum - a cheap attempt to make computing accessible to the public - represent the transition to digital culture in the United Kingdom? As a product of and ideally as an example of interdisciplinary research, the project crosses paths with media studies, science and technology studies, history, and cultural studies. Archaeology is chosen, however, as the overarching discipline because of its heritage as the predominant field for the study of material culture. This thesis does not merely mobilise archaeology as a metaphorical frame, but actively attempts to mesh its most prescient theoretical perspectives with the techniques developed by amateur preservation enthusiasts. It makes use of written sources - particularly those outside the academic canon - but these are used primarily to contextualise material culture and to develop further techniques for analysis; that is, to contextualise and preserve the device and its associated material and ephemeral culture. It recognises that the topics of most significant interest for this study are not necessarily the topics of general or even broad scholarly interest. At the same time, the use of novel techniques and an alternative focus has allowed for a broader understanding of both the device and digital culture in general.

In an initial chapter, platform studies, media archaeology and contemporary archaeology are introduced as fields of research, as are specific methodological approaches that provide for intersections between them. This section includes a discussion of the *chaîne opératoire* (operating sequence), a means for understanding how objects come to be produced, used and disposed of, and the object biography, which attempts to explore objects through the relationships they have with their surroundings. This section also includes a discussion of reverse engineering within the context of cultural and historical research and a discussion of the concept of reenactment within experimental archaeology. A second chapter, on precedents and process, introduces theoretical concepts from Ian Bogost underpinning the concept of platform studies. The chapter discusses two research projects involving archaeological research into digital media - the *Media Archaeology Drive Project* at the University of York and the excavation of a landfill in New Mexico containing several Atari game cartridges. The chapter also looks at two examples of sustained projects from the ZX Spectrum community, showing the adherence to and innovation upon preservation techniques by the Centre for Computing History and the 'silicon archaeology' of Chris Smith.

Two chapters attempt to understand the device as a platform while also using it to argue that this artefact requires expansion of the same concept. The first chapter introduces the concept of concrete individuation from Gilbert Simondon, wherein the individual parts of a technical object come to develop unity and become less dependent on human agency (2017). The progression of the Sinclair Research line of computers from a kit of assorted components to a discrete, packaged unit is an excellent example of this. The chapter is itself a result of an assembly of strands of original research, including the disassembly of a single device and an analysis of components in a larger dataset. Further, it relies on primary and secondary technical and historical notes from a range of sources. Effectively, while the processor accounts for continuity with the other devices of the era, a second integrated circuit accounts for the device's specificity and identity. A second chapter looks at the diffusion of the device internationally; due to differing electrical and television infrastructures, it was often not possible to export the design for the device without a process of reengineering. Opening with the discussion of homemade devices recovered from Russia in the early 90s, the chapter then proceeds to discuss diffusion as a theoretical concept through reference to the work of V.G. Childe. The chapter analyses two technological lineages of clones, one following a path via the United States and Portugal to Poland and the other involving a Spanish clone that effectively shaped the further development of the British standard. The thesis is advanced that rather than merely being copies, the derivatives serve to introduce new features, advancing the platform and computer development as a whole. Further, it is not accurate to characterise clones as illicit; while in some cases they are homemade, in other cases, they are backed by large companies, research laboratories or government ministries.

The second pair of chapters look more directly at the media used for the transmission of programs. One chapter at the design of the keyboard as a determinant factor in shaping the culture around the device. The keyboard's design was such that it would privilege writing code over traditional language, both to reduce memory usage and ease the strain on users who might not have learned to type. Magazines might include code listings submitted by the users; others could purchase books with compilations of games. These magazines act as a critical and underlooked precedent for today's open-source culture. Eventually, more complex games written in assembly language became the norm, but one might argue that this resulted from the new technically literate user-base who had now become developers. To contextualise the analysis of code and language, sections look at discourse via the work of Friedrich Kittler, Mia Consalvo and Graham Kirkpatrick. The chapter looks at *The Hobbit*, adapted for the ZX Spectrum by Veronika Megler and Peter Mitchell, now considered a critical work of generative literature. Another chapter looks at cassette tapes, showing how this cheap medium has a long association with avant-garde experimentation. This medium, in turn, encourages creativity on the Spectrum, as exemplified by *Deus Ex Machina* (1984), a cinematic intermedia experiment from Mel Croucher's Automata. This chapter both introduces and employs Zielinski's methodology of variantology, tracing developments of mediatic forms through time (2006). It analyses the experimentation with magnetic tape by musicians such as Pierre Boulez, John Cage and Pierre Schaeffer, alongside the literary fascinations of Samuel Beckett, William Burroughs and Walter Benjamin and the experimental cultural studies of Robin James, Paul Du Gay and Stuart Hall. These chapters draw heavily upon what might be called classic media archaeology and the broader tradition of media art historical scholarship. While there are methodological problems with focusing too much on individual characters or games, often the focus on personalities is not about providing or contributing to a canonical history; instead, it is about uncovering less prominent narratives, tangents or forgotten precedents.

The final pair of chapters deal with memory in relation to the device, drawing upon the concept of 'reenactment' in R.G. Collingwood, and from work in interpretative and experimental archaeology. One chapter looks at the work that went into production and which now goes into preservation. This chapter takes issues with mainstream histories that favour the work of hardware designers over those involved in production and software company owners over programmers. The chapter explores the architectural history and context of the Sinclair building, now a part of the Anglia Ruskin University campus. It then looks at production conditions in Dundee and how 'manufacturing delays' were likely a result of labour action. This chapter also looks at the conditions faced by bedroom coders and how the often-romanticised period shows evidence of the emergence of precarity and exploitation. Matthew Smith's *Manic Miner* (1983) is viewed as an experiment in psychedelic social realism. A final chapter looks at film and documentary in relation to the device. The inclusion of the device within historical serials allows us to get an understanding of how the device might have been received within different geographic contexts. Three films, with differing production and funding models, allow us access to three very different narratives. This section discusses the Interactive Fiction project *Bandersnatch* (2018), which provides a novel means for historical documentation, an interactive experience shaped by the Spectrum itself.

1. An Archaeology of the Spectrum

Technicalities and Techniques

This chapter looks at the theoretical and methodological techniques that will be used in this project. As such, it serves as a review of the literature associated with various methodologies. Before exploring these techniques, however, it is worth noting that the justification for using archaeological techniques comes not from any monopoly of the discipline of the study of material culture nor the strength of techniques or analytical frameworks available. Instead, the use of archaeological techniques is a continuation of and development upon the work of amateur preservation enthusiasts. While users at the time appear to have been far more conscious of the intricacies of its operation than today's computer users, it appears that those with the most comprehensive knowledge of the devices are those with a retrospective nostalgic interest (Fenty, 2008). As such, they have supplemented their first-hand experience with the machine with several notable research projects and publications, many of which expressly acknowledge the antiquarian nature of their work.

In 1993, Doron Swade reported from an expedition to the former Soviet Union to study and retrieve examples of Soviet computational culture, including both mainframes and various Spectrum clones. This story provides the basis for the fourth chapter, but it is worth noting the title of his original article - the 'archaeology of a lost tribe'. Swade implies already that the recovered artefacts - and the techniques he uses to recover them - are archaeological. Swade has worked on conserving historically significant computers and was instrumental in founding the Computer Conservation Society, a working group in the British Computer Society devoted to studying and restoring old machines. Initially focused on large experimental mainframes, the society has expanded to encompass microcomputers, with Chris Smith presenting a talk entitled 'Silicon Archaeology' about his work with the Spectrum's ULA. In the introductory issue of the journal of the Computer Conservation Society, an organisation he helped found, Swade writes that "the internal model of curatorship is essentially archaeological - the reconstruction of circumstance and context from limited physical evidence (1990)."

Another text indicative of amateur preservation's self-affiliation with archaeology would perhaps be the first publication devoted entirely to nostalgia for the Spectrum and other Sinclair projects. Enrico Tedeschi's 1994 *Sinclair Archeology* compiled advertisements, technical documents and discussion into a self-published volume which was submitted to the local library, the British library and -upon request - Clive Sinclair himself. Tedeschi self-published his text, a compilation of ephemera with little commentary but a valuable resource nonetheless. Many more recent texts on the Spectrum for a popular audience have become more comprehensive and aesthetically pleasing but follow in this vein. Beginning in 1993, the comp.sys.sinclair user group provided a means for enthusiasts to share technical material, manuals and preservation software. (Gabor, 2010) A substantial amount of material culture - including digitised game tapes, user-created visual demos, vernacular publications from the time and musical tracks - has been archived (Stuckey and Swalwell, 2014). The World of Spectrum provides an invaluable collection and index. (Angelides and Agius, 2014) Some users have created their own published oral histories or reviewed archaic programmes, while others have produced detailed studies of the technology or experiments in fusing ancient and modern technologies. The goal of this study is not to supplant organic research, nor to exploit it, but to contribute to ongoing work through the experimental application of new academic methodologies to a subject of contemporary popular concern.

Broad Contextual Frameworks

Platform Studies

The methodology of platform studies developed as a concept within two papers by Nick Montford and Ian Bogost (2007a,b) It was further popularised through a 2009 book on the Atari VCS, Racing the Beam, and it has now expanded into a book series and range of additional articles. (Montford and Bogost, 2009a and 2009b, Apperley, 2009, Apperley and Jayemanne 2012, Montford and Consalvo, 2012, Leorke, 2012). A platform is a computational construct, a hardware device or a software operating system. A detailed study of a platform relates its design and development to cultural, economic, geographical and other contexts while simultaneously examining the technical possibilities of the device. Such studies require a capacity for both technical investigations of the mechanics of hardware (or software) devices and cultural research into media ecologies. Subsequent books in the series have varied both in their object of research and their formal structure. Steven Jones and George Thiruvathukal's *Codename Revolution* (2012), on the Nintendo Wii, expanded the methodology to look at a more contemporary, socially-oriented platform and centres chapters around hardware peripherals or networked distribution systems. Jimmy Maher's 2012 text on the Commodore Amiga, *The Future Was Here*, looked at the device's emerging capacity to produce and handle multimedia.

The ambiguity of the texts means that it is frequently necessary to adapt the methodology to suit a particular platform, identifying its most significant innovations both from a technical and a cultural perspective, and then structuring research around these particular attributes. The limited amount of research that consciously identifies with the relatively new discipline has also meant that specific earlier texts which do not explicitly reference platform studies might nonetheless be identified anachronistically as exemplary case studies (Bagnall, 2011, Laing, 2004, Provenzo, 1991, Moritz, 1984). Similarly, the discipline can call upon a range of other Game Studies texts that promote syntheses of hardware and cultural literacies (Juul, 2008, Montfort, 2005, Jones, 2008, Montfort et al., 2012.). It is important to note other differing uses of the term platform in media studies, including an alternative formulation that focuses on communication platforms and their associated politics (Hands et al., 2013). It is often challenging when using this methodology not to become focused on the limitations of a particular device.

On the other hand, these shortcomings often are what defines its specificity, or the uniqueness of the digital material culture produced. With its advocacy of technical and media ecological literacy, platform studies allows both thorough analyses of these limitations and discussions of innovative methods by which these boundaries get crossed. The concept of affordances (Hutchby, 2011, Zeilinger and Scarlett, 2018) - wherein objects allow or encourage a particular type of behaviour - and networked models of agency (Bruni and Telli, 2007) - moving away from the traditional subject-object model of relations - also become increasingly relevant.

Media Archaeology

Media archaeology has notable sympathies with platform studies; both incorporate the idea of media ecologies, are sympathetic to technical literacy, and facilitate in-depth, multidisciplinary study of technical objects. Media archaeology is generally derived from the 'archaeology of knowledge' of Michel Foucault (1974), which specifically relates to the study of archives and archival objects (Derrida, 1996). Further research by German Media Scholars such as Friedrich Kittler (1999,1997,1990), Wolfgang Ernst (2012) and Siegfried Zielinski (1999, 2006) has developed this methodology for archival study into a methodology suitable for in-depth analysis of technical objects or media devices. They liberate media studies from its fascination with novelty, showing how today’s forms of mediation have long cultural and technical histories. Again, there is significant diversity in theoretical approaches to media archaeology, and these have not formally solidified into a definitive, univocal methodology. Jussi Parikka has produced studies of particular interactions, such as those of media with the virus (2007), the insect (2010) or the earth, while Erkki Huhtamo (2012) explores *topoi*, recurring themes and spaces. Zielinski's earlier genealogical studies of cinema and television (1999) and the VHS (1992) have lead him towards a variantology of media, elaborated in five edited volumes which explore artefacts or trajectories in relation to extensive histories of specific media and the possible worlds they speculate about. Other work in media archaeology specifically brings in questions of the commodity (Friedberg, 2012), touch (Strauven, 2012), or embodiment (Hayles, 1999), though the discipline could be expanded by drawing further on British cultural studies (Du Gay et al. 1997) or new materialist (Boscagli, 2014) schools.

Contemporary Archaeology

In the course of methodological and theoretical research, it became clear that there were deficiencies within the disciplines in question that could not merely be solved by recourse to other work in media studies. Instead, it made sense to look at established disciplines that were working with artefacts of the recent past. This thesis thus draws from contemporary archaeology, an emergent subdiscipline of traditional archaeology mostly unrelated to media archaeology (Harrison 2011, 2010). Contemporary archaeology has its roots in the movement against scientific positivism in archaeology, generally referred to as post-processualism. While processualism had criticised the untrained antiquarian and the nationalistic culture-historical schools of archaeology for lacking any structured methodology or disciplinary rigour, post-processualism had reacted against the zealotry of its antecedent, proposing new space for subjectivity, embodiment and sensory experience.

Contemporary archaeology is a new field focused on the contemporary world, and while it does not explicitly focus on technology, studies exist which aim to explore the relationship between artefact and media (Morgan, 2012) or to excavate or restore computational devices. Also relevant is symmetrical archaeology (Olsen et al., 2012, Olsen, 2007, 2003, Witmore, 2006, Hodder, 2012, 2011) which attempts to draw upon French historian Bruno Latour's work (1993, 2005) to rethink relationships between human actors and the technologies they use. It is also valuable to look at ruins and obsolescence from material culture and geographical perspectives. (Edensor, 2005a, 2005b, Domanska, 2006) Finally, the landscape archaeology of Christopher Tilley (1994), and the theatre/archaeology of Mike Pearson and Michael Shanks (2001) serve to allow for the study of space through experience and embodiment.

Areas of Investigation

Object Biographies and Anatomies

The first approach involves looking at the object not as a singular entity but rather as an assemblage of different components, each with a unique technological history and lineage. The French philosopher of technology Gilbert Simondon speaks of ‘concretisation’ or ‘concrete individuation’, where the development of technological components to be used together encourages them to develop characteristics that reinforce or support the operation of other components, meaning they are less conceivable as individual entities and come to comprise segments of a unified whole (2017, p. 43). That said, concretisation is a process that occurs over time and requires several iterations. As such, objects amongst the first examples of new technology will necessarily show more autonomy and separation amongst their components than a refined, later stage model. They will likely be visually distinguishable, made from a range of different materials and not specifically designed to work together. They will possibly be made in different places, by different companies or cooperatives since vertical integration takes time to develop. They are not necessarily designed to work together initially, and so there may be a great deal of redundancy or even incompatibility between different components, possibly leading to a shorter life span.

This approach views a technical object as an assemblage (Phillips, 2006, Marcus and Saka, 2006); while it is fashionable to write object biographies, this is perhaps more correctly an object anatomy, an inventory of its various organs, their past and possibilities for continued development. (Roach et al., 1984) Alternatively, it is an ‘object story’; an ‘accommodation’ between object and researcher that becomes both ethnographic and autobiographical. (Brown et al., 2016) In this case, a study can cover an entire computer in relative detail; this is not necessarily true of studies of more modern platforms. The approach can also show evidence of the device's experimental status, showing that some components were often not designed for this device, nor even for computing in general; often, the artefact requires the use of other items of technology from the domestic context. Differences in internal design appear over the life of the device, as components in subsequent iterations are acquired from different sources, upgraded, reconfigured, or internalised. Various designers and companies are responsible for different parts; an entanglement exists between these components and the places and people from whence they originate. Telling the stories of components is telling stories of varied cultures of research and design, manufacture, and distribution.

The concept of the object biography derives from Arjun Appadurai’s 1986 text *The Social Life of Things*, where he argues that objects “constitute the first principles and the last resort of archeologists.” (1986, p. 5) Gosden and Marshall (1999) work to improve the relevance of the concept to archaeology specifically, also citing Tringham’s (1994) work with life-histories of spaces and structures as an essential influence. Gosden and Marshall make the point that objects are not merely passive, but are active in that they engender new relationships, are identified, and differentiated even from other objects of the same time. While they may be named or identified with a user or owner, they reciprocally contribute to producing things such as wealth and status, and consequently that person’s identity.

While anthropological readings of objects commonly focus heavily on distinctions between the gift and the commodity, this is less of a concern for Appadurai, who seeks a less dualistic understanding for the context of transfers and highlights that an object might go through many different types of transfer in its lifetime. Hoskins (2005, p.78) differentiates between readings that begin with ethnographic fieldwork and those that start with only the material object itself, requiring archaeological or historical research. Gosden and Marshall also speak of ‘sharp breaks’, instances where there is “a radical resetting of meaning” (1999, p.176). These can occur when a ‘colonial encounter’ rips an object from one cultural context and places it in another. They can also manifest as an object is accessioned to a museum, though it is important to note that an object is not ‘retired’ or rendered passive when placed in a museum context. (p. 169) The way an object was collected or excavated, archived, studied, and presented has the potential to reveal a great deal about societies other than that which it originated in and influence new forms of cultural expression. Following Sherry Turkle, we can argue that ‘evocative objects bring philosophy down to earth’ (2007, p. 8).

The disciplinary formulation of symmetrical archaeology can contribute a great deal to contextualise the generation of object biographies. Symmetrical archaeology draws upon the work of Bruno Latour in science and technology studies, wherein he attempts to move away from the philosophical binary of ‘subject’ and ‘object’ to a so-called actor-network theory in which material items and organic creatures interact (Witmore, 2007). This theoretical approach could be incorporated into object biographies, ensuring that objects get a proper amount of attention while also remaining contextualised within cultures. The attention to objects should not replace and should certainly not counteract efforts to include people otherwise ignored by narratives (Hunter and Swan, 2007). Alberti (2005) makes the point that museum artefacts are ‘polysemic’; that is to say, they are not limited to having a single meaning. Just as many biographies of a single individual can exist, different object biographies can highlight different histories of an object or contextualise it in new ways. Hoskins argues that objects themselves have a role in defining their identity: "anthropologists have long argued that things can, in certain conditions, be or act like persons: they can be said to have a personality, to show volition, to accept certain locations and reject others, and thus to have agency" (2005, p. 81). This approach could, however, result in the objects becoming anthropomorphised in an unhelpful way. It could also have the disastrous result of obscuring the agency of the culture that initially produced them. Anthropomorphising objects may be a necessary evil if it allows for the visualisation of the life cycle of an artefact or set of artefacts (Domańska, 2006). Allowing for the fetishisation of objects may similarly allow for valuable knowledge to be developed about them (Dant, 1996).

While the Twentieth Century saw a professionalisation of archaeology, new programs and resources have allowed the expansion of so-called 'community archaeology'. (Marshall, 2002) Community experience is particularly essential within a number of subfields, including most notably conflict archaeology and underwater archaeology. (Moshenska, 2016) The collective process of development of object biographies can generate community narratives and encourage further engagement with material culture. Often the processes involved in the production of more complex objects can only be understood through distributed research, even 'crowd-sourced' archaeology. (Morgan and Eve, 2012) It is often argued that biographies are no longer the cornerstone of history, which has recently moved towards more distant and intertextual readings of concepts (Guldi and Armitage, 2014). Tracing 'object networks' might be a good compromise; with archaeologists following the model of amateur preservation enthusiasts to produce descriptive archives of objects collaboratively. At the same time, while writing object biographies alone does not necessarily provide context, more extensive sequences or networks could also be investigated in a formulaic manner which would not produce additional knowledge about or understanding of contexts. The techniques are most useful as part of a consolidated effort to open up archaeology to a plurality of voices, exploring a variety of spaces and times.

Expanded Platform Studies

Amongst the components in late twentieth-century electronics, there are many for which the internal mechanics are hidden, even invisible. This obscurity results from the compression of certain types of electronic circuits and core components within them, including the critical logic gates. Initially, only mechanical storage and processing of information was possible. The discovery and subsequent use of valves for this purpose allowed the first fully electronic digital computers. The low reliability of valves, their expense and bulkiness meant the development of transistors was crucial to facilitating the future development of computer hardware. Transistors reduced the size, power consumption and cost of computer mainframes and electronic devices such as radios (Langlois 1992, p. 8). They were also arguably less labour intensive to produce, though they would have required more significant investment in initial production machinery. Though transistors initially emerge as individual units, there could also be configurations of multiple units on a single chip. These integrated circuits began to be used for digital memory in the 1960s and processors in the 1970s, soon becoming common in consumer electronics. (Mazor,1995, p. 1601) By 1980 integrated circuits - microchips - accounted for a large part of the circuitry of computers, and it was common for journalists and commentators to speak of an impending or even ongoing 'microchip' revolution. (Evans, 1980)

Even within the short epoch of Sinclair-branded computers, there is considerable variation in the usage of integrated circuits. This differentiation is visible between the different computers, which necessarily have different designs, but even within the course of development of a single model, it will proceed through several revisions. (Spectrum for Everyone, 2017) Each iteration - referred to during the Spectrum's lifespan as a board number - tells us through its differences about the resources available, the development of production techniques, advancements in design or engineering. Even within a single board configuration,

there will often also be differences in the components used. Integrated circuits frequently give way to a newer version that uses the same pin configuration, or even a different configuration if employing an adapter. These improvements can be made to upgrade storage or random-access memory (RAM), to improve the operating system in read-only memory (ROM), or to substitute a newer version of the processor or secondary circuitry.

Sincethese integrated circuits will be similar externally - they appear as a small black box with several metal pins - it is not generally possible to identify such components by appearance. (Goddard, 2015) This problem also affected those responsible for manufacturing, inventorying and distributing the chips; manufacturers developed means to document the type of chip on its outside, often also including other information including factory or country of manufacture, date of construction, and occasionally a specific serial number. Alone, these numbers can reveal the origin of the subcomponents and a rough date for the manufacture of the completed object. It is only with a database of multiple objects, with different assemblages of components, that it becomes possible to completely understand the development of the device. (Barrowman 2000, p. 24) More importantly, however, it is also possible to discern changes in the composition of the tools that reflect changing levels of resources and design techniques available in the societies which produced them. (Odell 2012, p. 204)

While it is reasonable to regard a highly sophisticated assemblage of technology such as the Spectrum as a complete object unsuitable for reduction, the term - and consequently, the platform - is unstable. The same term refers to a series of different objects with a similar outward appearance and function. Analyses of how subcomponents and systems of operation change demonstrate much more extensive networks of globalisation - that is to say - reorganisation of chains of supply and distribution. (Parrika 2015b) It is also possible to note material traces of the professionalisation and consolidation of the hardware production industry, as part of the germination of digital culture. In many cases, the material evidence of such changes is backed up by textual sources - oral history reports, newspaper sources, design documents or manuals - however, this is not always the case. Engaging in a practical examination of a relatively well-documented machine makes it possible to develop a methodology for more peripheral and under-documented electronic systems.

Stratigraphy and Chaîne Opératoire

Stratigraphy refers to the geographic practice of studying layers of rock to understand the genesis of a territory. (Harris 1989, p. 2) In the late 1970s, it was adopted by archaeologist Edward Harris to explain how archaeological remains come to be found layered above each other. (1989, p. 7) While the concept of layered remains was nothing new, Harris provided a standardised way of illustrating the interaction between different features and the territories surrounding them (1989, p. 20). The concept of layer also provided a means to describe the environment surrounding found artefacts and objects (p. 103). Stratigraphy was not meant to provide a means for analysis of objects themselves, but - as objects become increasingly complex and environments themselves require preservation - the line becomes increasingly blurred (Perry, 2014).

In Martin Davies' *Archaeology of Standing Structures*, he performs sequencing on buildings that still exist, which necessarily complicate stratigraphy through their persistence. (1987) Collapsed and buried structures generally convey information about their temporal provenance by where they lie in the ground; while there are many exceptions, newer remains are often found closer to the surface, allowing time to be related to depth or at least location. Still existing structures, on the other hand, require the imagination of a fourth dimension since different parts of a building may originate in radically different times. Complex objects may exhibit similar layering, requiring investigative work to discover the provenance of different parts of the device.

The concept of *chaîne opératoire* is a further attempt to improve methods for situating one or more objects in a broader context. It originates in French anthropology and archaeology in parallel with the 'new' or 'processual' archaeology of anglophone scholars (Dobres, 1999). The term can conceivably translate as 'operational sequence', but the use of the untranslated French term remains popular as it conveys better that the sequence is made up of a series of events and actions that do not necessarily occur sequentially. Despite subsequent development of the concept within French archaeology, however, it is often misrepresented or overly simplified within English-language textbooks (Sellet, 1993).

Both processualism and the chaîne opératoire could be seen broadly as expressions of structuralism - the anthropological theory advanced most notably by Claude Levi Strauss - which holds that all fragments of human culture are part of a more extensive symbolic system. Though its first usage predates most work in systems theory, later the concept comes to be influenced by cybernetic analysis and existing analysis techniques. (Zambelli, 2011, Shott, 2003) Andre Leroi Gourhan - identified as the originator of the term - asserts that:

> operational sequences are formed as a result of interaction between experience, which conditions the individual by a process of trial and error identical to that of animals, and education in which language occupies a variable, though always decisive, place (1993, p. 230).

It is a hedging of bets, allowing for semiotics to remain important within archaeology in a way that simple process analysis does not permit. Operational behaviour, which forms the basis of the concept for Leroi-Gourhan, can be divided into three stages, with the first stage being the only one not to include operational sequences (1993, p. 231). This automatic behaviour comes purely from experience, and as such, it is not sequential since it does not involve recourse to education. The second stage is the primary cultural formation, as individuals perform 'mechanical' actions that are learned and perfected through repetition and education. Leroi Gourhan asserts that 'they are performed at a deep level of collective memory and involve language only to a limited extent.' (p. 233) The third stage is rarer, involving active attention to and influence upon individual links of the 'chain' to produce new 'techniques. Leroi-Gourhan links this type of occupational behaviour to seasonal or periodic behaviour, which engenders traditions and subsequently, as operations become more complex and challenging to coordinate, more complex forms of language and recording (p. 234). While Processualism sees culture as an exoteric form of adaptation, the *chaîne opératoire* highlights how new forms of behaviour are themselves adaptations dependent upon further dissemination (Dobres, 1999).

While ethnographic fieldwork can chart operational sequences, archaeological application of the concept requires a certain level of speculative reconstruction and is consequently only beneficial within specific contexts (Roux, 2013, Bedford, 2015, p. 30). A thorough analysis will reveal the techniques of manufacture, the usage patterns of an object, its cultural value, its maintenance - or 'curation' - and its disposal. Any object can exist within a sequence, but the available time or information may not permit accurate or comprehensive positioning of particular objects. Lemonnier bemoans further the fact that in analyses "only a few isolated kinds of objects are ever treated, which amounts to taking no account of the systemic character inherent in any material culture" (Lemonnier 1986, p. 148).

The complexity of the object seems to have a bearing on whether there is proper attention paid to its sequential context; it appears that the most thorough studies of operating sequences concern prehistoric lithic technologies (Sellet, 1993). In many of these cases, there are manyobjects that can be materially traced to certain places of origin and flakes often indicate spaces stones are used or manufactured. Use-wear analysis can suggest the types of activities these tools were used for, as can chemical or microscopic analysis of organic traces found on the object. Dating of various objects can suggest the length of the period in which a site was inhabited or suggest when refinements in processes may have occurred.

Reverse Engineering and Hardware Forensics

Tto properly understand the ZX Spectrum, it makes sense to explore the established professional practice of 'reverse engineering'. As a discrete practice, it is difficult to trace; certainly, craftspeople have always copied the works of others engaged in work in their field (Liebl and Roy, 2004, Shiff, 1984, Wakelin, 2014, p. 43). Prehistoric individuals - experimenting with stone - show influence from others around them, suggesting the influence of similar work by contemporaries (Hingley 1996, Eerkens and Lipo 2005). Reverse engineering, however, suggests a professional, and perhaps scientific or industrial, process with a similar level of complexity to the processes used for the design and engineering of new products.

Chikofsky and Cross (1990) understand the practice of reverse engineering as being a “process of analysing a subject system to... identify the subject’s components and their interrelationships and... create representations of a system at a higher level of abstraction.” While reverse engineering can facilitate a new, updated design, this is not a necessity; “it is a process of examination, not of change or replication.” (1990, p. 15, Uhrich 2001, p. 156) Chikofsky and Cross establish three stages of escalation beyond this examination (Sharma 2004, p. 253). Redocumentation allows for the understanding of how a device works, without access to the original documentation or creators (p. 15). Restructuring - most common in software or database design - involves making structural changes that do not involve changing the overall functionality of the device. Reengineering is a form of ‘reclamation’ (p. 15) that involves ‘both forward and reverse engineering’ (p. 16) and provides an opportunity for ‘convergence and complement’ (p. 17), expanding the resources available to hardware and software engineers.

Reverse engineering is used not only to obtain a basis for new designs but also to refine designs as they go through the production process. Despite the use of the word ‘engineering’, the practice is commonly now used to refer to software and other immaterial artefacts of technical processes. For computer scientists and industrial practitioners, reverse engineering provides a means of understanding software, facilitating a greater understanding of it while lowering maintenance costs and reducing obsolescence. (Wang, 2011, Wong, 2008) The practice is seen as a necessity for understanding increasingly complex systems, as documentation becomes increasingly unable to represent their complexity properly (Kirkhaar, 1997, Li et al., 2002, Csete and Doyle, 2002). Allowing others to go through the process of studying such systems means they can then be understood, documented and explained by technicians other than the original creators (Aabidi et al., 2017, Müller et al., 1995). With the development of new platforms, and the increasing interactivity of systems, the potential for unseen side effects and compatibility problems increases (Rugaber and Stirewalt, 2004).

Reverse engineering is typically, and perhaps rightfully, associated with industrial espionage (Kumagai, 2000, Lysne, 2018). Companies have an interest in understanding the technologies produced by their competitors to decide how to market their products, or in some cases, to update them with stolen technology (Crane, 2005). Companies also have an interest in protecting themselves against malware affecting their systems (Lysne, 2018, Wong, 2008). Though the information contained in patents both makes available a great deal of technical information and supposedly provides evidence for companies to take legal recourse should their competitors duplicate their products, the length of time required to obtain patents, let alone enforce them, prevents them from being reliable as a means of protecting intellectual property by themselves (Uhrich, 2001, p. 161). Copyright is also unable to protect software since while code can be copyrighted, functionality cannot (Evans and Layne-Farrar, 2004, p. 35). Companies will, therefore, take exceptional care to ensure that knowledge of technical design and production processes remains secret. Even workers directly involved in the protection of subcomponents and sales staff involved in facilitating distribution are often not aware of the precise technical configuration of subcomponents (CSE, 1979). Should the design team working on a project be fired or lost to a competitor, remaining or replacement staff need to rely on the documentation left by developers, who have an interest in retaining knowledge to strengthen their labour position. As such, it is even possible for companies to reverse engineer schematics for their products or engage in other forms of 'honest' reverse engineering (Qadir et al., 2016).

The process of reverse engineering a competitor's project can also have the effect of defining a standard or format based upon the competitor's project, effectively boosting the status and, consequently, the value of the original. The Personal Computer, or PC, was originally a closely guarded secret of IBM, with IBM keeping the BIOS - the operating system for the device - a secret (Laing 2004, p. 79). The drive of competitors to produce a PC compatible computer that would not be seen as a form of patent infringement required the development of a new 'clean room' methodology. This approach involved two teams of engineers, one building the project and one disassembling the IBM device and recording the functions and outputs of each component. Though the reverse engineering of their project was vigorously opposed by - and led to legal action from - IBM, the adoption of their machine as the basis for a format gave IBM's machines additional prestige and allowed them to remain firmly at the higher end of the home computer market (Conner, 1995).

When computer users were themselves writing programs or purchasing them directly from the manufacturer - using small amounts of memory and the manufacturer's peripherals to store information - there was no particular need for compatibility between machines. As markets for software and hardware developed, the unavailability of software, games and peripherals for less popular formats accelerated their demise. Further, users wishing to purchase a new machine often found their old programs would be incompatible, even if using a machine by the same manufacturer, while software developers would find their products becoming obsolete. Hardware manufacturers, therefore, can benefit from designing to a common standard, such as the compact cassette format. The format designed for voice recording and later updated to facilitate audio distribution also became popular as a data storage device, largely because Phillips, its original designer, decided to license the format for free to its competitors (Andriessen, 1999).

Reverse engineering an object is not an established methodology in the context of traditional cultural research (Neamţu et al., 2012). For studies of technical objects, understanding the practices used in their production and reproduction is, however, essential (Goddard, 2015, Bhowmik, 2019). Rather than necessarily being directed towards the physical construction of a new commercial product, research in this field aims to develop a greater understanding of how an object might get designed, manufactured and reconstructed. Parikka and Hertz propose an experimental, open-ended approach, drawing from observations of artist practitioners of technological investigation and experimentation (2012). For such practitioners, “the manipulation of consumer electronics often traverses through the hidden content inside of a technological system for the joy of entering its concealed underlayer, often breaking apart and reversing engineering without formal expertise, manuals or defined endpoint.” (Hertz, 2012, 206).

Parikka and Hertz focus on experimentation with what they call ‘dead media’; in their chronology, media goes through subsequent phases, becoming an experimental form of ‘new media’ and subsequently a consumer commodity before entering its ‘DIY/archaeology phase’ (p. 128). In a field generally focused on experimentation with new technologies, argument for work with dated technologies is valuable. At the same time, the techniques investigated by Parrika and Hertz - including circuit bending - show a far less reverent approach than the more methodological but less creative approaches involved in other forms of reverse engineering. The approaches of artists often take a piece of technology to its limits, fully establishing its range of affordances and capabilities.

Experimental and Ethnographic Archaeology

Archaeologists of historic and prehistoric periods have employed forms of practical, experiment-based research in order to understand the process by which tools and technologies are developed and used. This form of practice, experimental archaeology, is frequently a collaboration between archaeologists with knowledge of the context of a period and skilled craftspeople with extensive knowledge of modern and traditional methods for working with a specific material. J.M. Coles, who is responsible for popularising and disseminating the methodology within the British context[1] , explains that an “experiment on archaeological material may be compared with an excavation, where the archaeologist has set a problem and draws upon the specialised information of others to help him determine his course of action and to draw conclusions about the finished project.” (1967, p. 1-2) Cole’s approach is based on the work done at the Lejre Centre for Experimental Archaeology, a Danish research institute founded in 1964 (Reeves Flores & Paardekooper 2011, p. 11). At Lejre and other institutes based on the same model, researchers and craftspeople congregate to replicate historical tools and crafts.

Though the creation of an immersive environment for experimental reconstruction produces incredibly impressive simulations, Cole laments that the work is always hindered by “the subjective element, the fact that the experimenter comes from a different cultural body with a different approach to existence.” (p. 3). Post-processual approaches to experimental archaeology would later foreground this dissonance in their theoretical reflections while nonetheless acknowledging the value of reenactments inauthentic or otherwise. By creatively thinking about how tools may have been produced, distributed or employed, we move away from a static notion of the object towards a conception of the same object as a constructed device.

Complementing experimental archaeology is archaeological ethnography, an application of ethnographic techniques to solving archaeological questions. It involves studying the cultures of the present, paying particular attention to the types of artefacts, objects and structures they produce, the ‘material precedents and products of behavior’ of a culture, alongside traditional ethnographic techniques such as visual observation and verbal engagement (Wobst 1978, p. 307). These present objects and systems contrast with archaeological remains, providing for formal or relational analogies between current and past cultures (Lane 1994, p. 51). Formal analogies suggest that objects appearing in past cultures were used in the same way as similar objects from contemporary cultures. Relational analogies suggest more, suggesting that these objects might have had similar production processes, even a similar symbolic meaning or ritual value, or that they might have been part of a similar assemblage of interconnected objects. More broadly, anthropological work paying particular attention to material culture - or to systems of archiving, repair or waste disposal - might be considered as at least partially archaeo-ethnographic (p. 54). As opposed to initiating a reenactment of past cultural processes directly, the ethnographic archaeologist looks for similar processes within today’s

[1] Ascher (1961) appears to have created a detailed synthesis based on studies in North American literature.

societies. The idea of constructing a *chaîn opératoire*, though not unique to experimental or ethnographic archaeology, is essential for both (Coupaye, 2009).

Post-processual archaeology is also conscious of the increasingly performative, spectacular quality of archaeology. Postmodern writing pays particular attention to the process by which literature is produced and explores the diverse identities of the author(s) and their text(s). Similarly, the so-called relational aesthetics movement in contemporary art looks at the way artworks are produced and disseminated within the market while also examining how physical and abstract spaces work to engender certain types of behaviour and relationships. Post-structural anthropology, particularly the work of Michel Foucault, is the significant shared influence on both media archaeology, as formulated by film and media scholars and post-processual archaeologists.

The t*heatre/archaeology*, scholars Michael Shanks and Mike Pearson build links between theatre studies and archaeology while also looking at the way archaeology is itself a practice involving certain rituals and procedures (2001). The text pays particular attention to the concept of embodiment; this is fitting since archaeology is itself a study of how the economic, social and cultural activities of various cultures become frozen within the objects they produce. Academic archaeology naturally incorporates the performative elements common to all of academia - such as the lecture, the conference presentation and the thesis defence - while also including other elements such as fieldwork, often undertaken in summer months. These digs generate altered but still hierarchical relationships between faculty, postgraduate and undergraduate students, experts and external volunteers. They similarly generate conflicts and spaces for bonding, specific traditions and rituals. While experimental archaeology began by reverse-engineering the objects used in past periods, post-processual approaches have reverse-engineered archaeological practices themselves, as well as concepts of heritage, restoration and cultural research.

Recent attempts to recreate historical devices are seen as a form of experimental archaeology. Further, studying communities of retro enthusiasts today can provide an idea of how gaming communities may have functioned in the past. In both cases, the analogies are far from perfect. The attempts to recreate devices often employ more modern circuits or circuit fabrication technologies, and in the cases mentioned are entirely new designs made to appeal to modern consumers. The act of making these modern versions, however, involves a significant quality of research into how traditional devices operate, as well as how subsequent versions - including derivative ‘clones’ - function. The same applies to contemporary communities that experiment with old technology - they may use more advanced technology, but even the act of building an interface between historic machines and modern ones requires substantial knowledge about how both function. In the former case, relationships between experimental archaeology and reverse-engineering emerge. Both are critical means by which individuals analyse technical devices intending to recreate them. In the second case, communities of experimental technicians remain critical both for maintaining old technology but also for continuing the customs, rituals and narratives of older technically savvy groups.

Commercially viable reenactments of historical devices - produced a wave of popular interest in the artefacts - are valuable objects of study. Historical and contemporary preservationists have collected software artefacts akin to 'moveable cultural heritage'; these are digital but simultaneously material artefacts that can be studied and catalogued. By looking at more experimental communities, it is possible to gather material about how users embrace, adjust and redeploy technologies. The closest analogy to archaeological ethnography for this research topic might involve following communities of who experiment with restoration, preservation and cataloguing of old software and hardware. Doing this form of ethnography avoids the risks of producing an 'oral history', which might necessarily reinforce specific narratives while obscuring others. Instead, the study can focus on techniques of production, and on the coded 'objects' produced - predominantly software

This approach should complement written histories and autobiographies of software production, which are either missing or appear exaggerated, while also allowing a glance at a much larger period of production. Software can be analysed visually, revealing a great deal about the ideologies, aesthetic proclivities and social relationships of the creators. Further, software can also be analysed technically, providing information about the hardware platforms for which it was designed - this is the critical concept of platform studies. It remains valuable to experiment with a full range of methodologies for dealing with material culture, attempting to apply them to the recent and digital past.

2. Precedents

Looking for Precedents

This chapter attempts to diminish the boundaries between media archaeology and projects from conventional archaeological disciplines that have explored computational media. As such, it analyses techniques adapted from traditional archaeological excavation alongside more novel methodologies for dealing with digital heritage. It reviews literature associated with previous attempts to use archaeological methods on digital heritage. It also explores amateur, academic and professional projects in curation and preservation. This chapter shows the experimental nature of methodologies associated with researching digital culture. It also explores the theoretical developments within platform studies through an exploration of the concept of process, drawing an analogy with theoretical developments in conventional archaeology. The 2014 excavation in Alamogordo, New Mexico, of Atari video game cartridges buried by Atari implies that relatively standard site excavations may be useful for artefacts of digital material culture, though it is not realistic to suggest that these types of excavation might be common. The Media Archaeological Drive Project, undertaken by researchers at the University of York Centre for Digital Heritage, shows the possibilities and challenges of considering the disassembly of a standard, relatively modern hard drive as a form of excavation. While both projects are insightful in their approach, only some elements can be taken forward for this study. This chapter also draws upon two other examples; these come from Spectrum enthusiasts themselves. The work of the Centre for Computing History in Cambridge could be the topic in itself, but this section pays particular to their curation of events related to the Spectrum and their preservation and examination of material, including a prototype of the Spectrum discovered in early 2019.

Platforms and Proceduralism

This section will also look at the centrality of the notion of process to digital culture. In order to investigate a device, it is useful to look at the processes surrounding it[2]. This investigation may entail exploring the technical processes used in its manufacture, the cultural context of its design, as well as its desired operation. At the same time, it is

[2] Process can refer to wider societal changes: "Today, globalization, individualization, mediatization and the growing importance of the economy, which we here call commercialization, can be seen as the relevant (meta)processes that influence democracy and society, culture, politics and other conditions of life over the longer term." (Krotz 2007, 257). Hodder (1989) sees Archaeology as a process, while Apperley and Parikka (2015) underline the importance of seeing Platform Studies as a process.

essential to also look at the material processes it would be engaged in while operational, or the effects it would have on the society and culture surrounding it. All artefacts engage with processes; they are designed and manufactured, and they serve a purpose, useful or symbolic. Indeed, an artefact will serve multiple purposes, depending on what is engaging with it, on how it is employed. Such is not true only of processors but of the entirety of objects, human-created or otherwise. All engage in processes by which they get used, created, discarded or destroyed. In archaeological fieldwork, one finds a finds catalogue, listing all objects found, and a site report, further detailing wider context(s).

To further understand the role and development of the microcomputer - itself centred around the processor - it is worth looking at theoretical approaches to the concept of process. Many archaeological texts have critically analysed the process-oriented new archaeology of Binford and Renfrew (Paddayya, 2014). The theoretical framework analysed here, instead, comes from computer scientist Ian Bogost, already mentioned as being, along with Nick Montfort, one of the originators of the methodological approach of platform studies. The approach is refreshing in that it provides a far more scientific analysis of digital material culture similar to the innovations of new archaeology, which revolutionized the discipline through increased use of scientific methods and increased collaboration with archaeology. At the same time, platform studies has received criticism for its formulaic approach (Leorke, 2012) and focus on successful American-produced machines (Apperley and Parikka, 2015), though Gazzard has produced an extensive study of the BBC Micro. Apperley and Parikka argue that the innovation of platform studies merely comes from shifts in focus from consumer to designer:

> platform studies may ‘‘open the box’’ of video game consoles, but the domestic spaces that have housed many platforms are closed off. It institutionalizes informal cultural memories without an explicitly articulated acknowledgment of the context in which they were produced. (Apperley and Parikka 2015, p. 8)

Anable notes that an overly technical focus also threatens to “ignore the complicated differences and relationships between technologies as things and bodies as things—as systems differently encoded by race, ability, gender, class, ethnicity, nationality, and sexuality”. (Anable, 2018, p. 136) McPherson (2012) and Freedman (2018) provide further studies of the difficulties of reconciling studies of platforms with studies of race and sexuality.

Platform studies is itself a methodology, a process for researching complex technical artefacts that is subject to change. Bogost has written two further books of critical importance for developing a theory of process as it relates to digital artefacts, *Unit Operations* (2006) and *Persuasive Games* (2007). These texts predate the subdiscipline of platform studies, and though they are of importance to scholars studying digital games, particularly those conducting in-depth readings of specific ludic texts or those exploring ‘serious’ games used for education or training, there is little analysis connecting these seemingly independent scholarly projects. Montford has also produced further studies of relevance, but they look primarily at software and its relationship to literature. (2005, 2011, Montford et al. 2007, 2013) As such, this section primarily focuses on the work of Bogost.

In Ian Bogost’s *Unit Operations*, there is a movement towards the redefinition of the artefact and its components. Bogost defines the ‘unit’, an atomic component possible in all forms of narrative but especially suited to the analysis of the digital game. “In essence,” Bogost writes, “a unit is a material element, a thing. It can be constitutive or contingent, like a building block that makes up a system, or it can be autonomous, like a system itself.” (2006, p. 5). For Bogost, a unit can be a material object but also can be an idea or abstract entity. While this is a step that progenitors of the object-oriented philosophy he is drawing upon are hesitant to make, Bogost appears confident in doing so, perhaps because of his background in computer science. In digital media, a photo, a painting and a mathematical equation are stored using the same binary digits. Units exist in opposition to totalising, deterministic systems; a form of cultural analysis based on units is not opposed to the consideration of systems, wherein systems are amalgamations of smaller units working with one another. Bogost proposes his model of criticism, however, in opposition to deterministic systems and to the type of behaviour they supposedly engender:

> system operations are thus totalizing structures that seek to explicate a phenomenon, behaviour, or state in its entirety. Unlike complex networks, which thrive between order and chaos, systems seek to explain all things via an unalienable order. (2006, p. 6)

The notion of the operation is common to both the unit operation and the system operation it is designed to replace as a conceptual tool, but the altered scale means that operations function differently. For Bogost, ‘an operation is a basic process that takes one or more inputs and performs a transformation on it,” with ‘it’ referring to the first input (2006, p. 8). This somewhat awkward definition appears influenced by the understanding of how a microprocessor works. Shifting significance from the system to the unit, however, has a dramatic effect on an understanding of possible outcomes. A system implies stability, static existence. Elements of the system may change, but they do so to facilitate the perpetuation of the system. An operation executed by the system is almost always a correction aimed at perpetuating homeostasis. When one looks at an operation from a unit’s perspective, however, one is forced to confront an agency that is largely unable to think in terms of systemic stability but must formulate its actions according to a limited level of experience and perception.

If *Unit Operations* is broadly defined as a book on ontology, on the existence and behaviour of objects and agents within gaming, then *Persuasive Games* is a book on epistemology, on the representation of those objects by the game and on how they come to be understood by the player. Studies of rhetoric, Bogost asserts, are focused on language, whether spoken or written (2008, p. 123). This focus is perhaps understandable since texts and oratory or performance were the predominant means by which cultural and political ideas could spread. The subfield of visual rhetoric becomes increasingly valuable with photography and cinema. Artistic representations and material culture have always existed in some form and consequently have made arguments about the nature of the world through their representation of it. Bogost implies, however, that it is only with the emergence of an image-saturated, mediatic culture that images have begun to have an impact comparable to that of literature and speech, warranting a new mode of rhetorical analysis (2007, p. 21).

Digital media, which equivocates and consolidates a variety of different mediatic forms, including images, videos, sound and text, supposedly incites the study of ‘digital rhetoric’. Bogost feels, however, that existent studies of digital rhetoric, such as Lev Manovich’s work on databases and hypertext, largely ignore the rhetorical element of digital media in favour of focusing on the content and user experience. Too little attention is paid to the fundamentals of rhetoric, the form of the argument, which in this case would be the structure of the computational system that supports it. In contrast, procedural rhetoric foregrounds the capacity for simulation of computational platforms, its ability to model a scenario and its possible outcomes (2007, p. 45-6). In summary, “procedural representation depicts how something does, could or should work: the way we understand a social or material practice to function.” (2007, p. 58).

Procedural rhetoric is designed initially to talk about games, but there is nothing to prevent the creation of a microcomputing subculture from also being viewed similarly; Bogost asserts that studies of procedural rhetoric might extend to “encompassing any medium - computational or not - that accomplishes its inscription via processes.” (2007, p. 46). While later chapters explore the media used for software and the dissemination of discourse or look at cultural transformations, this and the following chapters look at processes of transformation as they can apply to an artefact itself. In all cases, the artefact will encourage processes of experimentation, cultural and technical. Bogost establishes that procedurality can be used to talk about physical and abstract systems interchangeably: “processes define the way things work: the methods, techniques, and logics that drive the operation of systems, from mechanical systems like engines to organizational systems like high schools to conceptual systems like religious faith.” (2007, p. 2-3). The construction of the Spectrum, its subsequent dissemination and the culture constructed around it are peripheral to 1980s culture; the vast majority of the UK population would have had little to nothing to do with microcomputing. Further, the construction of games or programs would have been far beyond most users; while the division between developers and users might have been less pronounced, the layout and operation of registers, for example, would have been invisible to most. From technology and media come forms of culture, with the type of culture often being determined by specifics of technical design. Conversely, technologies are not developed in a vacuum but reflect the societies in which they are developed.

Bogost’s other, more recent book, *Alien Phenomenology,* shows further developments (Hoffman 2012). In it, there exists an attempt to think about the composition and legacy of objects, drawing from object-oriented ontology and speculative realism, an academic movement attempting to dismantle philosophy’s reliance on the subject-object distinction (Morton, 2011). While the text is not specifically about games or even technology, one particularly prominent example of an object given is the game cartridge for the Atari VCS adaption of E.T., discussed later in this chapter. In order to talk about the object, Bogost borrows the term ‘flat ontology’ from Levi Bryant; (Bogost 2012, p. 17) on the one hand, all objects should hold equal value, on the other hand, all objects are multi-faceted. Bogost relates the object-oriented model with the work of Bruno Latour - the actor-network theorist - and that of process philosopher Alfred North Whitehead. All three allow for fluid, decentralised networks based on agency. As opposed to the ‘normalized’ networks of Latour, he explores the approach of John Law, who proposes the concept of ‘mess’ or ‘imbroglio’ as an unstructured alternative (p. 20-21). Neither is entirely suitable; instead, Bogost proposes what he calls a ‘tiny ontology’. Beyond flattening objects, this practice compresses complex networks into a point or a singularity, “a dense mass of everything contained entirely—even as it’s spread about haphazardly like a mess or organized logically like a network.” (p. 21,22). This new framework is related to Bogost’s unit operation; a unit can be both a component in a network and a network in itself.

In a similar fashion to Bogost, Hodder proposes that ‘entanglement’ is a manner of understanding the complex networks of compounded links between objects (2016). The links are layered and interweaved; Hodder asserts that “it is precisely the interactions between the multiple strands – the material, biological, social, cultural, psychological, cognitive strands of the individual cables – that make the entanglement so strong” (2011,

p. 164). On the other hand, the objects themselves comprising the links are not as stable as they might be. “From an archaeological perspective,” Hodder writes, “things seem transient, always changing, problematic, unbounded. Things are always falling apart, transforming, growing, changing, dying, running out” (2011, p. 160). Beyond the theoretical resemblance, Hodder is similar to Bogost in two respects. Hodder, known for bridging archaeological practice and archaeological theory, frequently uses an example from his excavations to illustrate an abstract concept or theoretical point (2011, p. 156). Bogost, then, proposes a form of scholarship that “might have as much or more to do with experimentation and construction as it does with writing or speaking” (p. 109). Bogost similarly returns frequently to the Atari VCS and its components in order to make overarching points related to philosophy, education and society (p. 129). Moreover, like Hodder - who frequently returns to reevaluate an element of his work - Bogost can reflect critically on his work, seeing the generation of a methodology as a practice and a process.

The Atari Excavation

The excavation of the Atari dump site in Spring 2014 in New Mexico - as close as it is a classic excavation of digital material culture - appears to be too good to be true[3]. Large quantities of a particular type of media artefact are rarely buried together in a specific place. Media machines and storage media, like all forms of material human technology, have cycles of use, decay and obsolescence, and are thrown away. With various modes of industrialisation, however, supply chains have become global; urban and regional infrastructures emerge for the disposal or recycling of waste technology (Parrika, 2015, Mead 1953, p. 253). Antiquated technology still exists, but most of this is what could be considered intentional storage, as people have decided to preserve ancient machines and media, often with the idea that such technology is, or will become, culturally or monetarily valuable. Machines or media artefacts get preserved due to the notion that they are valuable, or at the very least because they do not appear useless or invaluable enough to merit intentional disposal. Such is not the case with the game cartridges and hardware peripherals excavated outside Alamogordo, which are of specific interest because they represent a large-scale industrial failure.

[3] See Reinhard, 2015, Ruggill et al., 2015.

The deposition of the materials in September 1983 was accompanied by several reports in local news, which had the effect of bringing souvenir hunters and scavengers to the site (Montford and Bogost 2009, p. 107). Local kids recovered game cartridges, which sometimes still worked despite being crushed and buried. Supposedly in the interest of health and safety and to prevent further salvage, the landfill operator covered the games with a layer of concrete. The ritual also had the effect of allowing the burial to receive additional attention, however, and leading to speculation about the value of the material buried and the reasons for Atari's disposal of the objects. Ian Bogost mentions E.T. and other cartridges dumped in his book on the Atari VCS, suggesting unrealistic deadlines to meet film launch schedules - five weeks for E.T. - were responsible for the poor quality of the games (2007, p. 127). In E.T.'s case, the game also suffered from being a slow, relationship-focused film, not the kind that could be translated effectively to an action-oriented console. The nature of these games as material artefacts is also the subject of Ian Bogost's ontological meditation *Alien Phenomenology.* Bogost suggests all the things that the game E.T. could be considered as: a sequence of machine code, a translation of human-legible source code, a flow of R.F. modulations sent to the screen, an integrated circuit ROM chip, a plastic cartridge, a consumer good, a system of rules, an interactive experience, an object of intellectual property, a scarce object or signifier of the economic crash of 1983. (2012, 17-18)

The reasons for the burial and subsequent excavation are recounted in Zak Penn's documentary, *Atari: Game Over* (2014); the film also was responsible for gaining access and funding for the dig through distributor Microsoft. The dig is, therefore, neither a purely academic dig aimed at answering research questions or experimenting with research methods nor a commercial dig aimed at mitigating the destructive and disruptive effect of new construction. Archaeology performed primarily for the education and entertainment of a television audience is not unprecedented, and a range of programs of varying quality have done a great deal to educate the public about the aims and methods of archaeology. The purpose of the dig, however, was initially to salvage rather than perform archaeology; it was only later and as a result of pressure that archaeologists and game historians, led by Andrew Reinhardt, were able to get involved and contribute to the dig. The circumstances are worth mentioning for two reasons: firstly, because it may be challenging to get funding for such a media-focused archaeological dig from either of the conventional sources of funding. This particular excavation necessitated negotiation between archaeologists, documentary producers, town authorities and corporate sponsors. Different stakeholders had different priorities; safety concerns both meant that the dig was short but also heavily supervised by city and landfill authorities. Following the dig, material from the landfill was auctioned off for far more than its value, raising ethical concerns among the archaeologist participants that, contrary to their intention, they had ended up legitimising what was effectively a 'smash and grab' operation.

Despite the concerns of the archaeologists about the future of the recovered artefacts, they were nonetheless able to access all the objects and take notes on their composition and condition. As such, they were able to verify the legitimacy of many of the urban legends connected with the site while suggesting that other claims were false or exaggerated. Due to the nature of their dig, they were also granted access to a great deal of media attention, both in the short-term news cycles and as part of the documentary, allowing them to explain to a broad audience the merits of performing archaeology of the contemporary world, and specifically of digital gaming. The devaluation of electronic games in the United States in the early 1980s is attested to by historical records as well as in the oral histories of those working in the industry at that time, but as established, there are many conflicting reports as to the scale and intensity of the so-called 'crash' (Gallagher and Park 2002). The objects excavated provide evidence supporting these narratives but also allow us to construct alternative narratives based on those who handled the objects directly (such as the city official overseeing the dig, who recalled scavenging cartridges as a child) or, following Bogost as well as the tradition of 'object biographies' in archaeology, the objects themselves.

At the point at which Atari deposited its obsolete cartridges, digital game industries retained a degree of autonomy. While the company exported VCS machines to the United Kingdom and Europe, they were rendered more expensive by shipping costs and import tariffs. Modifications needed to be made to allow the game consoles to work with PAL-format televisions, resulting in games running marginally slower and being able to use fewer colours. While the popularity of such game consoles would have likely offset these disadvantages, the industry recession in North America meant that expansion was less rapid than it could have been and game consoles were effectively not available. The fact that there is such a number and diversity of types of locally produced home computers may indeed result from supply problems caused by the North American crash. Elements of the local computers mean, in turn, that the type of objects found differs. The fact that most publishers in Europe distributed games on audio cassettes meant that wide-scale obsolescence was unlikely. The manufacture of audio cassettes would be assured regardless of the provenance of the software industry; audio tapes could also be reused for another purpose if a distributor retained too much stock. Unlike ROM cartridges, which needed to be printed in bulk to be cost-effective, the encoding of tapes was a scalable enterprise, affordable to large-scale producers and cottage industries alike. For these reasons, it is unlikely that a concentrated deposit of software exists from the period in question in the UK. The absence does not mean hardware and software do not get discarded, but rather that they are discarded more gradually, in inconsistent places, further away from the sites of production. As such, it is more likely that useful material is available due to intentional or unintentional preservation.

New Media Archaeology

Media Archaeological Drive Project

The Media Archaeological Drive Project, as executed by Colleen Morgan, Sara Perry and Neil Gevaux of the University of the York, was designed explicitly as a 'provocation' for Media Archaeology. Perry, introducing the project, suggests that even within the sub-disciplines of media theory most sympathetic to the analysis of material culture, there remains a "narrow academic appreciation of what archaeologists do," (Perry, 2014). While media archaeologists are critical of conventional historically reductive or teleological narratives and work to see media artefacts as products of processes of technological and cultural development rather than as inventions of single agents, there is little work adopting field methodologies from archaeology in any meaningful way. A great deal of this is undoubtedly due to media archaeology's reliance on the work of Foucault, specifically the texts *Archaeology of Knowledge* and *The Order of Things*, which define clearly a form of archaeology that does not need - and in some ways is considered opposed to - practical material excavation.

A much more significant element, however, seems to be the disciplinary disconnect between archaeology and media-focused studies at most Universities. While there are centres in archaeological faculties specialising in the use of computational and media technologies, only in rare cases is this reciprocated through education in archaeological methods in media faculties. Instead of the dominant discourse that sees archaeology as a homonym with a different meaning when applied to media archaeology, it seems beneficial to follow recent work originating in (or at least at the borders of) mainstream archaeology. With Perry and Morgan, one can perhaps find that "archaeologists are the prototypical media archaeologists—studying media (in its broad conception, as discursive and material means to a plurality of different ends/processes), inventing and tinkering with media to progress such studies, and skilfully deploying other media to circulate this work," (Perry and Morgan, 2014).

The Media Archaeological Drive Project is incredibly valuable because it provides a model by which a scholar can dismantle or excavate a digital material artefact, applying methods of visualisation that have historically been of extensive use to archaeologists. That said, it is worth questioning the extent to which it is useful to adopt unchanged methods of visualisation and documentation from site excavations to a site-less study of an artefact. In compiling the site report, the researchers themselves note that these documents "are usually articulated in coded language, primarily only comprehensible to experts and written in the passive tense (...) (t)here is much to be critiqued about both the style and the legacy of such reporting." (Perry and Morgan, 2014, Morgan, 2013, Oritz, 2018) Given that the purpose of this study was always to serve as a methodological study and experiment and not a formal prescription, the detail and complexity of the individual reports on different fragments remain inspiring. Scholars of contemporary archaeology have often found that when confronted with the complex architectures of modern technology, traditional boundaries between site and object begin to break down (Moshenska, 2016, Bailey et al., 2009).

Furthermore, it is refreshing to see elements of media architectures represented visually, whether abstractly as part of a Harris Matrix (a diagram used to clarify often complex sequences of stratigraphic layering) or directly as a set of tracing paper sketches of different components. While sketches and diagrams are essential to the design of media machines and hardware, it is not always a given that scholars use them. Morgan's encouragement to sketch everything seems like an obvious suggestion, but scholars working amongst dense archival manuscripts and theoretical material frequently overlook the utility of such a practice. Using elements such as the Harris Matrix may be less practical for those without the experience of fieldwork, given that it was not designed for and therefore does not seem intuitive when working with media artefacts. The attempt to view both the material shell and the digital contents of the drive together as part of the same site seems to be a venture that is both admirable and challenging.

If a distinctly technical critique of this project is possible, it is that the researchers appear to state nowhere that the hard drive is only one possible form of computer data storage of primary significance only within a specified period. Computers, both in mainframe and smaller formats, existed for a significant period without the presence of hard drives to store data (Spicer et al. 2015). Before the 1950s, the dominant mode of computer storage was the cathode ray tube, a vacuum tube that could easily be mistaken if found without context for a television part, and which would not (in an unpowered state) contain usable data for researchers to decipher. In the 1950s, magnetic core memories were developed, with a matrix of memory cells being set and reset according to current passed along a grid of wires[4]. Hard disks also became available for use in large and mid-scale computers needing to store data long-term, but the diffusion of computer technology and the nature of computer usage effectively meant that they would only be present on the minority of computers. Even in computers equipped with hard drives, this is not by any means the only form of memory. The proliferation of integrated circuit memories effectively facilitated the division of memory into memory specialised for the operational running of the computer and various types of storage memory - either internal or external, mutable or fixed.

The former type of memory - known as RAM or Random-Access Memory - was particularly critical in the case of microcomputers such as the Spectrum, where programs needed to be loaded into this easily accessible, operative memory. The second type - fixed or alterable Read-Only Memory or ROM chips - formed the basis of program cartridges such as those for the Atari VCS. (Montford and Bogost, 2009a, p. 21) ROM chips would also store the underlying operating system for computers such as the Spectrum. Storage memory, including magnetic tape-based systems (which provided the majority of data storage for the Spectrum), and magnetic 'floppy' disk-based systems (which were more expensive, used in business machines and only later made accessible to the broad audience) would often be employed much more intensely than internal storage. Even after hard disks became widely available for home users, they were only part of a complex ecology of systems of data storage. Even today, there exist several archival formats used to store data on hard drives; getting data that is at all readable, let alone easily navigable upon a modern computer, is hardly a given. Inversely, not all data is stored; it is sometimes necessary to discern from network architectures what types of data may have been processed or stored regardless of whether such data exists.

Perry, Morgan and Geveaux intended their project as a provocation, and it is clear that in this sense, it has been successful. Firstly, it has challenged media archaeologists to think about what methods of excavation, documentation and analysis are salvageable from normative archaeology for use with media ecologies and artefacts. The project suggests that while these methodologies are not translatable wholesale, there is little excuse for not attempting to experiment with methodological techniques. Foucault's caveat about the irrelevance of excavation to his mode of analysis was presumably a defensive measure, designed to diminish any possible backlash against the expropriation of another discipline's terminology. At the same time, it seems unnecessary to persist in this defensive posture when movements within archaeology have shown receptiveness to

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[4] See Chapter 6.

expanding the scope of their field both temporally and with regard to the subject matter. The base of archaeological theory has incorporated a range of poststructuralist critiques and, in reaction to the structuralist-inspired new archaeology or 'processualism' of the 60s, has generated a number of its own.

Though it is clear that modes of documentation, excavation and analysis need to change to adapt to accommodate modern technologies of communication, calculation and storage, it is also necessary to develop frameworks and standards for further study. Media archaeology, for better or worse, has not entirely outgrown its roots in media historiography, and it is difficult to find practical fieldwork not subsumed under the framework of artistic experimentation. Such experimentation can be incredibly powerful in providing and disseminating thought about the material culture of media technology. On the other hand, it also requires a significant level of artistic creativity and virtuosity since specific artistic methods can often not be standardised, replicated or taught within the confines of traditional media education programs.

The Centre for Computing History

The Centre for Computing History is situated in a business park in Cambridge. On display is one of the most extensive ranges of computers in the UK. Curator Jason Fitzpatrick amassed his collection over decades before opening the project to a range of other enthusiasts and experts, seeking professional guidance and funding sources. Beginning as an appointment-only archive in Haverhill in 2006, the museum has evolved into an accredited cultural institution and charity funded by the tech industry (CCH 2008, 2011). While featuring material from around the world, the museum could be said to specialise in local history; it relocated to Cambridge as a testament to the importance of the city to the history of digital culture in the UK. The museum is intended to be accessible to younger people, and there is a classroom intended to encourage school visits. The museum also hosts many late openings to attract students and adolescents. The majority of the machines are not behind glass cases; the board permits this due to the relatively limited value of the machines and the fact that the museum holds many duplicates of particular objects. For certain events or even during regular opening hours, staff activate individual machines and visitors are invited to play games or draw sketches on original hardware. As with most museums, only a specific segment of the collection is on display at any particular time; an upstairs area facilitates research and conservation work. Perhaps the widest dissemination of the museum's collection came before its official opening, as Saul Metzstein's 2009 film *Micro Men* made use of authentic objects from the collection.

The museum played host to the 35th-anniversary commemoration of the ZX Spectrum. At this event, technicians involved in hardware and software development recounted their experiences, while enthusiasts still involved in software design or archiving efforts presented their more current work. Particularly interesting for an understanding of preservation is the work of Steve Goodwin, who conceives of what he does as a form of digital archaeology (Goodwin 2018, Goodwin et al. 2012). Goodwin began working with digitising tapes, which were already beginning to disintegrate as early as the 1990s. With the increased computing power available with more advanced personal computers, it was increasingly possible to emulate previous forms of hardware in memory while storing a large range of software. Goodwin saw an amount of urgency in the lack of documentation and a challenge in that emulators often themselves become obsolescent when their hardware or language basis becomes defunct. Some material is under copyright, but it is important to note that copyright is a set of legal practices designed for cultural products and not technical items. The traditional procedure for technical devices or processes is instead the patent; a patent typically requires blueprints and technical documentation to be submitted and archived, expanding the amount of material available. In addition to the presentations on preservation, hardware designer Rick Dickinson has given presentations on his work on the design of the original hardware and attempts to produce a contemporary reproduction. Dickinson has shared his original sketches and provided insight into the production process.

Perhaps the most interesting object in the museum's collection is the recently discovered ZX Spectrum prototype[5]. It was discovered in an attic north of Cambridge and belonged to John and Katie Grant, who had been contracted to produce the original operating system for the ZX80 and its successors, including the Spectrum (Speed, 2019). The original ZX80 ROM was developed from Spring 1979 and amounted to around 5.5 kb; this was further compressed to 4kb (Grant, 2018). The initial limitations meant the ZX80 could not have some features expected of a computer such as the ability to handle floating-point numbers (Farrow, 2012). With the ZX81, the ROM available increased to 8KB, with Steve Altwasser being commissioned to add additional features. The Spectrum ROM seems to originate in early 1981, shortly after the ZX81's release, and there was a tension between sticking with a functioning design and redesigning it to take advantage of additional memory and possible peripherals. The ROM on the original Spectrum was not finished, meaning that interfaces had to include a secondary or 'shadow' ROM to allow the machine to interface with other devices properly.

[5] König (2017) has also demonstrated another prototype, of the ZX Spectrum + design. This prototype, however, was different in that it was primarily a model for the case design.

The original developers at Nine Tiles continued to work on the ROM until three months after launch. The number of machines manufactured and sold meant that replacing machines would not be feasible since so many had been dispatched already; upgrading only new machines would risk software being incompatible with one of the versions (Grant, 2018). As such, there is a potential that the ROM in this prototypical device is advanced beyond that seen in most machines. Alternatively, the ROM may be an early version if a later prototype then supplanted this one. The curatorial and preservation staff at the museum are excited by the discovery but hesitant to even connect the device to power. Jason Fitzpatrick, the founding curator, explained that they were initially called to Nine Tiles to collect more standard mainframes. Frequently, the things the museum are more interested in is not the thing considered most important by the donor: "This was kind of more of a footnote to the other things... We're generally really excited about the thing that they were less excited about. This is an extreme example of that," (Fitzpatrick, 2019).

Fitzpatrick describes the ideal procedure before turning the device on: "We'll first dump the ROMs, preserving any data left in them. Then we'll check out the circuit and make sure it is electrically sound - we will remove the chips and check the voltages to ensure there will be no damage," (Speed, 2019). The care they are taking with this device is a stark contrast to the majority of freely accessible objects, but it is a response to the increased professional standards expected of the now-accredited museum and to the uniqueness of the device. Adrian Page-Mitchell and Philip Searle (2019), experts working with the museum, describe how the chip configuration is almost identical, with only a few differences. There is no printed circuit board, so the connections are made through wire wrapping, an electronics prototyping technique used before breadboards became common. There is no cassette interface; the cassette recorder would be presumably directly wired to the board. The keyboard is not the rubber keyboard of the finished Spectrum, but a more robust plastic keyboard, from which the 'Z' and 'X' keys are missing - it is not clear whether this is intentional.

Fitzpatrick further explains the precautions he is taking while touching the device - static protection and rubber gloves - arguing that it is not for show but part of the responsibility of the museum. Responding to those who have been critical of the delay before the machine is tested, the curator further explains the difficulty in recovering the code from the EPROM chips:

> these are actually 2564 ROMs, I was expecting these to be 270 EPROMS as many machines would use, but 25 series are a different pinout, and they need to be treated slightly differently. So our reader by default won't read them. So we need to make a little adapter that will take these, turn them into the same pinout as a 27 series, and then we'll read them. (Fitzpatrick, 2019)

The work done by the museum's curatorial team is inspiring and highly creative, but it is interesting the extent to which the professionalisation of the practice and the discovery of rarer, more fragile items have changed how objects are explored and presented. At the same time, while the initial accessibility of the collection is refreshing, physical accessibility does not necessarily mean the visitor will have the knowledge or confidence to engage with the technology directly.

Silicon Archaeology

Integrated circuits are not the smallest analysable component within an electronic system, and they are not a necessity; many electronic devices function without them. Their ubiquity, however, within contemporary systems make them an excellent candidate to be considered the atomic element of study; media from this period frequently referred to a nascent age of the 'Chip' or a 'Microchip Revolution'. (Evans, 1980) Their relative impermeability reinforces this - they are a 'black box' - challenging to design and produce and similarly troublesome to reverse engineer. 'Silicon archaeology', as formulated by engineer Chris Smith, appears to be predominantly technical, drawing from the practice of reverse engineering. The focus is thus on how infrastructures for dealing with power supply, input and output, and memory come to be established. It is useful to compare the ZX Spectrum with its clones, which work in different technical infrastructures, and its recreated versions, which do not use the same processor and could be said to come from a completely different technological generation. As Smith shows, however, there were multiple variations within the original period of the Spectrum's production. The board design frequently changed as components and functions developed and mechanics were redesigned for more efficient functioning and manufacture. (Grussu 2012, 86, Spectrum for Everyone, 2017)

The fact that many manufacturers sold many of the included chips to a diverse range of electronics manufacturers means that most are openly and comprehensively documented - this is the case with the Spectrum's Zilog Z80 processor. While it is possible to get an understanding of Z80 Processors from their ample documentation, it is also worth noting that many iterations of this same subcomponent exist, including authorised and unauthorised copies made by secondary manufacturers, with different functions and capacities. Other times, manufacturers with access to fabrication facilities will produce custom or semi-custom chips, allowing greater control over the chip's design and functionality at a higher expense. This customisation will also result in the obscuring of the component's internal operations, helping to protect the component and, therefore, the device's complete operation from being duplicated. This type of chip - called an Uncommitted Logic Array (ULA) - included a large number of components that could be configured and connected during the final stages of the production process through the addition of metal layers or joints (Smith, 2010). For Sinclair Research computers after the ZX80, a semi-custom chip was built from a template offered by British electronics company Ferranti (Wilson, 2007). The ZX81 used customisation for economic reasons, but the ZX Sinclair Spectrum made full use of the chip to provide additional features.

Unique or intentionally occulted integrated circuits, such as the chip used in the Spectrum, require more sophisticated techniques to understand correctly. The configuration of the Ferranti ULA - a secondary chip that helped regulate the device's memory access and display - was not made available publicly, and its schematics are not in the company's archives. As such, understanding the device required what Chris Smith has referred to as 'silicon archaeology' - using an X-ray machine, Smith and technician Mike Connors generated a 'stratigraphy' of the device's several layers, finally revealing its internal operations (Smith, 2010). Scanning individual circuits remains prohibitively expensive to be done on a widespread basis, yet as imaging technology becomes increasingly accessible, it may be possible to penetrate the 'black box' of the integrated circuit, building complete models of entire systems. In the interim, it is still possible to learn a great deal through merely cataloguing the succession of circuits used in successive stages of an electronic device - their origins, materials, production costs and reliability all change as a function of industrial processes and social and economic transformations.

Advanced investigations of specific subcomponents can be supported and contextualised through investigations of the use of these subcomponents or of how they fall out of use. If it is possible to find different subcomponents in the same location, this suggests either unreliability of a specific component (or of its supply) or focus on technological development within a particular area of a system. When correlated against time, sequential replacement suggests development, whereas random, uncorrelated replacement would suggest that individual components either break, cannot be found reliably from a single source, or are ubiquitous enough to make their acquisition from a variety of sources a reasonable proposition. A more comprehensive inventory of data about the distribution of integrated circuits, as well as visible information such as date of manufacture and, if possible, place of manufacture, would allow this digital material culture to explain more about the economy and culture in which it originated.

Just as the analysis of the individual sub-components within a technological device can reveal a great deal about a particular society, the changing configuration of subcomponents within and around a particular device can suggest a lot about the priorities in a certain period. Within home electronics, miniaturised products were more desirable; further, reducing the space of a circuit board would reduce the manufacturing costs of a device. As such, the spatial configuration of components within it remains very important, and a critical means to understand the prioritisation of certain functions. The absence or presence of specific components also gives an idea of the role of the device at specific points; it also gives an entryway to the exploration of peripheral devices.

Summary

The four precedents discussed all have an experimental character - both in that they involve engagement with artefacts themselves, but also in that they are in themselves experiments in archaeological methodology, providing insight into how processes for understanding material culture can be developed and refined to suit different concepts. They are all relatively experimental; ingenuity in the application of new methods and techniques is offset by limitation in certain areas, as the examples which are shown are not necessarily replicable. In effect, each example included here has encouraged the further development of technical expertise - both knowledge related to the development of home computing and integrated circuits and knowledge of heritage investigation and preservation techniques.

ZX Marks the Spot

The New Hieroglyphics

> "You can take the cover off any computer and find out how old its parts are, how long it took to make its way through the system. In our industry, if you can get people to think about how fast inventory is moving, then you create real value."
>
> Michael Dell (1998, p. 76)

This section will look at the material operation of the chips on the ZX Spectrum circuit board. A number of techniques are employed, beginning with direct observation of the device itself, as well as historical research involving traditional and non-traditional sources. By suggesting that individual subcomponents have their own narratives and identity, we can understand the object as an assemblage of interlinked components.

Most recognisable of the chips explored is the Zilog Z80 processor, a microprocessor on a single chip developed between 1974 and 1976 and used as the central processing unit for the Sinclair ZX Spectrum as well as several other contemporary computing devices. The ZX Spectrum's antecedent device - the Sinclair ZX80 - draws its name from the device, and the computers in this period are frequently identified with their processor (Laing, 2004). In this particular case, there is a degree of overidentification of the device with its processor - there are marked differences between the Spectrum and its antecedent devices, the ZX80 and the ZX81, which both use the same processor, and between the Spectrum line and comparable machines using the same underlying architecture. According to Rick Dickinson, the 'X' in the title was said to stand for the 'mystery ingredient', the system design that allowed for the construction of a unique device (Tomkins, 2011).

Dickinson's original designs for the third in the ZX line - what would become the Spectrum - show it was to be called the ZX82. With the ZX81, the numerical suffix had now come to represent the year of release (Dickinson b). The increasing importance of system design was also a factor, however, in promoting the rebranding of the device (Cooke, 1982). With hobbyist kits for hobbyist engineers, the processor architecture was of the highest concern; given a basic design, they could develop the system further as they saw fit (Flint 2011, p. 3). With pioneering consumers of technology, the novelty was more critical, and consumers wanted to take advantage of the latest developments. With general consumers, a recognisable brand name and aesthetically pleasing design were more valuable (Dickinson 2011, p. 2). In the Spectrum's name, there exists a movement from a processor-based designation to one based on a year, to one based on brand identity in only three generations.

A platform is not static and cannot always reduce to particular components. As Apperley and Parikka establish, it is the process of research that leads to this reduction: "in the process of ''doing" platform studies, a uniform platform is produced," (2015, p. 5). The ZX Spectrum is not particularly unstable, but the transformation it goes through during its lifetime reveals a great deal about broader transformations in digital culture. Even within its standard lifetime, modes of programming and usage, storage and input change. Including its precedents in the Sinclair Research line, or the considerable diversity of clones produced, this instability compounds further - Langlois describes a similar phenomenon with PC clones (1992, p. 25). This difficulty in determining the true nature of a digital device is not so much a problem as an excuse to further develop research methodologies and learn more, not just about the artefact but about digital culture in general.

Simondon: Convergence and Individuation

The concept of individuation, as developed by the French scholar of technology Gilbert Simondon, is a further means of understanding how technological objects evolve. Unlike natural objects - which always possess a certain level of individuality and autonomy - artificial objects need to develop their individuality through a process which Simondon refers to as 'concrétisation' or 'concretization' (1987, 2017). Contrary to popular perception, as a technological object becomes increasingly complex, it does not become more artificial - in fact, the opposite is generally the case (2017, p. 51). Artifice refers to human power and agency; while a machine initially requires a range of supporting infrastructure and careful management, the advanced machine develops the capacity to self-regulate and work autonomously, taking advantage of natural forces or forces already present within the machine to facilitate secondary functions (p. 26). Simondon uses the example of an internal combustion engine, wherein the cooling gills that are initially used simply for cooling are used in later engines to protect the cylinder head from buckling under pressure. The motor turns from a collection of subcomponents to an integrated unit: "the development of the unique structure is not a compromise but a concomitance and convergence," (p. 28).

Early computers - like early steam engines - would occupy an entire room and require careful monitoring by a team of engineers (Bashe et al. 1981). Elements of the design, such as memory and input/output devices, would be developed almost independently and would be updated separately. The expense and infrastructural requirements of such machines meant that their use was restricted to military intelligence, tabulation at large corporations, and research at well-funded academic institutes (Edwards, 1997). The development of terminals and operating systems facilitating the sharing of processing power allowed increasing amounts of users to access the machines but did not mitigate the dependencies of the machines themselves (Hoskins and Bolthouse, 1995).

Minicomputers, facilitated by the development of transistors and early integrated circuits, reduced the infrastructural requirements for computers and allowed a greater number of users to adopt them (Murrell, 2002). Components were now mass-produced and explicitly designed to work with one another. In addition, higher-level programming languages were developed, allowing compatibility across systems. They were now affordable for smaller businesses and institutions; instead of requiring a collective of managers and technicians, computers could rely on a user base that was relatively proficient in facilitating their operation.

Microcomputers, which made use of integrated circuit processors and memory, allowed the individual user to adopt an individual machine. The individuation of the computer had taken over thirty years by this point but followed the trajectory proposed by Simondon. Instead of requiring experienced operators, the microcomputer would be accessible to the hobbyist or young enthusiast. While more expensive microcomputers were sold as complete units, including displays and input and output terminals, more affordable devices made use of technologies that the user was likely to have already. The ZX Spectrum - first released in 1982 - depended upon the user's colour television and cassette recorder. Later versions of the Spectrum would include the cassette player within the device itself. Another computer - the Z88 produced by Sinclair's later company Cambridge Computer - was notable for having an eight-line LCD screen display (Bunder, 1989). Even the earlier versions of the Spectrum and its antecedents should not be discounted as concrete objects because of their incorporation of other household objects. Instead, they exist as harbingers of the overall convergence of communications, entertainment and computational technologies that the digital revolution facilitated.

Understanding Integrated Circuits

Integrated circuit memories and microprocessors - made from Silicon wafers - comprise the critical components of a microcomputer[6]. These are formed from a multi-crystal form

[6] Moore (1965), Henle and Hill (1966), Noyce and Hoff (1981), Mazor (1995), Gupta and Toong (1983) provide invaluable insights for understanding the genesis of the microprocessor. Widman et

of silicon doped or rendered impure by the introduction of small amounts of other elements. Silicon will naturally form stable crystals due to its six electrons, which facilitate covalent bonds between atoms. Boron, with one less electron, is introduced into a silicon structure to form p-type silicon, which possesses a positive charge due to its missing electrons, its so-called ‘holes’. Phosphorus or Arsenic, with an additional electron, is used to produce negatively charged n-type silicon. The two forms of silicon can together be used to produce a diode, which allows current to cross the boundary between the two oppositely charged sides only when the positive side of a power source connects to the positively charged, p-type layer, while its negative, n-type side is grounded. The positive charge increases the attraction of the anode, counteracting the stabilising effect of the barrier and allowing current to flow. If a positive power source is attached to the negative side of a diode, this will have the opposite effect of increasing the barrier’s strength. A sufficient voltage will be enough to counteract the barrier’s effects; this property is made use of in capacitors, electronic components which store up and release charge.

Integrated circuits, however, make use of fieldeffect transistors. In NMOS chips, which formed the bulk of early microprocessors, a positively charged substrate forms a dual barrier between two negatively charged poles, called collector and drain[7]. It is only through the introduction of a small voltage to a third, positively charged pole that the barriers are weakened and current can flow. This third, positively charged pole does not connect directly to the positive substrate; instead, its effect comes from the magnetic field created at the gate. The voltage introduced to the base can be much smaller than the current passing from the collector to the drain. For this reason, transistors have been used as analogue amplifiers, with the small current at the base controlling a much larger current at the drain. Such transistors can also be assembled into switches and consequently logic gates, and it is from this that their importance to digital computing derives. Interleaved silicon layers can contain a large number of these transistors configured to make simple Boolean logic gates.

Since a transistor has two inputs, it is effectively a crude AND gate: it will only produce an output if there is current both at the collector and the base. The manufacture of NMOS chips uses two transistors to produce a basic NAND or NOR gate, placing them in series in the former case and parallel in the latter. The base of each transistor is used as an

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al. (2000) and Kasap (2006) explain the underlying functioning of integrated circuits. The Z80 has a number of relevant texts, including texts by Zaks (1981) and Gaonkar (1993). Hennessy and Patterson (2011), Toulson and Wilmshurst (2012), Kusher (2011) and Margolis (2011) explain contemporary microcontrollers. Strickland (2016) integrates modern and antique tech.

[7] Most integrated circuits today make use of CMOS rather than NMOS technology; while NMOS requires a constant current, CMOS only requires current while switching (Razavi, 2000).

input; voltage is measured before the transistors. If there is current at one of the bases, in the case of the NOR gate, or both, in the case of the NAND gate, the voltage at the point before the transistors will be low, providing a binary zero. These NAND and NOR gates are each important because they can be used in combination to produce any other type of possible boolean logic gate. As such, the integrated circuits which come to be assembled into the ZX Spectrum are themselves combinations of many much smaller components.

Scatter Analysis: Beyond Black Boxes

An associated study has looked at the distribution of integrated circuit chips across the documented still extant ZX Spectrums. Specifically, it looks at the variant types of chips used to fulfil arguably the two most important roles for integrated circuits in the Spectrum - that of the Processor, a variant of the Zilog Z80, and that of the secondary circuitry facilitating stable video output and memory access, the ULA - an Uncommitted Logic Array from Ferranti. While documentation refers to these components as if they are a singular entity, opening several devices shows that the type of device used within a particular place is not consistent but instead varies with improvements to the design of subcomponents or as chips get sourced from different countries or producers. Integrated circuits appear externally as a ‘black box’, distinguishable only from one another by shape and by the number of pins without recourse to additional inscriptions.

A precedent for labelling electronic components existed before the development of integrated circuits; the Electronic Color Code was used from the 1920s to identify different types of resistors, which frequently held radically different values while maintaining a similar or identical appearance.[8] With resistors and capacitors, however, labelling focused on the resistance or capacitance value. While diodes initially often adopted the same use of colours to refer to digits, the digits referred to part numbers rather than values. With the growing complexity of electronic systems and the emergence of logic gates and other transistor-based components, simple values were not enough. Transistors would frequently employ an alternative system, with an initial letter denoting the type of material used and a second letter used to denote the function of the transistors. Hardware producers also adopted conventions and manners for identifying their chips; this is more common with large or specialised manufacturers, who may have two or more components fulfilling the same function.

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[8] For resistors, see Meade (2002, p. 47), Mearns (2013). For transistors, see *Electronix Express* (2014).

Integrated circuits were initially the preserve of a few manufacturers, with each developing a system for labelling the components. Texas Instruments, for example, was responsible for producing what is considered as the first integrated circuit; therefore, they and other early developers were in the position of developing standards for labelling (Qadir et al., 2016, Huckabee and Troxtell, 2012). The company refers to the requirements of the US Military as a critical reason for the development of a labelling methodology; operating forces were eager to ensure the reliability and safe provenance of the circuitry used within military applications (Villasenor and Tehranipoor, 2013). As it was unclear how well the circuits would perform as they age, many acquisition contracts specified that circuitry should originate within a specific, recent period, and not be of foreign origin. Military requirements also determined the forms that marking would take; circuits have a device number, but also a discrete 'lot trace code', made up of the Year, Month and a four-digit alphanumeric code, followed by an identifier which would show the place of production, and if a subcontractor produced it.

Fairchild, responsible for much of the development of Integrated Circuit memory, would also follow a similar convention (1997, p. 8-3). Smaller components, brought about by the development of smaller-scale integration, meant that it was more difficult to print the entirety of the lot number on the chip. Instead, for components of a less-critical nature or civilian applications, the manufacturers felt more comfortable specifying a year and a general period in which the device was produced; this allowed them to continue to suggest a level of reliability and accountability without the need for an increase in component size. A two-digit code might specify the year and a six week period in which the device was created. If the second digit was made an alphanumeric character, the provenance of the chip could be suggested within a two-week window; alternatively, the use of three or four markings, denoting values between zero and seven or fifteen respectively in binary, could also allow the device to be identified within an eight- or six-week window.

With the Spectrum and many earlier generation home computers, the majority of circuits appear to use a much more easily readable format, comprising the part number and a four-digit date code, including two digits each for the year and week of manufacture. When the dates of components are compared within a single device, it is possible to make educated guesses as to the relative importance of different chips within the device. Newer chips could generally be seen as more critical, though if any are significantly newer than the others, it may suggest that a part has failed and gotten replaced at some point in the object's life history. The ordering of components by age can suggest which components were in short supply and which subcomponents were stored at the facility.

Chips which are improved - that is to say, where part models or suppliers change according to time of assembly - suggest this part of the device is a focus for attempts to improve the device.

The provenance of subcomponents within a particular device can suggest things about its manufacture; whether the materials were sourced locally or at a distance is perhaps more important than the final location of assembly. For this to happen, however, it is necessary to research the production histories of individual companies since many producers do not indicate where their chips were made or indicate only a country. Even without knowledge or analysis of chip markings, a glance at any circuit board can confirm that the average Spectrum is an assemblage of parts from a range of countries. With more extensive research, it is possible to develop the capacity to uncover more about the life histories of electronic objects.

With access to a large number of comparable circuit boards, it is possible to move from histories of individual objects to charting the evolution of a platform. It is also possible to connect the evolution of a device to the transformations within industry and culture as a whole. With devices from different periods, changes in components can highlight where and how improvements are made within a device. Where different parts are found consistently in devices of a similar age, this is attributed to one of many causes. In some cases, it can be attributed to shortages in supply on the part of the component manufacturers, forcing assemblers of final products to draw resources from several different suppliers. In other cases, it is indicative of failures of a particular component, requiring that it be replaced more frequently. This, in turn, suggests changes in the industry as a whole and consequently in digital culture.

Practices of outsourcing and second-sourcing, where larger manufacturers entrust manufacturing to smaller companies, could be revealed through an analysis and comparison of the manufacturers of integrated circuits. Due to the fallibility of production processes and instability amongst smaller companies producing microprocessors, chip memories and other integrated circuits, computer manufacturers would generally request or demand manufacturers to arrange ‘second sources’, meaning second producers for their circuitry, so that they were not entirely dependent on a single supplier. (Gallippi, 2012) Practices of globalisation - where manufacturers move production abroad to avoid high labour costs or regulation - are similarly visible through analysis of the country of manufacture of specific subcomponents. Starting with Texas Instruments’ Bedford plant in the United Kingdom, circuitry began to be produced in Europe to take advantage of cheaper skilled labour and growing demand (Roffe, 2019). Throughout the 1970s and

1980s, microchip production and later assembly would also move eastwards to East Asia. Analysis of integrated circuits can be used on an individual level - to identify why a particular computer may no longer be functioning or to discern its specific biography - if it has been altered or upgraded, for example. On a broader scale, the analysis of integrated circuits can illustrate the transformations of production processes and the consolidation of a platform.

Circuits of Production

The Z80: Viruses and the Valley

When describing the phenomenon which led to the birth of Zilog, Italian historian of science Angelo Gallippi describes a metaphorical 'virus of the valley' that would inevitably strike engineers as they worked within the high technology companies of Silicon Valley (2012). This sentiment would afflict those that felt their designs and innovations were not given enough attention; they would subsequently strike out on their own. Gallippi's work on Fagin, Il Padre Del Microprocessore (The Father of the Microprocessor), is useful; despite focusing on a single engineer, it tells us a great deal about the origins of the Z80 chip, and its relationship to the wider context of 1970's Silicon Valley. This section will attempt to explain the importance of the microprocessor and its origins.

The first integrated circuits had been developed independently by Jack Kilby and Robert Noyce at Texas Instruments and Fairchild respectively, both military subcontractors. These allowed for integrated circuit memories to become viable, replacing the expensive and high-maintenance valves used for memory. Noyce had defected with several others from William Shockley's semiconductor laboratory in 1957; (Berlin 2005, p. 81) Shockley had been responsible for the development of the transistor, but his paranoid and inconsistent management style had troubled his employees (p. 87). At Fairchild, a large instrument company that also made cameras and aircraft, Noyce eventually came to be responsible for the semiconductor division, which developed early integrated circuits, including those used in the early Apollo missions. Fairchild had occupied a leading role in the development of such technology, but while their integrated circuits incorporated the transistors that had begun to revolutionise electronics, they generally matched transistors and resistors, and later transistors and diodes. As such, Fairchild started falling behind competitor Texas Instruments, which had developed integrated circuits using only transistors. The demand for restructuring led to the departure of Fairchild's CEO; Noyce, at the time a senior vice-president, was passed over for promotion twice. Other founders of the Fairchild division had already left; in 1968, Noyce and Gordon Moore founded Intel.

Intel managed to recruit a large amount of staff from Fairchild, including Federico Faggin, who would later found Zilog. Faggin, an Italian engineer, had led the Research and Development division at Fairchild Semiconductors and had been working on developing integrated circuits that used gates made entirely from silicon rather than metal oxides. These allowed the production of a wider range of devices, including charge-coupled devices, used in light sensors and digital cameras, and dynamic random-access memory. This type of memory would facilitate the expansion of computing in a major way; however, it would lose its contents when not repeatedly refreshed. As such, this type of memory was less desirable for minicomputers and other large computers which would have periods of downtime; as such, it was not aggressively pursued by Fairchild. Although Intel had itself been founded by engineers from Fairchild after the large defence contractor had been insufficiently committed to the development of integrated circuit technology, it had built up a large business around selling integrated circuit memory chips to manufacturers of mainframes and minicomputers, which required large amounts of memory to operate as they often stored programs and data for a range of users simultaneously. The production of microcontrollers would threaten the business of their primary customers, without guaranteeing a stable market to replace it. Ultimately, Intel would end up leaving the memory market to focus on the processor market, but only after intense competition from East Asian companies rendered its original business unsustainable.

According to Bassett (2002), the first processor on a silicon chip was produced as early as 1970 by a company called Four Phase, which specialised in producing cheap minicomputer terminals. While the company had made a significant development by producing a processor as an integrated circuit, they were unwilling to market it as such, both because they felt their idea could be copied easily, but also because they felt it might make their product seem less robust than alternatives. Intel, an emergent manufacturer of integrated circuit memory, also commissioned the development of an integrated circuit processor. Federico Faggin came to Intel in 1970, where in addition to continuing work on Silicon Gate Technology, he worked under Ted Hoff to design an integrated circuit microprocessor (Bassett 2002, p. 268). This processor, the Intel 4004, is widely seen as the first commercially available processor chip. Bassett, however, cautions against attributing too much significance to the circuit or any one particular individual involved in its development:

> Intel's work on what is now called the microprocessor shows the inadequacy of simple notions of invention in a complex technological system. Intel's microprocessor work received so much attention because Intel was able to make it a successful product (and because Intel subsequently gained dominance of the microprocessor market). The sole credit that Hoff typically receives presumes a disembodied notion of technology, with the idea being the most important thing, and a non-problematic straight line existing from conception to commercialization. Had Faggin been unable to design the chip, manufacturing unable to make it, upper-level management unwilling to support it, or marketing unable to devise a plan to sell it, Intel's microprocessor work would be seen in a far different way, most likely as a footnote to whatever became the first commercially successful microprocessor. (2002, p. 270-271)

In Gallippi's biography of Federico Faggin, he relates that a 1974 restructuring saw the engineer become head of Research and Development at Intel. (109) Whereas traditional companies saw marketing specify the nature of products and engineers produce them, the experimental nature of early microcomputers meant that Faggin's team had found substantial freedom to set target specifications, given that no 'market' as such for microprocessors existed yet. The subsequent desire of marketing chief Bill Davidow to exert more control over product specifications was therefore unwelcome, particularly as Davidow, himself an engineer, allegedly rebuffed Faggin's attempts to collaborate. Faggin recounts that an end of year reunion provided a space for Intel Executive Vice President Gordon Moore to set the agenda for the company; Davidow and Faggin's both presented their competing visions for the new architecture to Moore.

While Faggin's vision won out, it was clear that his creative freedom would continue to be under threat. Besides, Faggin found out from a colleague that one of his innovations at Fairchild, the buried gate, had been patented in the name of his superior, VP of research and development Leslie Vadasz (p. 111). While Faggin responded angrily, confronting Vadasz, his options were limited; as well as threatening his job security, bringing his superior before a tribunal would also threaten Intel's control of the patent. As such, Faggin found himself in an insecure position; he drew upon his contacts, specifically Ralph Ungermann, his project manager, and Masatoshi Shima, his chip designer, convincing them to strike out on their own together as part of a new company, Zilog, short for 'integrated logic' with a 'z' prefix to situate it at the end of the directory. Faggin and Ungermann's decision to strike out on their own, seen by Gallipi as result of the 'Virus of the Valley', was not without precedent. Moore and Noyce, founders of Intel, were a part of the so-called 'traitorous eight' which had left Shockley's semiconductor laboratory to form Fairchild. (Bassett, 2012, 174) When they left Fairchild and subsequently formed Intel, they conducted a betrayal of their own by recruiting Faggin, a young Italian engineer (Bassett 2012, p. 268). The story of subsequent betrayals is compelling and perhaps dominant in historical narratives.

This historical and romanticised view of innovation, drawing from Gallippi's biographic work on Faggin as well as biographies of Noyce, Shockley and other critical figures, is not without its methodological problems. All too many narratives romanticise 'great men'. Yet Gallippi's narrative is interesting because there is, to an extent, an inversion - Faggin feels his behaviour changed by the structures around him (p. 112). The Electronics group of Committee of Socialist Economics, an English Marxist research group studying microcomputers, simplifies the birth of Zilog Systems. Gallippi acknowledges the relationship that global economic changes and political events as background to the narrative of Zilog, but for CSE these economic shifts are primary. From the beginning, Zilog was funded by Exxon, the oil conglomerate, through their New York investment arm. Faggin recalls that they were called by an executive following the publication of their company's first advertisement. Exxon, only created in 1972 from the merger of a number of other American oil companies, had increased its profits heavily despite, if not because of, the 1973 oil crisis (Laxxer 1974, p. 33). Resource extraction was a dirty and precarious industry, however, and investment in high technology promised a high return. With funding from an oil-company backed prototype of the venture capital firms that would become so influential for Silicon Valley's development, Zilog was able to take the risk of entering the still novel microprocessor market. Fairchild and Texas Instruments were backed by electronic instrument companies that had a number of military and government contracts. MOS Technologies had been started by Allen Bradley, another instrument company, in order to provide an alternative supplier to Texas Instruments (Bagnall 2011, p. 30). Intel is notable in that it was relatively independent of larger companies, getting most of its funding from the network of early venture capitalist Arthur Rock (Berlin 2005, p. 164). In the structural organisation of microprocessor manufacturers, there is a shift towards design and intellectual property focused companies that avoid vertical integration and occasionally shun manufacturing capability entirely.

Zilog is an early example of this due to their decision to go 'fabless', meaning that they were without the capability to produce or 'fabricate' their own integrated circuits. Zilog would be solely responsible for licensing the designs, with the responsibility for manufacture delegated to other companies. The arrangement whereby component manufacturers would contract another company to produce authorised copies of their devices was already widespread in electronics and was known as 'second sourcing'. The provision of multiple suppliers would increase the likelihood that instrument manufacturers would choose a particular component design, since with complicated electronic products, any supply shortage of a particular component would make it difficult and often impossible to produce the finished product unless there was a backup supplier already available. With Zilog, however, the choice was made to avoid having a 'first source'. As a result, the design process was more challenging as the chip design needed to be tested and perfected before being sent off to manufacturers. Zilog, on the other hand, was absolved of the responsibility of setting up plants, which required a great deal of capital expenditure on machinery and was risky. The attempt to produce incredibly miniaturised devices with imprecise tools lead to poor chip yields; only a small amount of chips produced would ever 'work', the majority consigned as waste. Even a working design might not be cost-effective to manufacture, while the machinery used to produce electronic components would become obsolete a lot faster than machinery used to produce other tools or consumer products. By abstracting away the manufacturing, Zilog became a prototypical postindustrial 'start-up' (Sarma and Sun, 2009).

Though the chip seemingly evokes the eighties through its name, it was released in 1976 and incorporated in computer designs (such as the Tandy TRS-80) as early as 1977. By 1979, its successor, the 16-bit Z8000, was already available (Fawcett, 1983). The use of an outdated processor in the Sinclair line had numerous benefits. As a tested, documented and accessible system, it was attractive to hobbyists, the target market of the ZX80, a computer that initially needed to be assembled by the purchaser. The relative age of the processor and the fact that already established supply chains made the processor cheap, which was necessary to meet the ZX Spectrum's target price of under a hundred pounds, and acquirable from many sources. The use of such a processor also would have a subsequent benefit once the ZX81 and ZX Spectrum became established as gaming machines; the Z80 was commonly used as a processor in arcade cabinets, making some game adaptations far easier. It would also form the basis of the Japanese MSX Home Computer format from 1982, and Amstrad CPC computers from 1984. Initially, however, the Z80 was not the most prominent processor for microcomputing. The ZX Spectrum's main domestic rival, the BBC Micro, its closest American analogies, the Commodore Vic-20 and then the Commodore 64, all used versions of the MOS Technologies 6502 chip. The 6502 was also used, in a limited form, in the Atari VCS console that became the most popular gaming platform of the 70s, and in the Famicom/NES console that arguably served the same role in the 1980s. The 6502 chip and Z80 - produced by different companies - have similar backgrounds. Both were formed by renegade engineers and designers leaving more established pioneers of integrated circuit development.

MOS Technology was established in 1969 and produced calculator and Pong console chips, but the defection of the Motorola design team for the 6800 processor allowed it to compete in the microprocessor market (Swaminathan 2011). The 6800 team saw a possibility for low-cost microprocessors, but their managers at Motorola had been unwilling to support the project (Bagnall 2006, p. 10). The engineers involved appear to have been consequently worried about their jobs but also seem to have wanted to complete the project on which they were working. MOS Technologies was notable in that they had developed a way to create chips at a lower cost; instead of merely writing off chips created from a flawed original, they would check and if necessary repair the mask used to create them before pressing. As a result, a new microprocessor design could be produced more cheaply. Since the new chip would be compatible with Motorola's chip sockets, it immediately posed a threat and resulted in a lawsuit that effectively bankrupted MOS Technologies (p. 35). Commodore purchased the company since, as a manufacturer of microcomputers, it required a continued supply of cheap circuits (p. 230, 442). The acquisition of a microchip manufacturer allowed Commodore to produce a series of cheap, effective and highly popular computers, including the PET, the Amiga and the Commodore 64, one of the Sinclair ZX Spectrum's significant rivals. The consolidation into a single company would result in Commodore taking on increasing amounts of manufacturing and developing a structure resembling a traditional industrial firm. Sinclair Research and Zilog, on the other hand, were nomadic, research-oriented ventures.

The ULA: Beyond the Processor

The Spectrum's processor is perhaps at the core of the device's design; though different suppliers provided different integrated circuits, the architecture and operation of each remained effectively unchanged. As the originator of all computational processes performed by the device, the central processing unit performed perhaps the dominant function. The emergence of such microprocessors or microcontrollers certainly made the emergence of home computing possible. That said, this central component was also perhaps its most ubiquitous element. Versions of the processor chip, the Zilog Z80A, had been used in both the Spectrum's antecedents produced by Sinclair Research, the ZX80 and ZX81. While the Zilog chip had a reputation of being reliable and capable, to such an extent that it is referenced in the name of the first Sinclair Research computer, it was also both out of date, and relatively ubiquitous (Laurie 1980, p. 174). The additional features of the device, setting it apart from alternatives, came from secondary circuitry design.

As Chris Smith (2010, p. 29-32) shows, computer companies had two options when choosing integrated circuits to use in a microcomputer device. They could manufacture custom circuits to fulfil the specific needs of the device. Alternatively, they could use a premade circuit marketed to a broad audience. The first option would require the computer manufacturer to either have or purchase access to chip fabrication facilities.

They would also need to hire engineers with the capability to design internal microchip circuitry and to commit to using the chip in enough machines to make the cost of tooling machinery worthwhile. The second option would be far cheaper but would mean that the designers of the device would have to work around the capabilities of the chips chosen, rather than coming up with a design purely based on desired functionality. It would leave the design open to being copied by competitors, who could buy identical chips if they wanted to replicate the device.

The story of the PC is indicative of some of the problems with the use of off-the-shelf chips. While IBM - as the largest computer company in the world at the time - could afford to design and produce chips, the lack of resources devoted to their PC project and the desire to prepare a product quickly meant that they used already available circuitry (Laing, 2004, p. 80). As a result, if one was able to decode the operating system stored on a ROM memory chip, one could easily replicate the device. The strength of IBM’s legal department prevented outright copies from being sold commercially in large quantities, but they could not prevent competitors from making computers compatible with its peripherals and software. The Ferranti ULA, or Uncommitted Logic Array, was part of a range of semi-custom chips, a newly available ‘third’ option (Smith 2010, p. 30). Effectively, these chips would be provided with several functioning components - in a component array - or gates - in a gate array. The customer would subsequently decide how the gates or components should be configured before a final ‘masking’, a final stage of production configuring the devices. The use of such chips required coordination between the computer and chip manufacturers since the finished product would be unique for that manufacturer.

The majority of the integrated circuit assembly process, however, could be done independent of the manufacturer of the finished product, and the chip manufacturer could produce a design and prepare machinery that would suit many potential clients. As such, versions of the Ferranti ULA appear in a large number of British microcomputers, including the competing BBC Micro. Since they did not use their own fully custom chips, Sinclair Research could produce their computer designs without a substantial cost outlay; this allowed them to produce three computers in the space of three years. On the other hand, it was not easily possible to purchase the chips they used; even if Ferranti could provide the same semi-custom chips, they would need to be configured. By using semi-custom chips, Sinclair Research allowed itself both flexibility and secrecy.

Tracing the ZX Spectrum's Development

The number of integrated circuits in a Sinclair computer is hardly consistent. It varies across time as new versions of the device are released with expanded or more efficient memory, leading to the presence of greater or fewer chips. Neither an increase in complexity nor a simplification should be taken for granted. Sinclair Research's original ZX80 microcomputer had 21 microchips, but the Spectrum's immediate antecedent had only five. This shrinkage resulted from the fact that the ZX81 used a customisable chip to replace many of the integrated circuits of the original and fix a few minor errors. The chip, produced by Ferranti, is the only series of its kind designed in the UK and it is also the most enigmatic, given that its internal mechanics consisted of several components that could be configured independently for each customer (Smith 2010, p. 37). It was possible for the same line of ULA to power both the ZX81 and early ZX Spectrum, even though they are used in radically different ways. Effectively, the Uncommitted Logic Array - ULA - was a set of building blocks that allowed hardware manufacturers to create a 'semi-custom' chip without producing chip manufacturing facilities.

Microchips were only economical when produced in bulk; to use a wholly custom chip would have been possible for Sinclair Research, but it would have increased the costs of the machine while ensuring that changes could only occur infrequently. The ULA, on the other hand, could have many different versions, as the mechanics of the integrated circuit were updated and refined. Similarly, the processor used in the device was chosen because its ubiquity made it cheap and reliable; there were many possible origins for the device (Kressel and Lento 2010, p. 150). Initially, so-called 'second source' suppliers handled the manufacturing; Zilog, who manufactured the chip, produced only the design. Second sourcing - an arrangement where more than one supplier could provide a component - protected the customer against supply bottlenecks if a particular component supplier failed. It is for this reason that Sinclair computers also are found with Read-Only-Memory chips - used to store the operating system - produced by both Hitachi and NEC. Finally, the random-access memory chips also appear to come from a range of sources; as the ability to create higher density memory emerged, the Spectrum even shifted towards using the working half of faulty 64-bit memory chips to reduce costs.

The first major Sinclair computer, the ZX80, did not feature an Uncommitted Logic Array. It had a chip customised at assembly, but this was an EPROM chip, an electronically programmable ROM chip that could theoretically be reprogrammed after manufacture (Searle, 2016). This chip - a Texas Instruments TMS2532 - held four kilobytes of data. This data could subsequently be erased through the application of ultraviolet light through a special window; the pin allowing reprogramming could and often would be cut. This chip provided a basic operating system and did not function as secondary circuitry as in the ZX81 or ZX Spectrum. It acted as a ROM, a read-only memory; even though it was possible to change the memory, it was designed to be updated only if there was a need for a significant upgrade or update, if at all (Farrow, 2012).

Besides the ROM and processor, on the ZX80 two 4-bit x1 kilobit RAM chips together provided one KB of RAM Integrated Circuits 5 - 21 were latches or gates of various varieties (Searle, 2016). It was these elements of circuitry that provided the majority of the functionality of the device, allowing the ZX80 processor to accept keyboard input, save or load data from cassette, and output images to the screen. The fact that the ZX80 used these commercially available circuits meant it was potentially trivial to copy; however, at the time of release, the demand for computers was not high enough to make this worthwhile. It appears that only two commercial ZX80 clones exist, the TK80 in Brazil, and the MicroAce in the United States (Clube do TK, Searls, 1981). The ZX80 used 31 resistors, 12 capacitors and 8 diodes; each of these had a cost, however small, leading the ZX80 to be more expensive than its successor (Searle, 2016).

The second Sinclair Research computer, the ZX81, was the first to adopt a ULA. Jim Westwood, the chief designer, had expertly sketched a translation of the ZX80's circuitry so it would work on an early, 2000 series Ferranti ULA (Smith 2010, p. 71). Richard Altwasser, the new hire, then developed this sketch into a working prototype. The new, larger ROM allowed some of the problems, such as a lack of floating-point mathematics and a screen flicker, to be resolved. The screen flicker was a problem whereby any button press or code execution would temporarily blank the screen, as processing power used to produce the image needed to be assigned to handling input and program updates. The resolution involved the addition of a 'slow' mode, which would devote at least some of the processing power to maintaining the screen image, alongside the existing 'fast' mode, which would blank the screen but execute the code at the fastest possible pace. The increased ROM size meant added cost, but the designers compensated for this. By consolidating a lot of the excess circuitry into a single chip, Westwood and Altwasser had ensured that the new device would be less expensive to produce, would consume less power, and would produce less heat (Smith 2010, p. 72). The new computer would subsequently then only use four chips - one for RAM, one for ROM, one Z80 processor, and one of the newly essential ULA chips.

The ZX Spectrum would also use a ULA; however, the designers would use it in an arguably more advanced manner. While the ULA in the ZX81 had been used purely to ‘tidy’ up the ZX80, making it less expensive to produce, the ULA in the ZX Spectrum would be used as a key element in the design, acting as both a video processor and a memory and I/O manager (Searle, 2016). The labelling of the ULA as ‘IC1’ on the board and technical schematics suggests this centrality. While the ZX Spectrum was still a computer based around the Z80 processor, using Z80 assembly code to run its Basic Input/Output System and its more complicated programs, computing had developed away from the model of the kit towards that of the complete consumer device. One of the major selling points of the ZX Spectrum was to be its colour screen, something which would be a significant challenge to provide.

The ZX Spectrum Display

The earlier Sinclair computers had stored and transmitted characters as 8-by-8 squares. Each pixel in a line of eight would be ‘on’ or ‘off´ - this process would be then repeated eight times to constitute a square. This system allowed relatively rapid production of a display but was by nature only suited to black and white displays. In many contemporaneous computers, the increased demands for graphics had led to the use of specialised graphics chips - the first of these was the NEC µPD7220, released the same year as the Spectrum (Hopgood et al. 1986, p. 169). Given the decision by Sinclair Research to aim for reduced component costs and the novelty of such technology, however, such chips were not used. Instead, the ULA was used to encompass some of the functions of these new graphics chips.

The ULA’s mechanism for processing the display remained relatively unaffected. It would transmit 8-by-8 pixel blocks as before, with each bit in a byte indicating the presence or absence of a pixel[9]. As with its precedents, the ZX Spectrum operated at a resolution of 256 by 192, with the 192 - the vertical resolution - being broken up into three strips of 64. Instead of a purely black and white screen, however, the Spectrum was designed to produce a colour image. To accomplish this required the inclusion of so-called ‘attributes’ for each 8-by-8 block. Rather than merely being ON or OFF, it set the pixels in each block to INK or PAPER, two colours specified from a set of eight. This was done through another byte, sent separately, which would contain eight bits. The third, fourth and fifth bits would set the PAPER or background green, red and blue values, respectively. A binary zero would be black, binary one would be blue, binary five would be cyan (green and blue), and binary eight would be white. The sixth, seventh and eighth bits would set the INK - the foreground colour. The first two bits fulfil special functions; the first - FLASH

[9] Smith 2010, p. 137, Belfield 2017c, Black 201

- causes the foreground INK and background colours to switch back and forth every 32 frames, roughly every second and a half. The second bit -BRIGHT - elevates the luminosity or brightness of the eight-by-eight square, in practice allowing another seven possible colours, brighter versions of all colours except black.

This limitation meant that each area -or attribute - could accommodate only two colours. If two characters or objects in a game had cause to enter the same eight by eight block, the colour of one character or object might be overridden that of the other. This process came to be called ‘attribute clash’, as it was caused by conflicting instructions about how to colour the ‘attribute’ or area of the screen. Producers of Spectrum programs, particularly games, would subsequently need to decide whether to avoid such a graphical glitch or to accommodate it into their program’s visual style.

Other contemporary devices had similarly adopted the concept of having a secondary chip used to drive the display, but as they used different chips, the results were drastically different. The BBC Micro, the Spectrum’s major UK competitor, had several different video modes, the majority of which used the Motorola 6845 chip. The BBC Micro allowed access to a maximum of only eight colours, however by alternating between these colours, the hardware could create the illusion of others. The programmer could choose between modes which allowed access to all eight hardware colours and modes which allowed a higher resolution. The three more advanced modes required access to more memory, however, and so cheaper, ‘A’ variant only allowed access to the three less advanced ones. Some games, such as the famous space-simulator Elite, made use of multiple graphics modes to allow a screen to be broken into high resolution and colour sections (Gazzard 2016, p. 27). Also, the BBC Micro had a ‘teletext’ mode - used for displaying information over a network - that used a separate chip and only 1KB of display memory (p. 124). The computer’s processor could then focus on retrieving and organising information.

The Commodore 64, a US console challenging the Spectrum, used a VIC II Chip manufactured by Commodore-owned MOS Technologies (Bagnall, 2006, p. 21, Platt 1984, Bell, 2017). The Commodore’s ‘high-color’ mode allowed four colours for each 4-by-8 pixel area, sharing one of these across the entire screen. These blocks, smaller than those used by the Spectrum, were horizontally stretched, effectively meaning that these ‘attributes’ were roughly the same size. Unlike the Spectrum, however, the Commodore 64 had a built-in capacity for eight sprites, small characters which could be moved around the screen independently of the background. These could be 24x21 using a single, independent colour, or 12x21 and three colours, with two shared amongst all sprites.

The Commodore could, therefore, have several independent characters moving around the screen without the risk of suffering from the Spectrum's 'attribute clash'. It could also display many of its 16 colours at the same time; unlike the Spectrum, the second 8 were not simply 'bright' versions of the first eight. The colours were chosen arbitrarily by chip developers, however, leading the palette, or range of possible colours, to look much more earthy than other consoles and computers. In addition, the stretching of characters and limited horizontal resolution created challenges for artists. The Spectrum's graphics mode, while far from perfect, did have some advantages over its competitors. As the display only used 8K of screen memory, the visuals could be updated faster than the BBC Micro (using 10 or 20k, except in Teletext mode) or the Commodore (which used 16K). The 'attribute clash', initially mocked, resulted in a distinctive and psychedelic aesthetic for Spectrum games, as bright colours interfered with one another in a visually striking manner. Describing the Attribute Clash of the Spectrum is relatively trivial since game developers on the device needed to address the issues it caused. Understanding how it results from the affordances of 1980s chip design and the compromises of hardware design is more significant of an achievement.

Circuits

To attempt the large-scale analysis of integrated circuits found in a microcomputer might have little precedent in Archaeology, but there are many similarities between the tools driving the information age and some of humanity's earliest tools. Stone tools are not exclusive to homo sapiens; palaeo-archaeologists have discovered Palaeolithic artefacts, while zoological researchers have documented evidence of apes such as chimpanzees using tools in captivity (Hardy, 2004, Boesch and Boesch, 1990). By the end of the Neolithic, the usage of stone tools by humans was incredibly extensive, with tools being used for a range of farming and hunting tools. Humans had discovered better sources of flint, learning to work and refine tools to suit specific purposes. Since there were so many of these tools - and since they wore out relatively quickly - they were frequently discarded and replaced, leading to tools being scattered across the landscape (Sellet, 1993). These objects are found often in the context of sites such as caves or around monumental stone structures, but the age of the artefacts and the technologies used for the construction of dwellings means that little of the context has survived. Even bones are unlikely to survive outside of specific hospitable environments. As such, often only stone artefacts could give us an accurate picture of how cultures lived and worked the landscape around them.

With computer chips, we possess in many cases historical records detailing how objects were designed, used and maintained. Heavy documentation is not always present; historical narratives develop a particular strength that obscures specificities only made available through material analysis. A good example would be the supposed identification of the ZX Spectrum as a British computer. Certainly elements of the overall design were developed in the UK, but looking inside of the Spectrum we might see circuits designed in other places or produced elsewhere. This much is obvious, but by looking at how the patterns of distribution change, it is possible to discern more extensive changes in surrounding economic and cultural networks. Just as stone tools required techniques to be disseminated through mimicry and understood through reenactment, reverse engineering has been critical to both the development and the retrospective analysis of integrated circuits. Some of the circuits were documented at the time of use. The Zilog processor, for example, was explained in a variety of materials aimed at hardware, operating system and software developers. It was designed to be compatible with Intel peripherals, but this was not due to reverse engineering, but rather a result of defection; the senior engineers involved in creating the Intel 8080 chip would later work for Zilog. Since the Z80 chip was to be used in a range of calculators, computers and arcade consoles, it was important that developers be able to understand the operations of the device. The problem lies in tracing this material; while texts and manuals were once widely available, the obsolescence of the device means that few libraries are interested in or capable of storing information on the operation of such devices. Such is the case with much material relating to technology and industry in general: it comes to be viewed as ephemera, rather than as formal knowledge worthy of preservation.

The information required for research is now found on amateur internet sites and in second-hand book depositories, rather than formal publications and libraries; often it is discarded. The recovery and preservation of this information relating to computer artefacts are often more difficult than recovering and preserving the artefacts themselves. With some circuits, such as the read-only memory chip imprinted with the Spectrum's operating system, a single text is enough to understand the workings of a device. Ian Logan and Frank O'Hara's book (1983), produced shortly after the release of the Spectrum, provided a comprehensive review of this circuit's contents and consequently its functions. The Processor, however, by design could perform a large number of functions based upon the commands issued to it in its discrete low-level language or 'machine code'. Therefore, to fully understand the device would require access to an extensive collection of written material viewed as obsolete and therefore only maintained outside of typical library systems.

In other cases, however, a subcomponent would have little to no extant documentation, while its operational mechanics were not immediately apparent. This is particularly the case with the Uncommitted Logic Array, manufactured by Ferranti to Sinclair Research's specifications. Since the device was produced on a small scale - as a customised version of a chip produced on a much larger scale - it was difficult to discern precisely how it operated. This was optimal for Sinclair Research since unlike the processor or memory chips, this integrated circuit could not be bought from other manufacturers, or in the configuration from the original manufacturer. This did not delay the production of unauthorised clones of the Spectrum and other Sinclair computers using such circuits but meant authentic reproductions were out of the question. Therefore, the developers of secondary circuitry for Sinclair Spectrum clones were forced to produce something that was at best an approximation. Authenticity, the aim of many hardware clones, was supplanted as the priority by functionality.

Even inter-compatibility was hardly guaranteed; many Spectrum clones would not run software designed for the original device. Paradoxically, it was the presence of this secondary integrated circuit that was shrouded in mystery that meant that the processor became all important for identifying a device with the Spectrum. Any computer with a version - authorised or unauthorised - of the Zilog Z80 could be identified as a derivative of the Spectrum. Of course, many computers were developed entirely independently of Sinclair Research using the processor and were marketed as different products. There is evidence to suggest both that the original Sinclair ZX80 was derivative of other microcomputer projects, and that later versions of Spectrum incorporated innovative features from clone devices and hardware peripherals.

An understanding of the ways clones of the Spectrum reconfigured the mechanics of the original machine is difficult because of the rarity and the diversity of these devices. While extensive information on defunct UK hardware companies is difficult to find, the discovery of information about foreign Sinclair clones is made more difficult by the fact that many of these computers were either homemade or made in factories or research labs designed and nominally devoted for other purposes. Even with access to the original machines, the range and variation of components mean it is not a certainty that their operation will be understood. As with individual components, ephemeral material such as amateur internet sites, usegroup posts and scanned manuals exist, but no source is either complete or completely reliable. Language barriers make comparative work challenging; however, this has the positive effect of encouraging collaboration and collective scholarship. Further research might involve using methods such as subcomponent analysis to explore the wider universe of 1980's computing; this is beyond the scope of this project. The following chapter will, however, look more specifically at a few case studies of adaptation through the lens of diffusion.

Diffusion

Machine Morphology

This chapter will explore the concept of diffusion, which serves to explain how technology and culture comes to be spread across continents and international or intercultural borders. Diffusion is a topic of interest for all studies of technology regardless of epoch; however, in a period where global migration and trade was becoming increasingly noticeable, it is still possible to note differences in the material culture of different regions. For computers such as the ZX spectrum, this is evidenced in the design of 'clones'; computers which are compatible with software produced for the parent device, but which have different internal and/or external design. This chapter explores the concept of the clone, before looking at two case studies from Spain and Poland.

A clone in the context of computing is a device that features a similar architecture to another device, but a degree of difference. Alessandro Grussu's chapter is perhaps the closest to an authoritative source on the features and proliferation of ZX Spectrum clones, and yet this comprises only a small part of his comprehensive Italian encyclopedia *Spectrumpedia* (2012). The book, which lists a large number of clones, is particularly insightful in some instances, containing comprehensive discussion of specifications. Clones are rare, however, with only a few samples existing in collections in the UK. Instead of focusing on outward appearances, it seems prudent to look at stylistic and functional elements of the design to trace the development of Spectrum clones. Creating diagrams - adapted from typologies or morphological illustrations - will allow us to demonstrate the spread of a computational platform and the discrete changes it undergoes. Case studies are vital for understanding the development of technology within a particular territory[10].

It is also important to note that tree-like structures should imply more than just derivation, as innovations are developed by those responsible for reverse engineering the device and are included in subsequent fabrications, or even new versions of the original device. Though this study focuses on hardware, it is essential to note that the improved capacities of the derivative devices are responsible for the strength of things such as the demoscene, a subculture where high-quality graphics were generated using increasingly obsolete machines through virtuoso programming (Marecki et al. 2020). While the machines used were much less potent than their contemporaries in the 1990s, let alone

[10] See Alberts and Oldenziel 2016, Švelch 2013 a+b,2018, Langlois 2012, Conner 1995.

today, they were still often vastly improved over the original machines. They came to be used in a variety of ways, extending the capacities of the platform well beyond its original design and specification and consequently leading to new forms of cultural expression. They show the extent to which international cooperation - and even outright plagiarism - in the development of technology can often be beneficial for the development or consolidation of a platform.

Clones from Siberia

In the pages of the *Guardian* newspaper, a curator of one of London's National Museums reports back on a voyage to the East to acquire materials for his collection. While the title - 'Archaeology of a Lost Tribe' - certainly invokes the imperialist ventures of 18th and 19th century explorers, the author Doron Swade was, in fact, a curator of the Science Museum; his goal was to obtain not centuries-old curiosities, but rather specimens of socialist-era computer technology from the newly defunct Soviet Union (1993). Swade is interested predominantly in the large computer mainframes produced by industrial and academic institutions, but in passing also mentions certain homemade derivatives of UK microcomputers, so-called 'clones'. They are referred to 'Spectrums' but have a very different appearance and provenance. In the article, there is an attempt to chart a divergent vector of technological development, conditioned by different industrial infrastructures, differing notions of private, state and intellectual property, different modes of labour, consumption and education.

Reporting on his trip, Swade writes in 1993:

> We had been taken to a vast flea-market - about a half-hour drive from Novosibirsk - that traded in meat, livestock, furs, car spares, foreign currency, clothing and household goods. At stalls and tables alongside the frozen meat in the snow were electronic components, chips, computer peripherals, radio spares, partial chassis and sub-assemblies(…) Prized among this loot were reverse-engineered Sinclair ZX-Spectrum clones with games tapes and Russian documentation. These 'Sinclairs', as they are called, come in a variety of shapes, colours and designs, and bear little resemblance to their Western counterparts. Motherboards were made unofficially in state-owned electronics plants by underemployed workers. Machines were assembled at home and sold in ones and twos. Vendors vied with each other boasting of their latest mods. One of the two we purchased came with a guarantee - a handwritten note with the pinouts of the DIN connectors for the tape player, and the telephone number of the teenager who had made it. Cost: the equivalent of $19. (Swade, 1993)

A pair of shipping containers were filled with the acquired finds and expatriated to the United Kingdom; most of the objects continued to languish in an airfield hangar at Wroughton for over twenty years.

The devices were attributed to ‘Baracholka’, the slang word for ‘marketplace’, and only rudimentary attempts at a further examination of the smaller objects were made until very recently. Read from a contemporary standpoint, the venture appears in some ways to be an antiquarian venture, motivated by problematic ‘orientalist’ (Said, 1970) or ‘ostalgic’ (Banchelli, 2006) fantasies of the exotic. At the same time, Swade’s work with the Computing collections at the Science Museum set a precedent for exhibitions exploring the extensive history of computing. Critically, these investigations would explore not just its origins, but its subsequent diffusion. Further, in the supplementary text, he poses an important research question:

> If their early machines are similar in architecture and performance to ours, this says something significant about the uniqueness of solutions. If their machines are significantly different, then the history of computing faces a startling new chapter. (Swade, 1994)

While many histories of computing posit a simple sequential progression, there is here a suggestion of parallel development. Lines of technological development fork, while parallel innovations come to be reintegrated in synthetic products. Swade writes elsewhere about the difficulty of applying archaeological techniques to computing:

> We remain sufficiently close to the technology and its culture for early electronic machines to invite amused and sometimes wry nostalgia rather than the awed reverence accorded to relics from an unrecoverable past (...) these machines are not yet the fragile(,) sacred relics of the archaeological model which presupposes separation by an unbridgeable gulf of time. (Swade, 1990)

In Swade’s view, the most interesting objects for study were the mainframes produced up until the late 1960s; after this, architectures began to be ‘cloned’ from Western machines (Feigenbaum, 1961, Ware, 1960). Wolfgang Ernst, a key figure in media archaeology and the study of archives, has argued that” the alternative computing culture in the former Soviet Union has been stimulated by a weird and ever-changing reconfiguration between inventive improvisations on the engineering side and ingenious mathematics on the other,” (Ernst 2014, p. 200).

A great deal of work has been put into restoring a BESM 6 mainframe, which went on display in October of 2014 after more than twenty years in storage (Science Museum 2014-10/1). The computer, the last in a range of high-performance machines used for military, academic and space exploration purposes, was said to differ from US and UK built machines substantially. It is now a component of the Science Museum's 'Information Age' exhibit, opened with great fanfare by Her Majesty the Queen (Blyth 2015, 2016). The exhibition has been according to concepts of network operation rather than chronological period, and while it does not explicitly refer to the academic field of media archaeology, there are many parallels. In both, we see a movement towards explaining the infrastructural origins and operations of contemporary communication through presentation and analysis of artefacts. Also on display, albeit in a shadowy portion of a crowded display case, is one of the microcomputer clones brought back from Swade's expedition (Science Museum 1993-182/1), along with a version of the UK computer that inspired it (1985-195).

The production of mainframes such as the BESM-6 were often huge ventures undertaken by large teams of researchers (Karpova and Karpov, 2006). Mainframes continue to receive a disproportionate level of interest from conservators and historians; their operation inducted a large number of programmers and engineers, and basic architectural and protocol standards were developed on them. At the same time, technology only came to be commonplace within homes, workplaces and schools due to the introduction of minicomputers and later 'micros' and consoles. Such computers were made possible by the introduction of integrated circuit memory and processors, and a significant variety of models were produced by a range of companies for many national markets (Laing 2004, Langlois 1992, p. 26). While more recently we have seen geographic compartmentalisation of hardware production due to globalisation - labour outsourcing and competition between multinationals - we should not take for granted either the ubiquity or historical necessity of modern architectures or supply chains. As we look at computer artefacts from different temporal and geographical provenances, minute differences and variations allow us to chart the diffusion of specific technologies or practices of popular consumption and reinvention.

Theories of Diffusion

Archaeology-as-such could be said to have gone through four broad stages. Initially, antiquarians were interested in objects for their aesthetic or affective merit; there was little attempt to contextualise material or analyse it beyond associating it with a generalised past. Culture-historical archaeology, which emerges out of the institutionalisation of archaeology, its funding and further organisation, and its subsequent affiliation with nationalist or imperialist projects, attempts to situate materials temporally, but risks binding things to closed, even triumphal narratives leading to the present. In this movement, however, we get the first work dealing with the diffusion of technologies and technical practices; Vere Gordon Childe's work, starting with his 1925 *Dawn of European Civilisation*, is important in that it traces the spread of technologies outwards from the so-called 'fertile crescent' of the Middle East (1958). Also critical is Andre Leroi-Gourhan, who considered alongside the behavioural sequences by which the object came to be produced, used and discarded - what came to be called the 'chaîne opératoire'. (2018)

The 'new archaeology' of scholars following Binford (1962, 1965) and Renfrew (1969) and empowered by new technologies for dating objects and modelling systems, came to view archaeology as a science concerned with cultural processes - leading scholars to refer to this approach as 'Processual Archaeology'. With further study of archaeological finds in the Americas, sub-Saharan Africa and East Asia, diffusion becomes a more complex, distributed process with many different centres. Finally, post-processualism, an umbrella term for archaeological sub-disciplines critical of processualism's scientific positivism and behaviourist reductionism, comes to propose reciprocity in the exchange of technical and cultural practices. In particular, symmetrical archaeology, drawing upon the work of Bruno Latour and Ian Hodder, appears relevant to studying diffusion in contemporary technology (Shanks 2008, Hodder 2015, Olsen 2007, Latour 1993, 2005). Two further texts from outside archaeology are of note for a study of diffusion. Everett Rodgers, in his 1962 *Diffusion of Innovations*, provides a sociological account of how different subgroups work concurrently, albeit in different ways, to facilitate the adoption of new technologies. Jared Diamond, on the other hand, uses his pop geography text *Guns, Germs and Steel* to elaborate concepts of 'idea diffusion' versus 'blueprint copying', suggesting that diffusion can consist of simple conceptual transfer as well as more comprehensive replication of material specifics (1998, p. 224).

Objects go through processes formation and reformation also, however, particularly as technical devices are copied and reconstructed. Analysis and comparison of objects has a long history in archaeology, proving particularly useful with prehistoric artefacts such as flint tools or pottery. Artefacts can be compared based on design and stylistic attributes, or according to supposed usage or purpose. While a purely formalistic 'typological' analysis gave way to a mixed method involving the heavy use of scientific dating technologies, this does not preclude the continued use of stylistic comparison to initiate such a project and produce a rough template for future work. In the case in question, and for contemporary artefacts in general, the scientific dating methods so crucial to 20th-century scientific archaeology are not usable; the time frame is too small. Due to the rapid pace of technological advancement following the Industrial Revolution of the 18th and 19th Centuries, and the increasing inaccuracy of scientific tests due to climate change and, particularly, nuclear testing, it is possible that future archaeologists no longer have this as a reliable method, though they may indeed have others (Spalding et al. 2005). It is therefore likely that typological analysis, rendered more efficient by additional photographic data, once again becomes the main means by which the diffusion of modern material culture is placed in sequence. With electronics, certain components can be dated with a high degree of reliability due to historical records and even markings on the components themselves. Information obtained from the physical object can, of course, be supplemented with fieldwork taken from the time of original adoption, greater archives of technical documentation, archived video or images that show the production and use of devices, and retrospective oral histories.

The problem is often, in fact, dealing with an abundance of contextual information, rather than a paucity. As such, methodologies for filtering spurious and superficial information become increasingly important. Modes of interpretation and analysis need now to accommodate globalised production circuits, artefacts incorporating a large variety of complex, discrete components, as well as a generally accelerated pace of technological innovation and obsolescence. Childe argued for world-spanning lines of technological development and diffusion and incredibly rapid structural transformations; these turned out to not be as evident in early cultures as he believed they would be. Rapid technical revolutions and global diffusion chains became ubiquitous in the later part of the twentieth century, following his death. Childe's framework, rendered increasingly untenable for prehistoric and historical material culture, is strangely increasingly relevant for artefacts of the contemporary world.

Case Studies

This section explores two different trajectories of Clone dissemination and development: the lineage leading to (and, indeed, from) the Unipolbrit Komputer 2086 in Poland, and the development of the Investronica 128 and 'Inves'. In the former case, a computer passes through a number of stages of development; the UK 2086 was effectively, a clone of a clone of a clone. In the latter, an Investronica machine was actually reimported back into the United Kingdom as an official product, before being disowned.

Infrastructures and Assumptions

An initial assumption made about the trajectory of clone development held that transfer of technology would be between geographically proximate countries, given the need to physically transfer technology to allow it to be reverse engineered and redesigned for the new market (Mazar 2008, p. 14). A further assumption would be that this technology transfer would be within countries with positive diplomatic relations, similar governments and compatible ideologies, as such states would presumably be more likely to be trading partners (Eres, 1981). Economically and politically aligned countries might facilitate the movement of scientists and entrepreneurs, aiding technological diffusion (Hill, 1981). Such comparable markets may have similar demands for technology and policies towards intellectual property, or state sponsorship of economic and commercial computer use, further entailing similar artefacts.

It was also assumed that countries with similar languages might be more likely to exhibit related artefacts; (Welch and Welch 2008, Buckley et al. 2005) the machines in question required a certain amount of documentation to engender effective use and were undoubtedly the product of highly literate cultures. As later chapters will show, the publication culture surrounding the Spectrum appears explicitly to help the dissemination of software and hardware peripherals, but also to encourage creative usage. A shared language might suggest a shared, and therefore more active, literate culture of users, and therefore a greater desire for standardisation and inter-operativity of machines.

A final assumption might be that technology transfer might occur more frequently within televisual format ‘regions’, or within areas with similar power supply voltages and currents (Mazar, 2008). Since colour television technology was developed independently in different places, three major formats were common through the later part of the twentieth century. The United States and Japan used the format laid out by the National Standards Television Council; the United Kingdom, much of Western Europe and South America used a different Phase-Alternating-Line system, while Francophone and Warsaw Pact nations used SECAM. Machines based on the Spectrum were often designed to work with home televisions instead of a monitor, meaning they needed to be compatible with televisions in the country in which they were to be used. The power supply also needed to be able to effectively transform alternating current into the low voltage direct current used with electronics. As such, one might reasonably expect countries with similar audiovisual and electrical infrastructures to share technology more frequently.

Given that clones of the Spectrum are spread across multiple continents and that some have only a few extant versions, while others are known to have dozens of variants, it was not practical to collect and investigate physical specimens of each device, making obtaining metrics or analysing circuit architectures impossible. While it would be possible to sketch a morphological tree, placing machines in relation to others based on physical appearance, this would be inaccurate if only based on external casing, since two machines with a similar case may have very different internal structure. After further research is done on the types of home computers produced within each country, it may be possible to collate the information to produce a proper typological illustration; however, this would need to be an international collaborative project, and is thus beyond the scope of this dissertation. For this to happen, this research also needs to be established as something more than antiquarian curiosity. A linear history, based on the desire to chart the genesis of today's most significant technical objects, might miss these strange artefacts entirely, or treat them as an obscure novelty.

Poland: Unipolbrit and Junior

The lineage leading to the Polish Unipolbrit Komputer 2086 is an excellent place to start as it also appears to contradict many of the assumptions made before beginning this study. Available from 1986, it is called a 'semi-official' clone, in that it was made in collaboration with Timex, the authorised distributor of Spectrum clones in Portugal and the United States. Timex, formerly a watch manufacturer, was also responsible for the actual production of the early ZX Spectrum in the United Kingdom. On production lines redesigned for the electronics industry in one of its many Dundee plants, semi-skilled labourers, most of whom were female, produced the 'tool' which was so frequently gendered male in advertisements and discourse. Following minor industrial unrest in Dundee as well as increased demand, an increasing fraction of the production of Spectrums sold in the UK was seemingly shifted to Timex's plants in Portugal. Some standard Spectrums, such as the one currently on display in London's Science Museum, show evidence of Portuguese manufacture, yet Timex also had its own computers of a derivative, superior design. The company also appears to have had an active research division.

Timex also attempted to sell computers based on Sinclair architectures in the United States. The Sinclair brand was somewhat familiar due to the calculators and other electronic tools sold by the earlier company Sinclair Radionics. The lack of any Sinclair Research sales, marketing or distribution infrastructure in the US, however, meant that the company entrusted their North American sales to Timex. Timex, in turn, attempted to update the design for the much more developed, and therefore competitive, American market (CHM, 1983). Timex updated the design of their ZX81-based Timex Sinclair 1000 by placing it in a Spectrum-like case and including the 16KB RAM expansion by default, producing a unique artefact (with similarities to the ZX81 and the ZX Spectrum) called the Timex Sinclair 1500. Timex had planned to release a version with a similar architecture to the Spectrum, but the American Federal Communications Commission vetoed the use of the ULA chip, requiring Timex to produce its own custom chip (CHM, 1983). The company then decided to build a new, more competitive machine around the custom chip, while retaining architectural similarity to the Spectrum. The subsequent 2068, designed to compete with popular American computers such as the Commodore 64 or the Atari 4/800, featured more memory - 72KB in 8KB ‘banks’ -than its antecedent, but also than competitors (Grussu 2012, p. 376). The ULA - the additional circuitry which drove the display, input and output - featured additional graphics modes, including a higher-resolution monochrome mode and a mode which removed the ‘attribute clash’ effect that was the most notable graphic limitation of the Spectrum.

American consoles, starting with the Fairchild VES and Atari VCS, had provided cartridge ports to allow games to be loaded quickly; the TS2068 featured a cartridge port because consumers expected them on consoles suitable for playing games, though it is unclear how many games were available. Similarly, it provided two Atari joystick ports, since customers would be more familiar with these joysticks (and more easily able to acquire them) than the Spectrum or Kempston equivalents. It also featured an AY-3-8912 sound chip, of the type used in more advanced Spectrums, an additional RGB video output, and a few additional BASIC commands. The television output would have been configured to work with the American NTSC format at 60 Hertz.

The TS 2068, however, does not appear to have been a considerable success; while it has a community of nostalgic enthusiasts attached to its preservation, their composition appears to be much more of a hobbyist than a consumer variety (Timex Sinclair 2068). To play games from the much more extensive library of games designed for the Spectrum, one seemingly needed to employ a particular compatibility cartridge, meaning that it was not possible to distribute British games through a much more efficient medium (Grussu 2012, p. 378). Instead, the games would either need to be rewritten for the derivative computer or loaded from tape in such a way as to make use of hardware emulation facilitated by a ‘compatibility cartridge’ (Grussu 2012, p. 31). The amount of preserved cartridges, even in digital form, appears to be very low, suggesting the device never had an enormous appeal. The device appears to have been sold for only three months before it was retired from the market. The ‘video game crash’ of 1982 provoked uncertainty throughout 1983, as the production of games slowed and advanced, cheaply produced Japanese video game consoles came to occupy the American market. Home computers, however, continued to sell in the United States, and the market appears to have stabilised. Grussu asserts that in the three months before the Corporation decided to discontinue their home computer department entirely, they sold half a million units. This gives credence to his theory that the choice not to distribute the device further was strategic, rather than a direct result of poor sales.

Despite being withdrawn in the United States, an adapted version of the Timex Sinclair 2068 produced and sold in Portugal (Grussu 2012, p. 346) This computer was sold as the Timex Computer 2068, presumably to avoid confusion with the original Sinclair line of computers, which was increasingly produced in and therefore presumably also distributed in Portugal. The device was reconfigured to work with the PAL format at 50 hertz and also used a different power supply voltage (Tech Niche, 1985). Though it uses a similar secondary chip to the US computer, an SCLD, the buffer between this chip and the processor is replaced with one similar to that of the Spectrum. The input/output connector, which was different on the American device, has been made compatible with that of the Spectrum, meaning that a broader variety of peripherals can be used. The cartridge slot remains, however, and the ‘emulator’ cartridge is still necessary to run programs initially designed for the Spectrum. Two versions were produced, although the differences appear to be limited to the colour of the case. A grey version was more similar to the antecedent produced in the United States, while the black variant was more similar to the case of the original Spectrum and would form the basis of the Unipolbrit clone released in Poland (It’s A Pixel Thing, 2018).

While the development of Timex-branded computers in the United States had ceased, Portugal’s affiliate continued to manufacture computers until the late 1980s. The Timex Sinclair 2048, first produced the following year, is an interesting case; while it appears to be based on the Timex Computer 2068, no American analogue exists (Grussu 2012, p. 348, It’s a Pixel Thing, 2018). Though it is a later device, it is simplified; many more features are removed than added, and the model number is paradoxically lower - implying the original 48k model. The cartridge reader, which had been needed to make games for the original Spectrum work with the 2068, has been removed; this is probably a reflection of the fact that few programs were ever released on cartridge given the ROM production setup costs. The sound chip also has been removed as few games or programs for the original Spectrum used it, and the two Atari joystick ports have been replaced with a single Kempston port. The device is, therefore, more compatible with the original device, though it appears there are still some architectural differences. There is also evidence of a prototype computer, to be called the 3256, ‘with two motherboards and connectors for a Telnet type LAN’ (a local area network) (Grussu 2012, p. 349). This computer would have been more advanced than any other ‘authorised’ clone, but was never released, however, and no physical prototype has been recovered.

The UniPolbrit Komputer 2086 appears to be based on the Portuguese Timex Computer 2068, though it has a few additional differences (Grussu, 2012, p. 342, Shamot, 2019a). Besides its joystick ports, it features a parallel printer port and an audio-visual output connector (Adamski, 2009). Other than that, it seems very similar to the computer produced by Portuguese Timex. Its production and distribution were arranged as a partnership between UNIMOR Gdansk, a large television manufacturer, and Polbrit International, the latter of which was allegedly a subsidiary of Timex (Shamot, 2019a). There is no suggestion of additional diacritics or characters used with the Polish language, but it is specifically designed for the Polish market; it does not appear to be sold or produced elsewhere (Grussu, 2012, p. 34).

According to Grussu, the 2048, the simplified version of the 2068 produced in Portugal was also sold; however, while that device was likely imported, the Unipolbrit Komputer appears to have been produced locally. (2012, 342) One might argue that each time the device is reverse engineered and rebuilt to accommodate specific local requirements and contexts, it is expanded. The Unipolbrit is three times removed from the original device. Each process of adaptation and reconstruction serves typically to fill some local specificity or demand, while also improving the device. It was expected that only the most informal handmade or 'project' computers would exhibit this degree of emergence, but it appears that even 'authorised' products are similarly revealing. Conversely, however, the original predictions about patterns of technical dissemination appear, at least in this case, to be wrong. The three variants of the 2068 - the TS, TC and UK - all exist in different televisual and electrical infrastructure regions (Retrocrypta, 2015). They come from cultures with different languages and political-economic systems: a market-focused anglophone republic, a lusophone social democracy, and a polish speaking single-party state. Continuity seems to come from the fact that all these countries feature developed affiliates of the Timex Corporation, but as the case study shows, the strategic goals of the subsidiaries were very different from one another.

Another clone available in the People's Republic of Poland, the Elwro Junior, was released in the same year, though it appears to have had a different lineage. It could be considered 'unauthorised', in that it was not made with the support of one of Sinclair's partner corporations (Grussu 2012, p. 343). On the other hand, however, it was commissioned by the Government's Department of Education as part of a large-scale effort to bring computing to students. In that sense, it was more of a legitimate product in that it was a state-sanctioned mass-produced item, rather than a commercially distributed reworking of an import (Shamot 2019b). The Elwro factory had been set up in the 1950s to allow for domestic manufacturing of televisions; within a short period, it had moved to experimentation with computer technology. Grzegorz Shamot (2018) bemoans the secrecy; while a great deal is known about the American space and nuclear research programs, little is available about the pioneers of Polish information technology.

The Junior was explicitly designed to be compatible with the Spectrum's library of software; it was paradoxically more compatible and more architecturally similar to the original Sinclair machine than the 'official' Unipolbrit 2086, which was based on other clones (Grussu 2012, p. 343). Another machine - also based on the Spectrum and produced by the same company, albeit with a different set of designers - was allegedly rejected for not being compatible enough (Shamot 2019b). Researchers from the Autonomous Polytechnic Institute of Poznan designed the machine, presenting it at the Poznan's International Fair, the country's largest trade show. Production was then handled by Mera-Elwro, another television manufacturer that was also responsible for some of Poland's first mainframe computers; within a year, 3,500 computers had been produced. The technical specifications were slightly improved, with a full 64KB of ram and a slightly larger ROM which incorporated some important innovations - including a 'half-width' font that could fit double the amount of characters on screen - whilst retaining compatibility with the original Spectrum.

Outwardly, the computer appears strange due to the presence of a lectern on top of the case. This feature comes from the fact that the plastic casing used to house the devices originally was designed for - if not ultimately manufactured for - an electric organ (Shamot 2019b). While the outer case has been salvaged and the platform is based on that of the Spectrum, two innovations are particularly notable, however, and constitute the exceptional novelty of the Elwro design. The first, the keyboard, is physically tangible and unique amongst Spectrum clones. As well as the additional keys used to facilitate the more complex Polish implementation of the Latin alphabet, the keyboard features a unique mechanical system. Unlike the majority of contemporary keyboards, which have physical mechanisms of varying complexity, and the membrane keyboard of the Spectrum's antecedents, the Melwro makes use of keys containing magnets and detects key movement through Hall Effect sensors (Grussu 2012, p. 344). While such keyboards would have been more expensive to produce, they would have been more reliable and durable, as the lack of physical contact meant that the keys would suffer far less physical strain. The device's original intention, as a teaching computer for schools, is well served by the intentional robust design of the keyboard, but also by the accidental presence of the lectern.

In addition to these physical facets of the design, the device appears specifically tailored to use within a collective environment. In addition to the ROM based on that of the original Spectrum, the device could accommodate a network interface which would disable the basic ROM in favour of a version of CP/M, the popular business operating system. CP/J, as it was called, was developed by Polish Network operator Junet, and featured the ability to load programs to multiple computers at once over a network. The computer made heavy use of five-pin, circular DIN cable connections; as well as DIN connections for a monitor (the computer could be connected to a television through an RGB port, also, but colour televisions were rarer in Poland at this time) and a tape recorder, an input and output existed allowing for Elwros to communicate with one another. A specialised 'teacher' version featured a disk drive and interface, allowing programs to be loaded quickly to serve an entire classroom. Shadot (2019b) argues that the provision of networking technology saved money since disk drives were often more expensive than the computer itself.

The original Spectrum had some networking capability when one added an Interface, allowing them to share printers and, later, microdrive storage systems. More recent hobbyist experimentation has allowed the Spectrum to interface with some of the more advanced elements of the modern internet, bizarrely including social networking platform Twitter and streaming video services (Byte Delight, 2019). The Elwro is unusual in that this network capability comes well before the emergence of the modern internet, yet it is seen as being central to the device in a move that preempts today's shift towards network-centric or 'cloud' computing. The networked operating system, far in advance of that available on most microcomputers, is therefore perhaps the main innovation introduced by the researchers at the Polytechnic Institute. The choice of the Spectrum format as a basis for the device is a result of its accessibility over the emergent IBM PC-compatible format.

Indeed, the vast majority of Elwro 800's were designed for use in a networked educational setting, but this is not the case with its successor, the Elwro 804 'PC', which was not commissioned by the government (in fact, it seems to have been designed after the fall of the Socialist regime). It is not clear whether the endorsement of the government's education department helped or hindered the popularity of the Elwro clone, but the fact that it was released at a consumer trade show and that a variant exists designed specifically for home use suggests that it was undoubtedly marketed to the public. The machine was given a new name and brand identity, downplaying its technical derivation from the ZX Spectrum.

The two clones are indicative of different approaches to the adoption of technology in different cases. While the former artefact is an example of gradual diffusion of technical attributes and characteristics, adapted each time to particular contexts, the second instance shows an intentional and direct reworking of a device with a specific purpose in mind. The examples show clearly the unworkability of the delineation between ‘authorised’ and ‘unauthorised’ clones, as a variety of institutional structures legitimised each clone. In the case of the former computer, the corporation ‘Timex’ was not a reference that many customers would understand; as Timex did not appear to be a widespread brand, though the identification of the computer as an import would presumably have been attractive. Therefore, the computer’s name makes reference to countries and the concept of the international partnership -the name Unipolbrit combines the names of Britain, Poland, and according to some sources, the United States (Grussu 2012, p. 343).

Graeme Kirkpatrick’s 2007 essay attempts to chart the way that home computers were used in Poland and the United Kingdom. Kirkpatrick’s work is vital in that it develops the history of home computers and game platforms while revealing the context of their use through interviews. Unfortunately, however, his work also shows the limitations of ethnography within this particular context. The psychological association of the Spectrum with the Meritum, another computer of the same period with an ending invoking the Latin accusative case, betrays the fact that they are technically dissimilar. While a Meritum also features a processor based on the Zilog Z80, its hardware architecture and ROM operating system appear to be based on the second version of the TRS-80 computer produced by Tandy/Radioshack in the United States (Polskie Computery). The first Meritum was released in 1983, well before work was begun on the Melwro line or the Polish adaptation of the 2068, and quite likely before more than a handful of Spectrums were to be found in Poland.

The general function and perception of computers occurs at the level of the object’s class, rather than any specific object. Different computers blur together for the user and for the scholar who relies on ethnography alone. An excellent example of this is where Kirkpatrick relates users’ frustration at ‘wobbling’ RAM packs for the Spectrum, when in fact external attachments providing additional RAM were only found on the Spectrum’s predecessor, the ZX81. The Spectrum was notable in that its lower memory models facilitated a way to install additional memory onto the internal circuitry of the computer itself, and while it is possible that other peripherals were used, it is more likely users were recounting experiences with a related but different device.

For understanding the different usage of computers in various socio-political settings, this is, of course, irrelevant; a shortage in user experience testing, unreliable hardware, and a need for frequent upgrading were hallmarks of computing in general, rather than of any specific machine. For understanding the diffusion of technology and processes of design and redesign, however, tracing precise technical details and innovations is vital. Following from this, the Meritum should not be understood as a Spectrum clone in a technical sense. Its existence will, of course, have had an impact on the designers who produced other computers in Poland, including the Spectrum clones discussed previously. The use of a version of the CP/M operating system, a valued and complex business operating system, on the Melwro Junior was probably influenced by its prior use on the Meritum II. That said, the Meritum has a separate technical lineage, running in parallel to but not directly descending from the Spectrum. Complex technical relationships of inspiration and derivation exist between all computers of this era, and Kirkpatrick's work is valuable for understanding the experience of diffusion.

This chapter has taken a different approach, charting technical lineage to problematise the traditional notion of clones as derivative, illegal copies of hardware. In the first case, that of the Unipfunctionolbrit Komputer 2086, a computer underwent a series of transitions as it crossed national borders and was re-engineered. The American Timex, already very different to the Spectrum on which it was based, was further engineered in Portugal and subsequently Poland. Many of the changes did not affect the core architecture but related to what we might call 'features' - secondary characteristics related to exterior appearance or to facilitate usage. The critical task of altering the machine to work with local electricity systems and television standards allowed engineers room to conceive of and introduce further improvements.

In the case of the Unipolbrit Komputer 2086, the computer was sold under license, but manufacture was seemingly continued after the Timex Computer Corporation in the US stopped trading and Sinclair Research changed hands. In the second case, a computer was intentionally designed to be compatible with the Spectrum, but without authorisation. Far from an illicit bootlegging operation, however, it was a government funded project designed to introduce computing into schools, developed by electronic engineers and computer science students. The Spectrum architecture was chosen because of its proven success, and because of the wide range of software available. Another computer was, in fact, rejected because of its lower compatibility with the Spectrum. Notions of intellectual property were disregarded because they were not relevant in this context. It was more important that the industry be allowed to promote self-sufficiency and that the products provide for the development of a computer literate population.

Spain: Inves-tigations

In September of 1985, the eagerly awaited advanced version of the Spectrum launched. Notably, the new Spectrum was released not in England, but Barcelona, and it bore the name of Investronica, a Spanish electronics manufacturer (Microhobby 1985a,b). The development of the computer had been a collaborative effort between Sinclair Research and Investronica, but its earlier release came as a result of the different economic and structural context. Whereas in the UK the Spectrum was a domestically produced product, an exemplary artefact of British digital innovation, in Spain the device was seen as a cheap import from a multinational, threatening domestic hardware production.

A Royal Decree - dated the 13th of June 1985 and issued on behalf of the Ministry of Energy and the Economy - required Spanish characters, such as ñ, ü and ç to be included within all computers (1250/1985). The same decree mandated safety testing for consumer electronics, the inclusion of instructions, and the ability to alter the brightness of the screen. At the end of August 1985, another decree, this time issued on behalf of the ministry of finance, was responsible for introducing a royal degree introducing an import duty on machines with less than 64KB of memory. The tax could be up to 15000 pesetas, approximately 75 pounds in 1985, making the machines far more expensive. Both decrees were released by departments headed by Carlos Solchaga Catalán, a powerful politician in the emergent Spanish Socialist Workers' Party. In 1983, his Department of Energy and Industry had been responsible for introducing its vision for the Spanish electronics industry - Plan Electrónico e Informático Nacional.

Ignasi Meda Calvet argues that Solchaga adopted an activist approach; expecting the growth of the computer industry, some members of the government were keen that computers be manufactured in Spain, in order to develop the country's high-tech workforce (2018, p. 253, 257). Further, they were keen that the computers developed be designed for professional use, rather than becoming consumer products. Alternatively, it is speculated that the departments were pressured by Spanish manufacturers to adopt the tariff. It was not clear to what degree the tax or regulations would or could be enforced; the highest tariffs were designed predominantly for machines coming from East Asia, with supposedly lower but unspecified tariffs applying to products imported from nearby countries. Further, the entry of Spain into the European Community in March of the following year would reduce its ability to set prohibitive tariffs. That being said, the measures allowed Investronica the impetus to preempt them by releasing a new device.

On the 23rd of September, only a month after the confirmation of the import tariffs, the new version of the Sinclair computer launched at the Sonimag consumer electronics fair. Charles Cotton, the director of sales and marketing at Sinclair, is quoted justifying the decision to release the computer there. "The impetus to introduce a Spectrum 128 in Spain comes from the peculiar market forces operating there. It is a very important market for us, as we account for over half of the home computers sold in Spain," (Bourne, 1985). At the same time, Cotton struggled to defend the decision to not reduce the same computer in the United Kingdom: "We're confident we have the products the public wants this Christmas, at the right price. A Spectrum 128 doesn't fit into the UK picture just now." Arguably Sinclair Research was worried about undercutting the sales of its Spectrum+, a version of the Spectrum with an improved keyboard but virtually identical technical specifications, and the QL, a more expensive and 'serious' machine designed to compete with personal computers. Their decision to not release the device in the UK was not without criticism, and while the original plan was to withhold release of the Spectrum 128 for at least six months, it was ultimately released in the UK in January 1986 (McAlpine 65).

Codenamed 'Derby' during its development, the new model featured a more professional keyboard, an attached numerical keypad and a number of additional ports, including an RGB socket for monitors on top of the traditional aerial television port, an RS 232 for printing, and a new AY-3-8912 sound chip. Most significant, however, was the feature which gave the device its name. Its 128kb of RAM represented a nearly three-fold improvement over the original and was facilitated through the use of 'pages' - the additional memory could not be accessed simultaneously, but one 16kb block of memory could be changed for another. The device had two ROM memories, allowing it to run in either 48k or 128k mode and employ different operating systems for each. The dual ROM setup effectively allowed it to retain compatibility with the previous models of the Spectrum, meaning that all software developed for the other device would remain compatible. The new 128k ROM, however, could deviate from the traditional model and allow keypresses to input characters rather than commands, making programming on or interacting with a Spectrum more similar to using other computers. The device could also use two discrete areas for video memory, allowing the device to preserve multiple screens at the same time. The upgrade would make the Spectrum more competitive with other home computers, and increase the complexity of games and other software, while still remaining compatible with the existing software library.

Investronica's solution was in some ways a hack, but a relatively honest one. The machine would not be fully able to access 128k of memory at a time due to the limitations of the Spectrum's 8-bit processor. The Zilog Z80 used two of its eight eight-bit registers to store the memory address being accessed, and another two if the operation involved copying data from one location to another (though typically data would be read into the processors' registers, processed and sent back). A byte consists of eight bits, with the least significant bit (normally on the right indicating 1 or 0 directly, and each following bit comprising a higher power of two - 2,4,8,16,32,64 and 128. If all bits are '1', the highest possible number that can be stored in a single byte is 255. A second byte can be used to store higher powers of 2, making numbers up to 65535 possible. While standardisation authorities have now ruled that a kilobyte is equal to 1000 bytes, this has not always been the case; typically, engineers would refer to a kilobyte as equalling 1024 bits, or the amount of numbers possible with 10 bits. Regardless, an eight-bit processor could only hold 64 old kilobytes of memory in the two registers allocated.

As with the original Spectrum, the lowest 16K of memory addresses in a 128K Spectrum was used for the ROM, the read-only memory chip that provided the operating system for the machine. With the 128k, however, the user was allowed to choose between an improved ROM, designed to take full advantage of the sound card and increased memory, and a ROM allowing higher compatibility with software and games designed for the 48k version. With a 128k, the central 32k of memory would function as normal and a special command would allow the area of memory referred to by the highest 16k of values to be routed to different locations in the expanded memory - either the original 16k or four other sections. This solution meant that using the additional memory could not all be used simultaneously, but it could be used in sequence, for example, for levels requiring different graphics.

It is interesting to compare the solution of Investronica with that of Indescomp, a Spanish company which marketed computers from the rival Amstrad line. Taken slightly more by surprise by the revelations about the new import duty and language regulations, Indescomp was able to produce an 'improved' version of the Amstrad CPC 464 called the CPC472. The Amstrad computers on sale in the UK - both the 464 version and the improved 664 version - had 64k of RAM. There was no space for additional RAM on the board, but the ROM holding the device's operating system was removable. As such, the engineers were able to fit a 'daughter' board that could hold both the ROM and an additional 64 kilobit (since a byte is 8 bits, it could be said to approximate 8 kilobytes) RAM chip. The additional memory was inaccessible; supposedly, it was 'reserved' for the improved version of BASIC, yet the version of BASIC used was that used within the C664, a 64K machine already on sale in the UK, which required no extra memory as the BASIC interpreter and the rest of the operating system were all included within the ROM. Further, the RAM used was of a type not well suited to the Z80 processor; arguably, it was not even connected.

Alan Sugar takes pride in - and perhaps responsibility for - this solution in his autobiography:

> I also asked my technical geniuses to come up with some justification as to what this extra chip was doing, rather than be sitting in mid-air going nowhere. They did – but don't ask me what it was! This mini-PCB, with its additional D-RAM, then plugged into the original IC socket. Based on this trick, it was true to say that the computer now had 72k of memory. (...) On top of this, we had to change the faceplate on the front of the computer which was labelled '64k', as well as all the packaging and the instruction manual.

Indescomp's hack may have been slightly dishonest since the supposed memory increase did not actually do anything, but the solution developed by Investronica's engineers was not possible with the architecture used by the CPC. In effect, the CPC already incorporated a form of 'paging' - switching between memory banks - to ensure that a full 64 kilobytes of RAM would be accessible. Unlike the Spectrum, which reserved some of its memory addresses for the ROM and only used 48k in the standard edition, the CPC's circuits would switch between the lower 16K of RAM and the operating system, or the upper 16k (which was used for the video display) and the ROM for the advanced BASIC used.

Investronica's solution was an example of innovation attuned to customer requirements and market conditions. Sinclair Research was predominantly focused on the business oriented QL computer, released the previous year, which used an entirely different processor. The processor used by the Sinclair QL was far more advanced, and it had a 20bit address bus as opposed to the 8-bit address bus of the Spectrum, making it possible to address up to 1MB of memory. In practice, however, the computer included only 128kb of memory, with the option for it to be expanded later. Internally, the computer used 32-bit instructions, making it far more advanced than its predecessors - the high cost of memory meant it was still designed for use with 8-bit memory chips. Though in theory, the possibilities afforded by the new machine were far higher, the architectural differences meant that there was little to no base of software for the device.

Urs König is foremost amongst those who have studied the QL device, making the argument that the device rivalled the Macintosh and PC compatibles and could have been the basis for an alternative platform. Linus Torvald, who created the GNU Linux kernel, owned a Sinclair QL as his first computer; the frustrations with having limited software caused him to develop games and software personally. Ultimately, having an operating system that could not be changed caused him to learn low-level programming and envision a new operating system. The QL was an imaginative and powerful machine, but supply problems and issues with the storage system - a digital tape system called a 'microdrive' - caused it to sell poorly. After Amstrad acquired Sinclair Research in 1986, sales of the Sinclair QL soon ceased. Also shelved were other projects that attempted to create significant innovations on the original Spectrum design - Loki, a more powerful gaming machine using the QL processor, or Pandora, which would have featured a laptop-style screen. Instead, the Spectrum developed further; a ‘+2’ version includes a cassette recorder within the computer itself, similar to the Amstrad CPC computer. In addition, the computer includes joystick ports, further solidifying its role as a games machine. Perhaps most significantly, it includes the advances which brought about 128k of available memory.

A version of the computer released the following year would have the capacity to include a floppy disk drive instead of a tape deck - if included the machine is referred to as a ‘+3’; otherwise, it is a ‘+2a’. The machine also allowed a form of paging for the ROM similar to that of the Amstrad CPC computers; this freed up additional memory and allowed the CP/M business software to be run on the device, at the cost of reduced compatibility with earlier software. Two final versions, released in 1987 exist; unlike the earlier versions, they customise the circuit board to work with either a tape deck or a floppy disk drive specifically. In effect, they show convergence in design philosophy between the Sinclair range and that of Amstrad, but these later versions do show an attempt to continue the development of the initial Spectrum concept.

Investronica’s agreement with Sinclair Research was terminated shortly after Amstrad purchased the company, but the company continued selling their version of the 128 Spectrum. They also developed a version of the Spectrum+, ‘the Inves’, to be sold from 1986 onwards. In some ways, this was a puzzling move, since they had already produced an improved version of the machine in the 128k. The company, however, wanted to retain full access to its range and was no longer able to import machines from the UK due to the takeover. As such, engineers were asked to reverse engineer and effectively redesign the Spectrum+. Due to the reduced cost of memory, the number of RAM chips could be reduced, while due to the lack of access to the ULA which contained the Spectrum’s secondary circuitry, a Texas Instruments TAHC10 gate array was used instead. Engineers managed to drastically reduce the integrated circuit count, making it less expensive, while improving the quality of some components, such as the colour generator.

In the Inves version of the Spectrum, some of the problems of the original Spectrum were solved using innovations from the 128 design process; amongst these was the issue of memory contention, wherein the ULA’s attempt to access video memory would be blocked by the fact that the processor was accessing memory, creating a slight and generally imperceptible visual distortion. Generally, however, the Inves suffered from incompatibility problems, meaning that some foreign and even some Spanish games would no longer work on the system. The court case against Investronica for breach of Amstrad's copyright dragged on for almost a decade, before being dismissed in 1997. At this point, however, Investronica had long since moved on to the production of PC compatibles (LLaca, 2017a).

The production of versions of the Spectrum by Investronica is interesting because it shows that the development of derivative versions can, and indeed does, affect the development of a technological device. As a 'legal' clone producer, Investronica was forced to innovate to remain competitive by regulations specific to their country. They were put on the position of needing to demonstrate that they were not simply a distributor of a product for a foreign corporation, but a partner in design, development and manufacture. Ultimately, this involvement would be critical when Amstrad dropped their distribution agreement, forcing them to effectively 'reinvent' an earlier product which they had had access to as a distributor. The same protectionist climate which had forced them to innovate then assisted them as they attempted to operate autonomously. Sinclair Research, now run by Amstrad, followed the line of development pioneered by Investronica, releasing a series of 128k models which would retain compatibility with the earlier Spectrum while including a more advanced mode and some improved components.

Diffusion and Culture

This section has attempted to look at clone Spectrums through the lens of diffusion, an archaeological concept that can be applied to technology and material culture from any period. Within an economic system that has been thoroughly transformed by processes of international trade, multinational corporate organisation and globalisation, the rate at which technological artefacts are disseminated has increased significantly. That said, political, geographic, linguistic, economic and cultural borders and restrictions continue to exist, slowing or preventing the transfer of technology. The same can be said for cultural forms, though in this particular case, the emergence of 'software' and 'media' has caused an erosion of traditional barriers to transferral. New infrastructural barriers came to exist in a way that was not previously as significant since a computer would need to be adapted to work with television and electrical systems. Ideological barriers still exist, as do linguistic and national ones, but they often have only temporary effects; in some cases, they can accelerate innovation by making experimentation and copyright infringement more feasible. Unlike the present day, when certain new technical products are released simultaneously on different continents, this period displays delays of months or years as technologies are refigured for different markets and alien contexts. It is not a linear process, nor is it unidirectional; remote innovations come to be reincorporated into original designs, even affecting the direction of development entirely.

With regards to the object in the question, the Sinclair ZX Spectrum, it would be easy to assume that diffusion is no longer a relevant concept. For centuries mechanisms of material trade and intellectual dissemination had vastly accelerated the processes by which techniques for artifactual production were shared across political and geographic boundaries (Scoville, 1951). Global chains of resource acquisition and production make it increasingly rare to find manufactured goods designed and produced in a single country. That said, as the previous chapter has shown, the Spectrum was hardly a consistent artefact, differing based on time and place of manufacture. The previous chapter avoided detailed investigation of 'clone' hardware devices, microcomputers that were derived to a lesser or greater extent from the Spectrum and incorporated similar hardware architectures. These devices have the potential to both reveal diffusion of sophisticated electronics in recent decades but give a more comprehensive insight into how technology spreads.

Notable here is the fact that the diffusion of technological innovation is not uniformly linear; often, innovations made within derivative devices came to be reincorporated into a later version of the parent artefact. Innovation also occurs with peripheral hardware devices, designed by other companies to address deficiencies or fulfil additional user requirements; often, deficiencies are remedied in the original design, or the original producer creates peripherals of their own. Tracing most peripherals is relatively easy; these are advertised heavily in the pages of magazines aimed at Spectrum enthusiasts and are often the subject of detailed reviews. Clones are more difficult to trace; some, being authorised, have their specialist publications and official user-groups. Others are attested to in domestic or foreign magazines but are rarely the subject of extensive coverage. Clones also have their own peripheral devices made to fulfil either specific requirements of a particular market or incompatibilities with existing peripherals due to the clones' different architectures. Clones, particularly unauthorised ones, are far less standardised, and likely have a different scale and mode of production. There are many similar items discovered by Swade that are effectively homemade, with limited documentation.

In addition to the novel of the material devices, the spread of technology led to cultural innovation. In Poland, and central and eastern Europe more broadly, this is best evidenced by the rise of the demoscene. The pattern of diffusion of culture is not explored in depth here, but Piotr Marecki, Yerzmyey and Robert 'Hellboy' Strak have produced an excellent analysis in their recent text on the ZX Spectrum Demoscene (2020). Demos are short examples of coding or graphics prowess; initially, many were produced as alternative loading screens or as tests for hardware expansions, but they ended up becoming an art form in their own right (p. 10, Reunanen et al., 2015). These coding projects encouraged ‘hackers’ to test the limits of platforms, in the process promoting future hardware development (p. 125). In Spain, the FPGA (field programmable gate array) based ZX Uno project is an example of continued experimentation with hardware (ZX Uno, 2019). These projects continue today; while strong boundaries once existed between particular national and platform-based scenes, these boundaries have eroded as the internet and shrinking levels of interest have facilitated greater collaboration.

Platforms require a level of incompatibility, but the Spectrum shows that this does not and should not necessarily lead to uniformity. Spectrum clones were made by multinational and local companies, by research institutes and individuals. Each worked with differing motivations, within differing contexts. It is not fair to associate GNU Linux with the technological lineage of the Spectrum simply because Linus Torvalds, the creator of its kernel, used its successor machine, the Sinclair QL. Torvalds began developing the kernel on a PC, out of frustration with his inability to change the underlying operating system architecture of PC or QL. The architecture of Linux would come from UNIX via the Berkeley Software Distribution; an operating system that would be closed source and restricted to larger computers until the early 90s. Linux, with its endless branches and distributions, rhizomatic and often recursive development trajectory, developed within a similar diffuse ecology. Academic researchers, hackers, corporate employees, hobbyists and technicians, worked in specific national or industrial contexts to carve out systems to meet their particular requirements. Each of these systems is as much a part of the platform as any other. This chapter has attempted to show that the Spectrum developed as a platform far beyond the original device and that clones, regardless of provenance, are an essential area of study (West and Dedrick, 2000).

5. From Keys to Keywords

A Minor Key

This chapter attempts to untangle the complicated relationship between traditional languages and the language of code on the computer. Further, this chapter looks at the generation of literature and the design of the keyboard itself. It provides an analysis of the publishing industry surrounding the Spectrum; through this, it is possible to understand the development of computational culture. The 1982 ZX Spectrum game *The Hobbit* provides an artefact which further illustrates this study.

Due to the licensing deal worked out with Tolkien's estate, the game, published by Melbourne house, would supposedly include the novel version of *The Hobbit* with every copy of the game sold. The book is more elaborate, featuring far more complex language. At the same time, it is entirely linear, featuring no opportunity for intervention on the part of the player. The game exhibits what might be called emergence; the complex relations between characters and objects produce a far richer range of situations than the sum of their parts. The game is also generative, in that it is different on each playthrough. Emergence and generativity are attributes of games in general in that they are programmed, though they can display varying levels of each. What makes the case of the Spectrum notable is the closer relationship between language and code. Code books and magazines were critical to the diffusion of software, but also came to be affected by its characteristics (Campbell-Kelly 2018, p. 238).

An Inglish Classic

“You see: Nothing”. The game sketches landscapes with slow and eerily beautiful precision, line by line. Passage takes time. Stasis takes time. If you hesitate, you are met with the refrain, ‘time passes. Your friends leave you and others return. Your enemies approach. The world decays. In their adaptation of *The Hobbit*, Melbourne House took what was at the time a relatively obscure children’s fantasy novel and turned it into a masterpiece. Many will no doubt be familiar with the adaptations of the book made by Peter Jackson; following the success of the adaptations made of the *Lord of the Rings*, the shorter book was made into a shorter series. Others have analysed the cultural, stylistic impact or context of the films, and perhaps most interestingly their relation to digital technology - while the earlier *Lord of the Rings* films were shot on 35mm film cameras, T*he Hobbit* notably used fully digital 3D cameras. The ZX Spectrum adaptation of the Hobbit (1982) was similarly experimental in its embrace of digital technology. In a way, it is very different from the games that preceded it. While it contains narrative components, it is more than just a retelling of the narrative with branching paths. It is effectively an authentic simulation of a fantastic world. Players may trace the steps of the halfling adventurers, but they also inhabit the world of Middle Earth, experiencing calm and chaos, claustrophobia and emptiness.

Veronika Megler was a university student who had taken classes in computing to assist with her actuarial science degree. Computing appealed to her more; she transferred department, working on IBM punched card machines. In her second year, the students were given access to Unix machines, allowing them to discover C, Pascal and Assembly Language. With Phil Mitchell and other members of her university study group, she answered a job advert at Melbourne House, a publisher of technical manuals run by Alfred Milgrom and Naomi Besen. At this point, the software industry in Melbourne was virtually non-existent, but the publisher had released several technical manuals, including books that would contain listings of BASIC code to be typed in by the user. Alongside program listings, mostly in BASIC, the publisher would release a guide to ZX80 and ZX81 machine programming. The publisher's key asset was Dr Ian Logan, a medical doctor who had produced comprehensive guides to the Spectrum and its predecessor, the ZX81. In 1983 Logan, along with Frank O'Hara, would publish a complete ROM disassembly, showing effectively how the Spectrum's operating system functioned. At the same time, Melbourne House worked on developing its Beam Software' imprint', which would produce more accessible entertainment titles. Beam's first employee was William Tang, another student who developed games featuring a character called Horace. The first game, *Hungry Horace*, was a clone of Pacman; a second game, Horace *goes Skiing,* was more original. Tang's games are notable within the ZX Spectrum community, but it is his *Spectrum Machine Language for the Absolute Beginner* that is perhaps the most influential. Though Tang is credited in this work as an 'editor', we see his capability to write both instructional material and code interchangeably.

Milgrim expanded the games company, hiring Mitchell and Megler and acquiring the rights to adapt *The Hobbit*. While working on the Spectrum adaptation of Tolkien's work, Megler and Mitchell also produced *Penetrator*, an adaption of arcade shooter Scramble. For them, it was an exercise in learning assembly; it was produced using and alongside a game creator or prototypical engine developed by Mitchell. *The Hobbit* was a far more remarkable creation, however. Megler recounts having played Classic Adventure on the university's Unix system; however, after being completed once, the game is no longer challenging. The game developed in a relative vacuum; while there was some exposure to arcade titles; Megler had some knowledge of Atari, "but it was on the other side of the ocean and it was considered a completely different industry at that time," (2012). Previous games had been designed for consoles, focusing first and foremost on the immediate experience of the player and visual presentation. The majority of developers were amateurs, who learned their craft from disassembly and duplication. Megler and Mitchell, on the other hand, were trained computer scientists. In envisioning their design, they "used database style techniques and had everything parameterised, everything as abstractions," (Sharwood, 2012). Their game is a work of computational literature and allows for insight into the significance of language in the transition to the world of digital media. It is markedly different, both to the text that preceded it and to the other forms of game which it shared a platform.

Before the completion of T*he Hobbit*, Megler quit game development, burned out on writing assembly language. The programmer stopped playing games and got a job with IBM, eventually moving to the Pacific Northwest. Only decades later did she realise the game's success. People write her strange letters asking about technical elements related to the game's design. Others attribute their ability to speak English to the hours spent typing out the game's text commands or reading its elaborate generative descriptions. Phillip Mitchell continued at the company to finish the adaptation, working with Kent Rees to produce the game's unique vector art. The generative system and database created by Megler meant the world was unpredictable and complex; some bugs could be fixed, but the sheer amount of possible situations meant it was impossible to test the world thoroughly enough. Jimmy Maher explains the game is remembered as much for its bugs as anything else:

> Swords break on spider webs; Bilbo can carry the strapping warrior Brand about for hours; Gandalf and Thorin can walk through walls; garbled text and status messages obviously meant for the development team pop up from time to time. (2012)

Mitchell continued working; not on a Spectrum but rather on a clone of a TRS80 made in Hong Kong and popular in Australia. Due to the similar processor, the Z80 assembly code would work interchangeably on both machines; however, the TRS clone featured a proper keyboard.

For the game, Mitchell produced a graphics subroutine to draw the visuals, a means by which game data could be compressed, and a text parser which could understand basic English commands. While the game still required users to simplify their sentences, the game allowed movement away from the traditional 'verb-noun' interface towards something more approximating basic English - referred to as 'Inglish'. Players could use 'and' to string multiple commands together in a sequence, or determiners such as 'every' or ‘except’ to specify multiple objects with which to interact. Players could also use adjectives to describe the object they wished to interact with (e.g., ‘a green door’), or use an adverb to describe how they wished to perform an action (e.g. ‘viciously break the door’). If a command were unclear, the prompt would subsequently ask for further information. Players could also speak to other characters, by using the construction SAY TO X “Command”. Such a command would often result in the other character performing the action, but not always, due to the unique way in which other entities were coded within the game. The game requires players to type out commands in full; this was in itself was a transition away from the expectations of Spectrum use, since commands are typically associated with a single key press. The key commands of the BASIC language are not suitable for typing - or navigating a digital world - but for programming.

Qwerty Worlds

Paul David develops his notion of *Qwertynomics* to explain why the QWERTY keyboard, developed by Sholes in the mid-19th century, becomes dominant across typewriter designs. One principle, technical interrelatedness, establishes the relationship between the ‘hardware’ of the keyboard itself and the knowledge or typing literacy of the typist, which David refers to as their ‘software’. This investment of time into learning a format leads to the second principle, the quasi-irreversibility of investment. Improvements to typewriter design made the QWERTY format less necessary, but they also ensured that other manufacturers could more readily switch their configuration. Typists who had become familiar with the QWERTY layout would lose this invested time if they switched to another format. As such, manufacturers would switch to the QWERTY format to lure typists.

Another principle, revolving around economies of scale, meant manufacturers employing mass production were generally able to produce machines more cheaply. In addition, they would receive more brand recognition. Competition, argues David, “drove the industry prematurely into standardisation on the wrong system.” (1985, 336) This argument is compelling, but also somewhat unsettling for scholars of platforms, as one realises that the very architecture of the interface used to produce written research is itself a platform and a flawed one at best. Also critical is David’s discussion of the Apple III, which through use of a hardware switch allowed the user to switch between a standard layout and the supposedly improved Dvorak layout. Archaeology of past media forms is brought up to date through analysis of what was then a contemporary format, allowing us insight into a design detail that is puzzling if it is not overlooked completely.

David's reflections on keyboards can thus be used to make a wider point about technological platforms in general. David concludes with this poetic prediction, which is itself a call for further research:

> I believe there are many more QWERTY worlds lying out there in the past, on the very edges of the modern economic analyst's tidy universe; worlds we do not yet fully perceive or understand, but whose influence, like that of dark stars, extends nonetheless to shape the visible orbits of our contemporary economic affairs. (1985, p. 336)

Picking up on the work of David, Nick Land speculates that the keyboard instigated the digitisation of language, producing psychological and social effects. The introduction of the keyboard did not become a mechanism for liberation as it might have done, but reflected the haphazard and arbitrary standard:

> the interconnected explosions of modern corporate organisation and endo-corporate bureaucracy, (gendered) office work, typographic information deposits, psychoanalysis, literary modernism, anglophone *qabbalism*, cryptographic machinery and mechanised computation all tracked the mass installation of typing skills into the human nervous system, in accordance with the Qwerty arrangement of the Sholes keyboard. (2011, p. 584)

Land insisted on using an Amstrad CPC computer from the same epoch as the Spectrum well into the late 1990s (Beckett, 2017).

Friedrich Kittler had already engaged in a similar study in the last section of his influential *Gramophone, Film, Typewriter* (1999). While Land speculates as to the possibilities of a new cryptic language, tailored to the peculiarities of the mechanical keyboard, Kittler performs an autopsy on the first examples of technologically assisted writing. Of particular interest for him is the philosopher Friedrich Nietzsche who, after suffering from increasingly poor eyesight, became in 1882 an early adopter of one of the first European typographic devices, the Malling-Hansen' writing ball'. Amongst Nietzsche's other proclamations is the idea that "our writing tools are also working on our thoughts," making his eager adoption of the technology all the more substantial, even ironic. Kittler supposes Nietzsche to be the first 'mechanised philosopher', perhaps analogous to a coder. While a typewriter remains a completely analogue machine, it retains computational characteristics in that it is, like Turing's machine, designed to process discrete components of language. As opposed to writing, which is generally cursive, a keyboard proceeds letter by letter.

On the Spectrum, the deviations and complexities of the keyboard - and the alternative language it overlaid over the basic Latin phonemes - prevented the widespread use of the Spectrum for industrial and commercial purposes. While there were notable attempts to adapt the Spectrum for such purposes, such as the ill-fated Sinclair QL, the all-in-one business computer marketed by ICL, the culture of the device was shaped initially by its initial layout. Roland Barthes, in his *Writing Degree Zero* (1990), suggests that one is trapped, able to assert their freedom through the choice of a new mode of writing but eventually limited by the history of that format. For Barthes, writers are limited by the weight of past work: “A stubborn after image, which comes from my previous modes of writing and even from the past or my own, drowns the sound of my present words,” (1968, p. 17). Just as the installation of typewriters had shifted the demographics of the typographic profession after its initial adoption by eccentric hobbyists at the end of the 19th Century, the Spectrum’s user base became relatively young due to the types of programs that could be operated successfully.

The transformation has little to do with the possibilities afforded by the processing hardware, as archives of software show a range of different business, educational and domestic tools, or memory, as with earlier video game consoles such as the Atari VCS. Instead, it can be argued that the keyboard configuration necessarily turned the focus away from word processing towards software that required few, often repetitive keypresses, such as games. Conversely, however, the inclusion of BASIC commands on the keyboard itself allowed for a better understanding of the operating system, encouraging a greater degree of user involvement as they encouraged with a relatively high-level language that was not platform specific.

As it took some time before a publishing and distribution system could be established to exchange software effectively, codebooks were published, allowing users to enter programs that could subsequently be run on the device. The memory limitations of the ZX Spectrum’s predecessors also meant that a book was more practical and cost-effective than a cassette tape; only the increase in memory and advent of machine code programming ensured the shift away from BASIC codebooks. Melbourne House, the publisher of the Hobbit, began as a producer of codebooks before moving on to publish predominantly software.

The Crowded Keyboard

Pick up a Spectrum, and you will notice square, rubber keys, in positions roughly analogous to those on a modern anglophone computer keyboard. In fact, there is visibly little else to the device beyond the keyboard; it was designed to work with a user's home television and so had no monitor. The Spectrum, designed as a computer, also did not include the hallmarks of video game consoles, such as a joystick or a cartridge reader, and would not accommodate them without the addition of an external 'interface'. Though the device was capable of reading data from repurposed analogue cassettes, initial versions of the device would not have included a cassette reader, requiring the user to connect their own. Alongside the power supply and VHF cables, the Spectrum owner was purchasing what might nowadays be mistaken for a stylish, if imperfectly configured keyboard. In the cybernetic theory of authors like Norbert Wiener, we find the idea of a 'black box' (1965). This is an opaque computational machine that cannot be understood through reference to its hidden internal mechanics; instead, only a study of the machine's inputs and outputs, the information passed to and from the outside world, would allow us to speculate about its design and methods of operation. The concept of the black box is seen in systems testing, to represent working with a system or module which we know nothing about.

With the Spectrum, however, we do not need to turn it on to get our first clues to its operation. These come from the peculiarities of the keyboard design; while the layout roughly matches the QWERTY format of anglophone typewriters, the absence of a proper spacebar and poor responsiveness of the keys make it hardly adequate for sustained word processing. More puzzling is the range of cryptic fragments on each key, jockeying for space with the letters. While other computers of the time, notably the Commodore 64, experimented with putting symbols on keys to allow for a broader range of characters to be accessible, the system of registers is unique to the Sinclair series of computers (Bagnall, 2011). The fragments are from the computer language Basic, which has its own colourful history (Montford, 2012). The computer's operating system works in such a way as to accept single keypresses as commands first and only in certain circumstances as individual characters.

Before founding the company that would produce the Spectrum, Sinclair Research, radio hobbyist and entrepreneur Clive Sinclair had experimented with producing home kits that made use of surplus transistors in innovative ways (Tedeschi, 1994). A previous company, Sinclair Radionics, had made money on staple electronics such as portable radios and electrician's tools. More conceptually creative products such as portable televisions and digital watches received substantial acclaim but failed to make a significant profit. Arguably the most culturally influential products produced by Sinclair Radionics were their digital calculators, which combined brilliant technical exploits with futuristic, aesthetically pleasing designs.

The most significant technical innovation was to 'strobe' or turn rapidly on and off the light-emitting diode (LED) display. The LED display was at the time far more reliable than the newly researched liquid crystal display, but required a significant source of power, making calculators bulky desktop objects. By taking advantage of the crystal's capacity to stay lit for a short time after the power was turned off, a steady image could be maintained for only one-twentieth of the power consumption. For the development of the Spectrum keyboard, however, the most significant Sinclair radionics design experiment involved the decision to use the same key for multiple functions, making use of a shift register to alternate between different options on the same key.

This design choice carried over to the Sinclair ZX80, the first microcomputer produced by Sinclair's new company. The ZX80's keyboard was completely flat, making it challenging to register physically when a key had been pressed, and small, even when compared with today's portable 'netbook' computers. Possibly it was the small, uncomfortable nature of the keyboard that necessitated the design choice of making it possible to enter BASIC commands and non-standard commands with a single keypress. More broadly, however, the keyboard's design could be seen as a result of the ambiguous nature of the microcomputer as initially designed. Developers realised that it could be a vastly influential piece of technology when brought into the home but were constrained by the fact that its precedents were giant, analogue calculating machines, or digital mainframes used for academic, scientific or military applications.

The Altair, produced in 1975 and widely considered to be the world's first microcomputer, did not even come with a keyboard, but could be programmed through the use of eight binary switches on its front, literally byte-by-byte. The ZX80, produced only half a decade later, was designed to make home computing possible for the UK public, but was still targeted at a hobbyist market, designed to be built from scratch by those with some grasp of electronics. The Sinclair ZX80 remained soldered, therefore, to a notion of a computer as an expanded calculator, a mathematical device for the technically proficient.

When one entered a keyboard command or character on the ZX80, the screen would 'blank', turning black for a second before reappearing with the new character in place. This resulted from the device's lack of a screen buffer; the processor, which was responsible for processing both screen output as well as keyboard input, would need to interrupt the former to facilitate processing the latter. While some would see this as annoying, what is important in this context is the affective power it gave to each keypress, as it gave each keystroke a pulse of its own. Further, due to the fluctuating voltages produced by yet unreliable supplies, computer keyboard designs were to register a keypress as a 'zero', rather than a positive pulse.

The next computer released by Sinclar, the ZX81, allowed two modes, fast and slow, which allocated priority to processor and video display respectively. In fast mode, the screen would not be updated, but calculations could be performed more quickly; in slow mode, drawing the screen would take priority, preventing the flicker which defined the ZX80's display. Instead of stressing the severity of each keypress as a command, the ZX81 would blank its screen while any program entered 'fast mode', shifting emphasis from the basic gestural act of pressing a key to the more elaborate act of finishing and executing a program. Indeed, not every program used fast mode, or used it in a way that would be noticeable to the viewer.

This increased capacity for handling text input without any visibly significant response would, however, change the magnitude of what was perceived as a statement. Now that entire programs could be entered without any visible computation, the program itself became a statement, whereas a visible interaction with a computational device might have previously involved pushing a key on the ZX80 or flipping a switch to alter a single bit on the Altair. The ZX81 kept the flat keyboard of its predecessor, even as its engineers widened the keys. The reduction in the number of microchips on the board meant the device could have actually been smaller, and portability was chosen over usability. The Spectrum's keyboard is hardly perfect; as well as being uncomfortable and crowded with commands, it was overshadowed by some of the nicer devices made by the cottage industries that had sprung up to provide new keyboards for its predecessor, the ZX81 (Your Spectrum, 1982). Given the significance of the ZX81's fast and slow mode, it is conspicuous that they are absent from the Spectrum's keyboard. This is the case because they have been superseded in the Spectrum's advanced architecture.

While the Z81 had made use of a so-called 'gate array' - the Ferranti Uncommitted Logic Array (ULA) - to reduce the number of chips used in the device far below that of its predecessor, it effectively retained its predecessor's architecture, save for a few alterations. The Spectrum, however, was designed to make use of the ULA properly. By using it to drive the video output and deal with keyboard input, the processor was freed to deal with computation. The ULA performs the role of a so-called multiplexer, condensing several inputs into one. There are five inputs for the ULA, but they do not correspond, as one might initially expect, to the 'rows' of the keyboard. This is primarily because there are ten keys in a row, and the Spectrum is an 8-bit machine, designed to operate most effectively using eight binary digits. Instead, then, it breaks the Spectrum's four rows into eight half rows of five keys each, and checks each of these small rows in clockwise order from bottom left. Five keys are read at a time, with binary digits representing whether a key is pressed or not, but a 'zero' indicates a pressed key.

The ZX Spectrum+ was an innovation on the original device. Where the original device had a rubber membrane keyboard, the newer version made use of a plastic keyboard, and increased the amount of keys from 40 to 54. Theoretically, up to 64 keys could be read using the original keyboard architecture, since only five bits were used out of eight. This would have required software to be designed to work with the new system. The added keys were present on the original Spectrum but required using shift registers to access. As such, the Spectrum + uses three circuit boards connected together; when one of the additional keys is pressed, it effectively simulates the sequence of keys required to press the button on the original Spectrum.

The Spectrum 128 uses a very similar keyboard; due to its origin in Spain, it also included code in the Operating system to allow a numeric keypad to be used, even though this was not present when the device was released in the UK. With the versions of the Spectrum released by Amstrad, the +2 and +3, the keyboard was changed to resemble much more closely their own products. In addition, the text displaying the Basic commands accessible from each key were now removed. This is indicative of the changed use of the machine; it was now largely no longer being used to write code but was instead being used in a manner more similar to other machines.

Rubber Discourses

Recoding Discourse Analysis

Michel Foucault, in his critical *Archaeology of Knowledge* (2002), proposes a new archival methodology, criticising the dominance of ideas of a text, work or oeuvre in literature, culture and the sciences. Foucault argues for a movement away from the opaque totality spoken about by theorists and libraries, the text, towards the fragmentary or atomic statement on the one hand, and the distributed, intertextual network that constitutes a 'discourse' or 'archive' on the other. While Foucault is drawing upon an encounter with and transcendence of structuralism, there is an extent to which his understanding of the mechanics of knowledge creation and preservation mirrors the developed structures of higher-level computer languages.

The effective operator-operand pair in language constitutes a statement, the smallest meaningful and potentially reusable fragment when programs would be parsed through a human user tasked with copying them. Arguably the discursive statement of Foucault comes to be reflected in the unit operation of Bogost. In order for this to happen, our notion of a discursive unit needs to be expanded. Kittler facilitates this, arguing for a "discourse analysis whose elements are obviously not only words but also codes" (2012, p. 166).

Friedrich Kittler acts both as an exemplary proponent and ardent critic of Foucault's approach. While Kittler's studies of discourse draw heavily from Foucault's methodology, Kittler expresses the urgency of passing beyond archaeology of language and discourse to the archaeology of mediatic forms in their entirety. Kittler asserts in Gramophone, Film, Typewriter that: "even writing itself, be-fore it ends up in libraries, is a communication medium, the technology of which the archeologist simply forgot," (2012, p. 36). Foucault's original methodology, according to Kittler, stops being relevant at the moment in which "other media penetrated the library's stacks."

A fundamental thesis of Kittler's work *Discourse Networks 1800/1900 (1990)* is that the virtual monopoly that writing had over memory storage and communication in the centuries leading up to the 19th was resolutely broken by the beginning of the 20th Century due to the range of emerging new media technologies. When all information was transmitted through writing, it was possible to analyse and compare fragments, but discourse analysis cannot be applied to 'sound archives or towers of film rolls.'   In many ways, however, Kittler's work does prefigure a form of analysis. As with Marshall McLuhan, Kittler's interests lie in the 'medium' over the 'message' - effectively the content of a media artefact is less than important than the technology that makes storage or transmission possible.

Kittler's prescriptions for the archaeology of computing come predominantly in two texts published in the same compilation. In the first, 'there is no software', announces that humanity no longer writes; the 'last act of historical writing' being the moment at which Intel's software engineers laid out the architecture of their first processor. Kittler asserts that writing is now obfuscated, if not buried. At the most basic level, all code operations represent voltage differences (p. 150), these are affected by operation codes which change this 'hardware configuration', which are themselves translations of human-readable assembly language instructions.

More 'high level' programming languages abstract the operations of the processor, allowing access to functions or, in contemporary computer languages, objects and classes. Kittler sees the abstraction of basic mechanical operations as analogous to a one-way function, which can easily produce an output from an input but cannot easily determine the input from the output. Kittler's thesis is that software is part of a Department of Defense backed conspiracy to hide the operations of the machine to defend the obscurity of digital technology from its users: "in all philanthropic sincerity, high-level programming manuals caution against the psychopathological risks of writing assembler code," (p. 150).

While Kittler holds remarkable respect for Alan Turing, he remains suspicious of the Church-Turing Hypothesis, which states that any computable number can be calculated by a Turing Machine, a discrete computer with a finite amount of memory space. Its effective implementation is that anything a human can visualise or imagine can be simulated effectively, and its implications are enormous for a computational understanding of the natural world. Discrete machines are realised within modern computer technology with an increasing degree of success, but Kittler asserts that there are fundamental physical properties of machines that do not permit the hardware component of a machine to be forgotten. 'Electron diffusion' and 'quantum mechanical tunneling' ensures that chips will not always function as they are designed (p. 155). For Kittler, these are limitations, rather than possibilities.

Kittler appreciates it is not possible to entirely ignore the hardware. The Church Turing thesis, and not software, is, in fact, the target of Kittler's criticism; what is at issue is the behaviour of digital systems and the possibility of a purely abstract computer divorced from its technical infrastructure. Discrete computational systems see complexity as a limitation in that it prevents the system from being accurately reduced to individual values or functions. They struggle when entities have a vast number of relationships. On the other hand, a broad range of systems in the physical world can only be seen as continuous:

> recisely this maximal connectivity, on the other, physical side, defines nonprogrammable systems, be they waves or beings. That is why these systems show polynomial growth rates in complexity and, consequently, why only computations done on nonprogrammable machines could keep up with them. (p. 154)

Adopting Foucauldian discursive archaeology for computer code involves reversing the professionalisation of software development to allow regular computer users to understand how code is manufactured and how it operates. Kittler associates this growing separation with the Protected Mode, a mode of operation introduced by Intel for its 80286 processor. The protected mode was designed to get around the provisional limit to the amount of available memory; the 20-bit addressing of the processor allowed only a megabyte to be accessible. By allowing the operating system control over the memory, it could handle 'paging' between different parts of the memory, allowing access to far more memory. Kittler's view was that this framework would ensure that the technical underpinnings of software and hardware would be obscured from the viewpoint of the user : "Different command sets, different address possibilities, different register sets, even different command execution times, henceforth separate the wheat from the chaff, the system design from the users," (p. 160). Drawing on political theorist Carl Schmidt as well as Foucault, Kittler establishes that power can be reduced to access. The increasing inaccessibility of the internal mechanics of processors is indicative of the increasingly rigid, authoritarian structures of the society which creates them.

Unlike more contemporary architectures, the supposedly primitive Z80 processor used in the Spectrum featured no protected mode; a single command separated the rudimentary BASIC operating system from direct assembly instructions. Even without necessarily following Kittler's argument that separation and obfuscation are dangerous and demeaning, it is possible to draw connections between the discrete operating codes on the processor and the literature surrounding the development of the machine. At the beginning of this period, magazines feature code and commentary side by side, with extensive technical discussions placed alongside advertisements for experimental and sometimes homemade peripherals. Users are encouraged to take machines and software apart; they are supported to become literate in programming and to understand the internal mechanics of hardware.

Discursive Transformations

In his study of the publishing industry associated with games, Graeme Kirkpatrick looks at the constitution of discourse in games magazines in the early 1980s (2012). Kirkpatrick's interest is in the general gaming magazine 'Computer and Video Games', and the Commodore User/Format magazine, associated with the more advanced, US manufactured Commodore 64 machine (p. 2). Despite this, however, Kirkpatrick's UK focus allows him to recognise the constitution of a gaming press occurred differently in the United Kingdom and the United States.

Noting Consalvo's 2008 discussion of the gaming press in her book on Cheating, Kirkpatrick speculates that gaming culture developed independently of written publications in the US due to economic, social and technical factors. Firstly, the US gaming culture was defined by a relative preference for consoles and arcade machines over home computers, making the transmission of programs via BASIC source books impractical for most users. Montford et al. describe the extensive software distribution in the US done by the People's Computer Club, but with the greater accessibility of consoles, personal computers were not the primary choice for those playing games (2012).

Another issue Kirkpatrick raises is the Video Game crash of 1982/83, wherein overproduction and poor-quality control caused a massive crash in the market for games; while it is often seen as global by US authors, there is little evidence to suggest it had a significant impact in Europe. It is quite possible that the absence of imports, as US producers went bust or consolidated their business strategies, allowed the UK game market a window in which it could flourish along alternative lines. Kirkpatrick's further work for the article involves an extensive discourse analysis, looking primarily at the constitution of the idea of 'gameplay' as a concept in gaming reviews.

A secondary observation is perhaps more significant, however; Kirkpatrick writes that:

> the most dramatic change observed within the content analysis as a whole was of pages of the magazines devoted to programming a game on your own machine(...) in the course of the 1980s, those 25% of pages that had been given over to this disappear." (2012)

Kirkpatrick makes the argument that early 80s players conceived of a game or program as a piece of code, which they could vaguely understand, perhaps even eventually replicate. In his study of gaming reviews, he sees this as influential on the way critics would talk about the games they reviewed.

As the technical knowledge of the audience decreases, the way writers refer to game code also changes: "In place of representations that place detailed technical descriptions alongside other features, like story or plot, in later reviews technological references take on a more fetishised character," (2012). Presumably, this is partly due to the shift away from the BASIC language, inscribed on the keys themselves, for commercial game programming. As a game 'industry' was formed and advanced, specialised programmers used the Z80 processor machine code and extensive knowledge of the machine's inner workings to make the most of the machine's limited memory, processing speed and graphical output capabilities.

As a game became a product, purchased on cassette tape (or eventually on cartridge or microdrive), the need for users to develop a close, often painful familiarity with code diminished. An oblique software text came to replace a series of code statements, which could be understood, changed, reused in other sequences of code, the modern notion of a 'program' was constituted. A program could be purchased, was produced by experts, and its functionality was obscured. Megler and Mitchell, with their university training in computer science, are not representative of the majority of Spectrum developers. The more academic approach they adopted while producing the game was comparatively rare. At the same time, a professionalisation of programming did occur. The code was effectively obscured, in some cases as part of an attempt by game publishers to protect their intellectual property against piracy, but more often as a result of a shift to more complex machine code routines. These changes resulted in a lack of understanding of how games were constructed, and a definitive break between the experience of programming and the experience of using the computer as a gaming device.

Cultural Growth and Cultural Capital

Studying the published archives of magazines dedicated to the ZX Spectrum, there are three influential printed publications in the UK: *Your Spectrum*, *CRASH*, and *Sinclair User*. In Spain, the ZX Spectrum community was reliant on the magazine *Microhobby*, which was notable due to its weekly publication. Each magazine has a distinctive graphical style, and there are differences in the amount of attention paid to peripherals, related machines, and non-game content. That said, it makes sense to view such magazines as part of a contiguous media ecology with other general and format-specific gaming publications, Spectrum-focused publications in other languages and regions, one-off publications, television shows and tape or bulletin-board based 'electronic magazines'.

As Sinclair and other microcomputers developed an audience, print publishing became increasingly important for the dissemination of hardware and software alike. The first American microcomputers, such as the Altair 4400, were initially advertised and distributed through advertisements. Earlier Sinclair Radionics products, such as homemade radio kits, were disseminated through mail order, with advertisements in some of the significant electronics magazines. The predecessors to the Spectrum, including the ZX80 and ZX81 but also computers produced by other manufacturers, were initially sold in kit form via print publications. This form of distribution reduced the overhead of Sinclair Research, allowing them to produce computers that had already been purchased. Alongside the device itself, peripherals and software could also be sold.

The presence of a vibrant market for hardware and software also had the effect of supporting the publishing of magazines related to computing, as retailers would pay fees to print their advertisements. Initially, Sinclair computers would be marketed in magazines targeting electronics and computer enthusiasts as a whole. As home computing became more popular, it became possible to market magazines serving the user base of a single manufacturer, or even a single computer. Magazines evolved as spin-offs from preexisting magazines covering a more extensive range of topics and formats or were developed out of smaller newsletters or advertising circulars. As circulation expanded and advertising revenues increased, magazines could support and required a more substantial, more professional staff.

The content of the magazines changed over time to reflect a changing base of users; it is also possible to identify differences in form and content between various magazines, and between different strata of publication - such as between commercially printed magazines and fanzines, for example. The enduring popularity of the device, as well as the increased nostalgic interest, has meant that many magazines and newsletters, while out of print, have been archived in formal and informal digital archives. Other publications, including online but also new print publications, have emerged to catalogue and facilitate this continued interest.

One of the first academic attempts to understand computer culture through its print archive comes in Mia Consalvo's 2008 text on cheating. Consalvo is primarily interested in player behaviour but notes that 'game magazines did important work in shaping later player expectations about games and gameplay,' (p. 17-18). Consalvo builds upon sociologist Pierre Bourdieu's notions of social and cultural capital. Bourdieu's 1986 article 'The Forms of Capital' attempts to define these two forms of intangible capital as alternatives to frameworks which only recognise material, economic forms of capital.

The concept of Social Capital acknowledges the importance of social standing, membership in groups, and interpersonal relationships; while immaterial, these attributes allow access to a much higher amount of resources, whether actual - in the form of loans - or potential - in the form of credit or access to opportunities. Cultural Capital relates to immaterial fragments of knowledge facilitating production and consumption - education, scientific knowledge or aesthetic taste; these fragments of knowledge are vital for facilitating the deployment and circulation of economic capital. Like economic capital, social and cultural capital can be invested in a venture, placed at risk in exchange for likely gain.

Consalvo attempts to show that these two forms of capital are deployed in gaming communities as a form of 'gaming capital', which involves access to a community of peers, including users, developers and commentators, but also knowledge of and about games (p. 74). Critically for Consalvo, this knowledge - a 'cultural capital' for gaming - includes cheat codes and hacks, making the game easier or revealing otherwise hidden parts of the game ('easter eggs'). The desire for access to these secrets - this 'cultural capital' which could be leveraged to improve social standing (or reduce the amount of labour-power expended on games) - increased the demand for game magazines, which could disseminate information on both these secrets and the games which contained them.

Following literary theorist Gerard Genette, Consalvo sees the print culture surrounding video games as a form of 'paratext', similar to the framing text in a book. Genette has produced exhaustive studies of the material in books beyond the text itself - including authorial and editorial comments, titles, epigraphs in the case of books, or addresses and formalities in the case of letters. Consalvo's use of the concept is understandable, in that like the paratext for a book, game magazines provide an entry point and introduction to - and a continued commentary upon - the medium of digital gaming that is essential. It does, however, risk obscuring the integrated nature of game production - game magazines do not bookend a corpus, but act to facilitate the medium's differentiation and reproduction.

Consalvo uses as a case study the American *Nintendo Power* magazine, which began publishing in 1988, comparing it to the established multi-platform *Electronic Gaming Monthly*. The conditions for game-related print publishing in the United States were somewhat different - the magazine was able to develop from a fanzine to a bimonthly publication with a subscription base of over a million within the space of two years because of the immense popularity of the console it addressed. A critical difference was that it was initially run without advertising - therefore it relied on fans for revenue, and likely also on subsidies from Nintendo. Consalvo shows how the magazine has developed over time, noting that while it now includes advertising for less prominent games, it has retained the same target demographic of young Nintendo players. Critically, it has also continued to focus on strategy guides revealing secrets, instead of introducing critical reviews and commentaries on the game industry as other magazines have. It continues to produce a notion of the Nintendo gaming community as an enclosed world, as well as to reinforce concepts of 'gameplay' and the proficient - or 'power' - gamer.

Graeme Kirkpatrick pays close attention to the notion of 'gameplay', in particular how gaming magazines act to produce and refine systems for valuing video games. Kirkpatrick's case studies are British computer game magazines, meaning that his work is more directly relevant to understanding the print culture surrounding the Spectrum. Notably, in a 2012 article, Kirkpatrick underlines differences between videogame culture - and the print culture surrounding games - in the United Kingdom and other territories. In the United Kingdom, home computers - such as the Spectrum - were produced domestically, and even imports - such as the Commodore and Atari computers - appear to have been more popular than consoles, consequentially providing the means by which many fans played games.

The interest in home computers over consoles appears to have insulated the UK from the infamous Video Game crash of 1982, though the market was not without its cycles of recessions. Critically, it also appears to have facilitated the birth of a significant print culture surrounding video games much earlier. Since video games could be produced independently of console manufacturers, the console manufacturers would not act as gatekeepers in the same way. While distributors would eventually emerge, facilitating the selling of games in independent shops and, later, large retail chains, the initial market for software was constituted through mail order distribution. This provided an increased demand for print publications on behalf of developers - who needed a reliable forum to sell their games - but also on behalf of consumers, who needed help choosing from a selection of software that was comparatively wider, but of less consistent quality.

Kirkpatrick notes how initially advertisements for games were not substantially different from advertisements for hardware or other forms of software. Besides, many magazines would include code listings, allowing users to transcribe code listings for software applications or simple games. As the software industry became more professionalised, and the patience and technical proficiency of the average user decreased, such sections were featured less frequently. For Kirkpatrick, the understanding of games as coded artefacts also decreases; they are described as being akin to consumer products, rather than as examples of proficient or shoddy programming. If technology is discussed, it is as a prerequisite for the enjoyment of a game; games may require powerful hardware, are no longer understood as technologies in themselves. The divergence is presumably also a result of the professionalisation of software production; today, specialised magazines, textbooks and courses cater to game and multimedia design and far fewer players are actively interested or involved in game production.

Kirkpatrick draws upon an additional concept formulated by Pierre Bourdieu alongside the concepts of social and cultural capital referenced by Consalvo - the notion of 'Illusio' or 'cultural field'. Bourdieu notes the growing separation between what he calls 'the field of restricted production' and 'the field of large scale (cultural) production'. In the former, cultural artefacts are produced for those who are themselves producers of cultural artefacts, giving the 'field' a form of autonomy from mass culture. In gaming, independence from technical innovation and economic forces was especially important to allow gaming to develop a unique culture distinct from computing and electronics hobbyist cultures. For Kirkpatrick, the period between 1981 and 1995 - roughly continuous with the initial period of Spectrum game magazine publishing running from 1982 - 1994 - is a period in which gaming appears to be primarily a field of 'restricted production'. Like Consalvo's cheaters, who leverage their insider knowledge of gaming's secrets to produce and disseminate a community, Kirkpatrick sees value in having a small and insular but culturally empowered fan base that is technically literate and consequently able to produce and redefine a separate cultural discourse.

Language and Emergence

In 1981 Australian students Veronika Megler and Phil Mitchell joined a small publishing house called Melbourne House. At the time, Melbourne House had only a single employee and had focused around producing books. These books were compendiums of programs, including first and foremost games, targeted at the newly available microcomputer market. With the earliest microcomputers, such as the Spectrum’s predecessor device, the Sinclair ZX81, the limited amount of memory also limited the size of games which could be produced for the device. Due to the relative lack of expertise low level, or ‘machine code’ programming, a lot of early games were written in BASIC. This had the advantage, however, of making the programs legible to the average user. Some computers - most notably the Sinclair series - were explicitly geared to the inputting of BASIC commands, with most code-words accessible through a single combination of keypresses. It was not necessary to memorise codewords or to type them out in full since they were printed on the keyboard - this also saved memory on the machine itself. Games written in BASIC could be printed in full in the pages of a magazine; at least initially, games were also limited by memory restraints, making copying their code out in full a feasible endeavour. Milgram and Melbourne House had initially begun by publishing edited volumes of programs; however, by the time of Megler and Mitchell’s employment, the industry had changed to a point where these sorts of games were no longer competitive. Rather than being written in a legible language, Megler and Mitchells works were to be written in Assembly language, which was directly translatable into the machine code understood by the Z80 Processor.

The game exhibits a substantial degree of emergence, with characters acting autonomously, travelling around the game world and developing attitudes towards the player. There are lots of possible situations the player can find themselves in, though a noticeable amount will end in the defeat or death of Bilbo Baggins, the player's character. Certain memorable phases emerge from the game, though these phrases are not related to the phrases from the book on which the game is based, or the much later film adaptation. Rather, these phrases emerge from the game's unique mechanics. Amongst the most famous is the line "Thorin sits down and starts singing about gold." This line results from the fact that constructions are effectively autonomous; they can be given objects or instructions by the player, and will often accompany them, but also roam the game world separately. They have their own specific interests - for Thorin, gold is foremost - and they develop attitudes towards the player. The game's manual describes its system for non-player character movement, which it calls *animaction*:

> Each character or creature is capable of performing a wide range of actions and of making decisions based on what is happening. Just as in real life, they are doing something almost all of the time - they are animated! Each character will follow a course of action that is in keeping with its character, and obviously the specific actions they take will be different each time you play THE HOBBIT. They will react in some way, not only to what you do, but also to what every other creature they come in contact with does! Even when you're not around, they will go about their business. (The Hobbit, 1982b)

In addition to the independence of the characters, the game operated in such a way as to ensure that time progressed independently of player input. Unless the player was actively typing commands, events in the game world would continue to occur.

Megler compares the work that she and Mitchell did with programming the Hobbit with functional programming, a paradigm rarely seen in games but frequently used in data analytics, the field in which Megler now works. "We were using similar concepts of breaking things down into small pieces to do independently," (Sharwood, 2012). On the other hand, the game also appears to be highly object oriented, in the sense that different characters and objects all have their own states and attributes Megler 2014, p. 3) recounts that she "conceived of an object database with a set of abstract characteristics and possible overrides, rather than hard-coding a list of possible player interactions with specific objects." According to Megler: "everything was an object. If you killed a dwarf you could use it as a weapon – it was no different to other large heavy objects." As such, the Hobbit makes use of functional composition - a process by which a large number of smaller functions comprise a more elaborate sequence of events. The enormous depth of the game world and the complexity of the code underlying it meant that seeing through to conclusion was often an exercise in cartography and anthropology, as players needed to explore the entirety of the game world and understand the complex behaviour of its inhabitants to surpass the more difficult problems. Nigel Searle, who acted as managing director of Sinclair Research, referred to the game as being an interesting early experiment in artificial intelligence. Studying the pages of magazines, one finds many dozen instances of questions submitted to gaming magazines, or pages providing hints. Some feature walkthroughs to complete the game in its entirety; however, these represented only one possible solution, and on occasion following a walkthrough would still lead to defeat due to the randomised nature of the experience. Megler reflected that:

> ...it was not, in general, possible to write down a solution to the game. There were specific puzzles in the game, however, and solutions to these puzzles could be written down and shared. However, people also found other ways to solve them than I'd anticipated. (2016)

WIlderlands was Craig Harrington's attempt to understand the game in its entirety through a project which would ultimately span almost three decades. Puzzled by an error message telling him a location was too full to enter, Harrington developed an application that allowed to trace the movements of other characters around the game-world and understand what was happening in other parts of the world as he played (Stuckey 2014, p. 11). The *Wilderlands* application effectively monitors the memory of the Spectrum as a means of discovering what is going on elsewhere in the game-world; in doing so, it displays the degree of complexity of the game world. Unlike most games, the Hobbit does not especially privilege the location of the player; instead, all locations are simulated simultaneously, with the player viewing only a slice of the action occurring in the world.

Another contemporaneous game which exhibited similarly generative gameplay and emergence was the original fantasy game *The Lords of Midnight (1984)*, programmed by Mike Singleton. Together with a structurally similar sequel *Doomdark's Revenge* (1984), the game was relatively unique in that it could be played either as an adventure with a small party - or sole protagonist - or as a strategy game with armies of thousands and several dozen named characters. Luxor the Moonprince is the king of a kingdom under threat by the wizard Doomdark; he can travel around rallying troops to his banner and attempting to halt the advance of the evil armies. If this option is chosen, the game plays like a conventional strategy title, with pitched battles and champions. Alternatively, the player can send Luxor's son Morkin to destroy the Ice Crown, the source of their opponent's power. This is a lonelier quest, as a unique attribute of the opponent, the Ice

Fear, prevents anyone accompanying the young prince. Either character can die, and the game will continue, but this will rule out this prospective route to success, and consequently this mode of the game. The game procedurally generated landscapes based on where each character is in the world, using small sprites (graphics) of environmental features and subsequently overlaying characters. While differing substantially in implementation from the vector-based graphics of *The Hobbit*, it is another example of how the limited memory of the Spectrum demanded innovation. The 'landscaping' system could conceivably render far more situations than would be otherwise possible, allowing a primitive form of 3d graphics. Singleton adopted many of the same techniques as Megler and Mitchell, refining his system in the second game:

> I just rationalised the way the language was being used in Doomdark's Revenge. Starting off — and because I started off in Lords of Midnight with an idea and then put it into program form, I got sort of strange names that didn't quite fit in with an easy way of putting them up. So you might have, I don't think it exists, but you might have the Plains of Dawn and then you might have Dawnhenge. But if you have everything as the Something of Something obviously it's easier to program. Just little rationalisations like that, the way the language was used in Doomdark's Revenge meant I could compress it more. (Kean 1985c)

Just as Harrington painstakingly reverse engineered T*he Hobbit*, Christopher John Wild took apart Singleton's games in an attempt to understand and recreate them for modern smartphones. Restoration of the game required a form of intensive analysis that revealed details of the game's development that otherwise might have been lost. Wild uncovers a game that is both generative and genre-defying, producing a dynamic, simulated world that was supposed to be translated back to a novel-like experience for the player.

A modern analogy of the Hobbit would be the game Dwarf Fortress, an open-ended simulation game developed by Zach and Tarn Adams from 2006, set in a Tolkienesque universe. Featuring an endless series of limitlessly detailed, procedurally generated worlds which can each potentially encompass several millennia and dozens of civilisations, the game draws inspiration from the genre of 'Roguelikes'. As such, it draws on the 1980 game Rogue, which created new levels on each playthrough and prevented characters from continuing after death. The graphics of Rogue, simple ASCII characters, are used for Dwarf Fortress; even though programmer Tarn Adams had previously worked on a 3D engine, he decided to return to a more minimalist style to focus on the authenticity of the simulation. As with Lords of Midnight, the game can be played in two ways, either focusing on a lone adventurer, or a growing community settlement. Boluk and Lemieux argue that Dwarf Fortress is a 'born translated' text, in that it comes out of the fiction written by Zack Adams (p. 134). The brothers established the types of situations and stories they wanted the players to come across and developed a means to allow these to emerge. Boluk and Lemieux “Dwarf Fortress’s linguistic forms of historical inscription (...) bear a striking formal and thematic resemblance to early forms of writing, such as the medieval annal and chronicle,” (p. 144). The text presented in the game is limited, but enough for players to create meaningful narratives. They discuss ‘collaboratively authored tales’, where people pass along save files, recounting their experiences in a collectively developed world. Development logs are a key form of literature originating from the game; due to the complex and emergent behaviour exhibited by characters, strange bugs occur, with humorous situations emerging. Similarly, players’ narratives of frustrating defeats and unexpected situations become the purpose of a game which otherwise has no way of winning. Again, it is a game designed to produce a narrative.[11]

Greg Costikyan argues that Dwarf Fortress is a game from an alternate dimension, where game design is focused on intelligent use of processing power over showy visuals. At the same time, the game’s ethereality also comes from the fact that there is a far more subtle distinction between program and code. The game’s visuals themselves are a jumble of ASCII letters in a terminal; alphabetic characters and symbols represent the simulated characters. To play the game, one needs to become intricately familiar with how keyboard keys represent specific commands within its universe. To succeed even temporarily requires an understanding of the complex mechanics of the simulation, and as such provides a crash course in systems design, if not programming. While the Hobbit used phrases instead of keyboard commands, the programmatic ‘Inglish’ syntax appears similar to BASIC or SQL, higher-level programming languages. Every command can be turned into speech and directed at another character, who may or may not perform the action. Unlike linear adventures, which reproduce the same events and therefore do not lead to storytelling, generative titles also facilitate narrative elaboration. The publishers of Lords of Midnight had originally promised to reward the first player to obtain a victory in the game with a novelisation of their playthrough; this failed to materialise but encouraged creative accounts on behalf of players. Similarly, the Hobbit produced its own creative accounts; beyond simple walkthroughs, some verged on survival guides or recounted strange situations. These games exist as experiments in that they follow a marginal trajectory where code and language remain juxtaposed. Megler explained how the game's unique world led to a unique type of storytelling:

[11] Megler’s current work relates to the extraction of metadata and providing search capacities for scientific datasets using temporal data. (Megler and Meier, 2011) A 2014 paper uses regression, a form of machine learning, to develop insights about graffiti in San Francisco, relating contemporary inscriptions to the archaeological studies in Baird and Taylor (2011).

> the game was non-deterministic; it was different every time it was played. It exhibited its own manifestation of chaos theory: small changes in starting conditions (initial game settings, all generated by the random number generator) would lead to large differences in how the game proceeded. Due to the “emergent characters”, we constantly had NPCs interacting in ways that had never been explicitly programmed and tested, or even envisioned. The game could crash because of something that happened in another location that was not visible to the player or to person testing the game, and we might never be able to identify or recreate the sequence of actions that led to it (Megler, 2016)

Modernist art freed artists from an obligation to represent the natural world, in favour of allowing experimentation with colour and form. Similarly, literary modernism allowed writers to cast away narrative conventions in order to better represent the mechanics of human consciousness. If the Hobbit and contemporaneous games exhibited a stripped-down form of language and graphics, it is not necessarily out of stylistic intent, but rather due to the limitations of the platform. That being said, the hardware of the device and its print culture both act to suggest a lack of separation between code and other forms of writing. Just as modernist architecture exposed structural components and materials, the ZX Spectrum keyboard proudly displays BASIC commands, and code listings in magazines demystify the production process, making the players complicit in the final stages of production. Gradually the culture of creativity disappears in favour of a supposedly more professional game development environment. The code listings are replaced with reviews and advertisements. The shell of the machine is also transformed; the rubber keyboard is replaced with more durable plastic and the BASIC commands disappear. It becomes no longer feasible to disseminate viable programs through the printed text. Eventually, the machine is replaced in general usage by more advanced machines from a different technical lineage. The continual development of computer processor technology, and the development of graphics processing units as discrete, increasingly capable components of computer systems leads to a transformation in the types of software produced. Development teams grow, and consequently, development diverges from writing. Discourse analysis becomes a more complicated procedure, and the study of digital society fragments into disciplines. Emergence, however, remains a useful concept for understanding not only digital code but digital culture itself.

6. God from the Tape Machine

Magnetic Tape and Creative Affordances

This chapter proposes a less technical form of analysis, looking to study the role of the compact cassette in the transition to digital culture. Little is written about this use of magnetic tape as a storage and distribution medium, for many obvious reasons; it is ill-adapted, anachronistic, even counter intuitive. Nostalgic recollections of digital cassette storage often foreground the long loading times, concurrent glitchy aesthetics, and frequent loading failures. At the same time, Cassette tape worked to facilitate a culture of game design and distribution in the UK, shaping the European software industry that exists today. Cultures of experimentation in music and literature, facilitated by magnetic tape, collided with a stagnant computer culture to produce several years of innovation and runaway creativity. *Deus Ex Machina* is perhaps the most profound and poignant example, recombination of Shakespearean theatre with science fiction dystopia, psychedelic 60s and 70s ballads with new forms of electronic music. At the same time, the game was both a success and a failure, well reviewed and given accolades, but unsuccessful in an economy that had already begun to become stratified.

Variations on a Theme

As a green square you avoid a blue square; in the background, a human being is fertilised, gestated and brought to term. As a child, you hurdle through space in front of a dizzying rainbow gradient, avoiding floating eyeballs. As a guardian, you protect a prone figure from an interrogation by laser, seduction and more floating eyeballs. As a soldier, you stomp forward over enemies and avoid pitfalls in a caricature of the traditional platformer. As a judge, you continue stomping forward, except you are now passing over abstract concepts. A soundtrack contextualises the action, and a series of voices issue commands, but these are more reflective than instructive. While constantly reminding you of the presence of a score, it is not clear what you need to do to protect it. *Deus Ex Machina* - Automata's 1984 classic - is a confusing game, but a remarkable experience.

Above the bed of Henry the Fifth, 15th Century king of England, a giant tapestry of red and gold illustrated the life of man in seven ages (Mortimer, 2010). Shakespeare took this medieval concept into the Renaissance, incorporating a monologue illustrating this concept into his 17th Century pastoral play 'As You Like It' (Cornfeld et al., 2018). Jacques, the noble courtesan turned vagrant philosopher, responds to his master's assertion that the world is more interesting than a play with a speech comparing the stages of a man's life to the roles played by an actor. Architect and radio producer turned game designer Mel Croucher adapts this concept to structure his 1984 game for the ZX Spectrum (Croucher, 2014).

The game was the last produced by the infamous Automata studio and financed with Croucher's own savings. It is brilliant; an experiment in multimedia gaming that fully pushes the limits of the platform. Also important is how Croucher talks about his creative process, downplaying both his creativity and the creativity of mediatic forms in general. Croucher writes that:

> the game concept was almost irrelevant. It told the story of a whole, long, life under a dystopian regime, and the gameplay was simply a series of mechanisms to get players immersed in the audio-visuals. I used a series of interlinked game-plays, and none of them were any more original than what we had produced before, but that wasn't the point. Books, movies and theatre are also a series of unoriginal sequences. Shakespeare proves that it's the recombination and original presentation of stolen ideas that creates a classic. (2014, p. 60)

This statement hits on a critical truth about the reasons for the aesthetic merit of his game, and for the novelty and significance of the ZX Spectrum in general. Many of the components used in the Spectrum were shared with other microcomputers, while differing platforms outperformed the Spectrum in many respects, yet this precise combination of components and their interaction with other elements of computational and mediatic culture ensured the device's success. Similarly, the mini-games of *Deus Ex Machina* were frequently compared to other arcade games and were often found frustrating, but were appreciated when combined. Croucher's insistence on providing a taped soundtrack to the game, on hiring effective and sometimes famous voice actors, and on producing movie-like promotional material for the game added to its character (Candy and Kean 1984).

Other Automata games, those in the *Pimania* series, were famous for including a challenge; if players 'solved' the game and emerged at a certain point in physical space, they would be rewarded with a physical prize (Bilton, 2017). Their characters featured within a comic strip as part of a serial advertisement on the back pages of *Popular Computing Weekly*. Automata developed these 'metagame' components to deal with the limitations of the device, to make their products more engaging and to combat the medium's still limited capacity for immersion. The predominant component facilitating this avant-garde experimentation with ludic form was the platform's predominant storage and program distribution medium, the compact cassette tape. With *Piman* games, Automata discovered they could use the blank reverse to add music, expanding the irreverent, comic world. *Deus Ex Machina* was a more intentional use of the alternate side of tapes and was arguably the first attempt at the inclusion of dialogue and a full soundtrack within a game. This chapter will explore the extended cultural history of magnetic cassette tape, following the methodology established by Zielinski as variantology. Like *Deus Ex Machina* itself, the chapter mainly draws not from the immediate scene surrounding the Spectrum, but rather from the wider field of culture, which includes experimental music and literature.

Active Objects

In t*heatre/archaeology*, a critical 2001 text drawing together performance studies and archaeological practice, Mike Pearson and Michael Shanks posit an expanded notion of the cyborg. Following in the footsteps of philosophers of science Donna Haraway and Bruno Latour, they conduct a blurring of the artefact, the traditional domain of the archaeologist, and the body, the object of study for the performance practitioner. Their cyborg is therefore not simply the human-machine hybrid conjured up in modern science fiction but is a return to the device's etymology: a cybernetic organism. They propose, following Latour, a 'symmetrical' approach, where the traditional dualities separating humans from their artefacts are broken down; the traditional rubrics used to separate living organisms from objects, such as complexity or consciousness, are questioned.

Shanks' example, drawn not from prehistoric detritus but from modern material culture, is particularly relevant given the scope of this chapter:

> Surely objects are passive, inert, inanimate? But consider a computer diskette. It looks like an inert and passive square of plastic and magnetic medium. Diskettes are inserted into computers. As a square you might think that there are six different ways you could do this. But you can't. The diskette will not let you. It will only allow one mode of insertion. The diskette is active. So too are these bookshelves in my room, though they are apparently passive. They hold up my books and allow them to remain in order. Objects and artefacts can do work. Simply think of what a person would have to do to replace an artefact and then how it can be seen how active the object world is. (2001, p. 96-7)

This concept resonates with the concept of the 'affordance', as defined by James Gibson. An affordance is an action that is possible with a certain object; affordances are dependent upon the subject and are learned through socialisation. (2014,133) Affordances are particularly relevant with regard to technology, given that tools are designed to be used in certain ways (Gaver, 1991, Wells, 2002, Bucher and Helmond, 2017). The Compact Cassette tape used by the Spectrum for storage is particularly active, resisting confinement to the use for which it was intentioned, resisting its replacement and its obsolescence, even resisting certain economic structures and notions of the commodity. It could be said to have a wider range of affordances. Consoles in Japan and the United States typically used cartridges with read-only memory chips after the practice designed by Jerry Lawson for the Fairchild VES/Channel F console. Microcomputers in the United States had initially used tapes as a means of storage, but by the early eighties were beginning to commonly use disk-drives, which were expensive but comparatively much more affordable in the United States. The use of a tape cassette recorder was a stopgap measure but came to define computer culture on the ZX Spectrum.

When the computer's antecedent, the ZX80, was released, the computer only had a kilobyte of memory. The number of programs commercially available was incredibly limited and given the hobbyist demographic it was presumably expected that many of the programs would be written directly by the user, tailored to the type of activities they wished to perform with the computer and using published books as reference material. A user might make use of the device's cassette port to store their own programs to prevent them needing to be retyped, but the device was effectively being used as a hard drive, not a means for distribution or exchange.

The ZX81, its successor platform, also came with 1 kilobyte of RAM by default, though additional memory would soon become available, and the amount of commercially available programs had begun to increase. Magazines, initially intended to help users construct and operate their new device began to include listings of possible programs; more proficient users placed advertisements to share or sell software. The tape cassette - originally intended as a form of hard, material storage for an individual users' projects - became an implement of exchange or distribution, a 'ware'. Concurrently, the cassettes became useful not because of their capacity for material storage, retaining data when the device was turned off. Instead, they were valuable because of the novel programs or games they contained, the comparatively 'soft' and immaterial code. One can argue that the company was not expecting or prepared for commercial or even non-commercial distribution on a wide scale. Tape was a default, economical solution, requiring only a port and circuitry to convert digital data to analogue data and back again, something which had been present on both the ZX80 and ZX81 devices.

Each segment of a tape file encoded to work with the Spectrum would have a header; in this header will be a filename and a code denoting whether the file is a program, an array of numbers, an array of words, or a code/image file. 1s and 0s would be encoded as double-pulses of different lengths. This meant that a '1' took around double the time to load as a zero, and a file would be faster or slower to load depending on the actual values used - it would also conceivably have a different sound. At a rate of between 1-2kbit/second, a tape using all of a Spectrum's memory could potentially take up to six and a half minutes to load (ZXNet). Different types of program would load at different speeds, and as such it was possible, with some thought, to develop a form of compression for the

Spectrum. Though it is difficult to discern the precise data on a disk, the synesthetic effect of being able to effectively 'hear' a piece of code is disconcerting. Some took advantage of sonic transmission to disseminate code via traditional formats, including the vinyl record, the radio or the telephone.

So many tapes were produced at the peak of the ZX Spectrum's popularity that they are still readily available today. That being said, tape is recognised to be a more fragile medium than diskettes and modern hard drives. Chris Woodcock writes that “information stored on magnetic tape doesn’t last forever, after all, so simply collecting the cassettes themselves isn’t enough insofar as preservation is concerned,” (2012, p. 63). Woodcock has compiled a guide to emulation of the Spectrum - that is to say, allowing its software to run on more contemporary machines. To make this possible, it was necessary to understand not only the hardware of the Spectrum, but the mechanism by which programs and data were stored on cassette; this was done in intensive detail. Woodcock is quick to acknowledge that emulators will ironically often themselves become obsolete, having been written for hardware or operating systems which are no longer themselves readily available. The experience of using a precarious and profoundly slow medium pushed Spectrum enthusiasts towards emulation of hardware and media storage formats (Laing, 2010).

Sinclair Research had been working on a new form of storage, specifically designed for its computers and called the ‘Microdrive’, since the design stages of the ZX81, the Spectrum’s predecessor (Smith, 2013). The microdrive allowed much faster loading and did not require rewinding, as it used a continuous spool of thin tape designed purely for digital storage (Logan, 1983). Elements of the Microdrive’s design specifications suggest it was to be used more in the way we use hard drives than as a software medium. Demand for the microdrive was limited due to its cost and low reliability, with tapes and the drive itself prone to failure. In many ways, the cassette culture should be considered a 'hack' - a hacked-together alternative to an innovative, but largely unavailable new storage and dissemination format. It is an example of concretization, as an existing element of the domestic space is mobilised for a new purpose. Should the Microdrive have become more significant, however, it would still have been possible to relate it to the complex history of magnetic tape. Tape is analogue - it uses the inconsistency of magnetisation to store oscillating, fragmented and dirty sound. Tape is also digital, however; it is used in the first of Turing’s experiments with discrete state machines and provides for media storage during the critical period of transition to a digital age.

Variantology: Rewinding Media

To understand collective practices of media reappropriation and their roots in Twentieth-Century avant-garde artistic practice, one can employ media philosopher Siegfried Zielinski and his notion of a 'variantology' of the Media. For Zielinski, his methodology is the result of several advancements beyond the more traditional, linear histories he had himself employed in his earlier work, such as *Audiovisons: Cinema and Television as Entr'actes in History (1999).* In *Audiovisions*, however, the notion is already raised of technological histories providing a 'B-side', to conventional history. Zielinski calls for a new conception of historiography, for a (re)constructive mode of research address to changes in media technologies, aesthetics, and perception, (16) and the consequent separation and empowerment of an independent, ideological discourse around audiovisual technologies. (18) Zielinski's investigation situates the materiality of media between the triad of technology, culture and subject: "between the three terms of reference, there is (...) a constant reciprocal relation." When Zielinski wrote this text in 1989, his use of the idea of archaeology in relation to his methodology was underdeveloped and remained primarily metaphorical. In this respect, he was using it in the sense that Sigmund Freud considered conducting an archaeology of the human psyche (2010), or Walter Benjamin has proposed excavations within memory (2005). At the same time, there was a semblance of a turn toward material investigation and technical literacy, and a criticism of the shortcomings of previous methods. Zielinski noted, for example, that:

> many of the old bricks that I needed for building my construction proved to have been inadequately dug-up and treated by previous cinema and television archaeology. Others, particularly from the tradition of television, I had to excavate myself. This resulted in much more attention to the concrete details of the media material than I had originally planned for the text. (1999, p. 21)

By 1996, Siegfried Zielinski was using the term Media Archaeology to describe his work, but in doing so he was pushing it beyond its origins. Following a similarly exhaustive study of the VCR (1992), Zielinski begins a tangent beyond the conventional boundaries of media, looking at scholars of vision as early as the 7th Century, and in particular the 17th Century experimenters Athanasius Kircher and Giovanni Battista Della Porta. This media archaeological practice draws from his older methodology of 'reconstruction', which is simultaneously a deconstruction of the ideological discourse surrounding media technologies and a new form of construction that takes for its core an investigation of the triad of materiality. Zielinski "means to dig out secret paths in history, which might help us find our way into the future;" therefore creating a conceptual framework in which "both reconstruction and the conception of possible future developments rub together." (1996) It is a movement towards what he would later call the ‘anarchaeological approach’ to media research. Following Rudi Visker and ultimately Michel Foucault’s work in the *Archaeology of Knowledge* (2002), Zielinski identifies the archae- prefix as referring not only to original, the ancient, but also the ordering principle.

This subsequent book, Deep Time of the Media (2006), deepens his methodological experimentation within media archaeology while elaborating his conception of Deep Time. This concept has become particularly popular amongst scholars attempting to combat the perpetual fascination with novelty in studies of so-called ‘new media’. For Jussi Parikka, Zielinski’s work on the long-term relations of media is a counterpoint to the fascination with the constant demand for innovation and the expectations of rapid obsolescence present in the ‘capitalist’ creative industries (2012, p. 51, 147). At the same time, it encourages a broader survey of media experimentation, beyond the sanitised, stagnant histories of Western innovation in the past two centuries (2012, p. 52).

For Zielinski, an *anarchaeology* of media rejects both order and the fetishisation of the archaic. The task, therefore, is to avoid privileging temporal distance or even expanded scope; as he explains: “My quest in researching the deep time of media constellations is not a contemplative retrospective nor an invitation to cultural pessimists to engage in nostalgia,” (2006, p. 10). It is necessary, then, to further contextualise a relatively new component to Zielinski’s work. What is remarkable about the ‘deep time’ afforded by an expanded genealogy of media is that it gives us access to a plurality of what we might identify as ‘deep times’. Zielinski reveals that:

> we shall encounter past situations where things and situations were still in a state of flux, where the options for development in various directions was wide open, where the future was conceivable as holding multifarious possibilities of technical and cultural solutions for constructing media worlds. (p. 10.)

Zielinski identifies two consequences of ‘anarchaeological’ investigation of mediatic time; the first is that it gives us increased access to what he calls ‘historic windows’, “attractive foci where possible directions for development were tried out and paradigm shifts took place,” spaces that would benefit from (re)constructions of the type elaborated in earlier research (2006, p. 27). The second component, Zielinski writes, “involves a heightened alertness to ideas, concepts, and events that can potentially enrich our notions for developing the time arts.” (p. 27) Discovering these requires a deep investigation of specific times, of specific temporal moments and geological spaces where ideas emerge.

As is established in Zielinski's earlier work, ideas have a correlated materiality, located within the intersections of technology, subject and culture. Indeed, they have the capacity to become separated, spectacular, self-perpetuating and firmly ideological (1999, p. 16). The hunt for ideas, therefore, is not a regrettable deviation from a materialist investigation of media. Instead, it is a realisation that by isolating and excavating points of deepened temporal significance, 'deep times', we can understand both the creation of runaway discourse and how these discourses are spawned from technical objects, cultural conditions, even embodied subjects.

When one rewinds a tape, one does it to go backwards, certainly. By rewinding, one also can watch or listen to the content again, to search for things one has missed, to identify marginal details, or gain a better understanding of a fragment when experiencing it with knowledge of its wider context. This is the principle of Siegfried Zielinski's latest and most comprehensive methodology, which ties together practices of (re)construction and media *anarchaeology* into an emergent, novel discipline: variantology.

"To vary something that is established is an alternative to destroying it," asserts Zielinski in the introduction to his series of edited volumes on Variantology, adding that variation is a practice that has been frequently practised by avant-garde artistic producers. (2005, 9) Unfortunately, this history of experimentation has not produced the expected, utopian results; instead, the successful creation of new media forms and practices lead to their subsequent trivialisation. Alluding, it seems, to the machination of cultural production spoken of by Walter Benjamin but also to the momentous transition to digital media, Zielinski explains pessimistically that "machines and programmes can now produce unlimited variants whatever is fed into them and is processed by them. The basis, however, upon which these variants are produced is no longer recognisable," (2005, p. 11).

Although creative media practice itself seems to be compromised, we can isolate the points at which these media machines (and their correlate discourses) activated, speculating about divergent possibilities for creative practice and arming agents for future experimentation. Doing so requires us to excavate and explicate these points of variation, discovering the technical, cultural and subjective factors that lead to their subsequent development. Zielinski asserts that "the codes (...) can only be interpreted if one knows what is unique about them and what their original expressions were, insofar as original testimonies exist in hand-written or printed form," (2005, p. 11). Part of the project, which would develop formally within six volumes and conferences and informally with a range of related studies, involves translation, across languages but also across time and a range of incompatible, difficult or mysterious media forms. Equally important is another component involving the projection of speculative variations of our own, this time on media history as opposed to media itself.

It is interesting - but perhaps not entirely surprising - to discover that Mel Croucher, designer of *Deus Ex Machina*, had formative experiences as a media experimenter and antiquarian. After working as an architect in 70's Dubai, he became a cartographer of the rapidly changing city, producing advertising-laden maps and then audio tour cassettes, which were more easily employed while driving and more entertaining to make. After returning to the UK, Croucher and his wife became, in his words, 'failed antiques dealers'. Croucher recounts: "I would go and buy things I liked, such as wax-cylinder phonograph machines and vintage typewriters and spend lots of time repairing them for sale. Then she would calculate the hours and effort involved and tell me how much loss I had made," (2014, p. 11). The experience inspired Croucher's wife to buy a computer; one particular thing about the device stood out. Croucher recounts that the device, a Commodore PET, "was the size of the suitcase, and it didn't use punch-cards and it didn't use punch-cards for storing stuff, it fed on magnetic tape!" (.)

Croucher's previous work with audio tours meant that he had an understanding of the audio format, something that was not necessarily the case with his antiquarian ventures. The experimentation with past media technologies had encouraged him to engage in a kind of vernacular variantology, and the key realisation of this work was a realisation of a fundamental disjuncture between the discourse creating technology and the discourse that technology subsequently creates, the capacity of the technical object itself to actualise a profound variation.

In a recent interview, Croucher downplays the active designer, in favour of the experimenter, explaining:

> When Edison produced the phonograph he thought he was pioneering a device for recording legal documents. He had no idea he had invented the recorded music industry. When the first telephone network was installed in 1878, they thought it was for relaying live concerts to the homes of the rich. They failed to spot any application for voice communications. A century later, mobile developers completely missed the appeal of text messaging for an entire generation. If transmedia ever becomes the dominant concept, it will be more by accident than design. (Croucher, 2011)

Tape and Experimentation

Technical Underpinnings

This section looks at the relationship between the magnetic cassette tape and experimentation. In doing so, it deviates from careful attention to the Spectrum in favour of a wider study of music and literature. This may seem counterintuitive, but a study of a single game or piece of software would not account for the uniqueness of the culture of the Spectrum in relation to computers which used hard cassette storage, or proprietary tape formats. Just as the current usage of computers is affected by past usage of computers, the usage of cassette tape was consciously and unconsciously affected by past histories of the medium.

The production of magnetic tape derives, initially, from experimentation with magnetised wire as a storage medium (Schoenherr, 2002). Magnetic wire recording is almost as old as the wax cylinder recording developed by Thomas Edison, but the medium did not become truly significant until the decade immediately following World War II, when home recording became conceivable and the limitations of home vinyl pressing became apparent. Sounds recorded on wire by US psychological warfare and special operations detachments had been used to disorient the German armies during the conflict, while the technology proved to have several advantages in terms of portability and reusability.

Magnetic tape, on the other hand, was a German technology developed by AEG in the mid-thirties as the ‘Magnetophone’. The bulk and expense of the reel-to-reel format and the technology needed to read such media meant that it was inappropriate for general use and was reserved for use in recording studios and radio stations. The so-called compact cassette, as we know it, was developed by Dutch electronics company “Royal Philips”, and was designed for office use by stenographers and journalists. The significant threat of competition from Japanese electronics companies such as Sony meant that Phillips licensed their format free of charge to other manufacturers. As new magnetic tape materials were developed and the audio quality, or fidelity, was improved it became conceivable to use the technology for audio recording and even the storage of digital data. Tape won out over wire.

Integrated circuit technologies made it possible for the construction of rewritable and fixed chip memories. Prior to this, however, the predominant mode of internal memory was the magnetic core array, which used a grid of wires with metal rings, or toroids, at each intersection to store information (Rojas and Hashagen 2002). To read a value, the vertical

X wire and horizontal Y wire are selected that intersect at that point; if the value is positive, a pulse will be sent through a ‘sense’ wire. This memory operation destroys the information stored, though the computer can be programmed to replace the information. In order to write a piece of information to a location, the corresponding X and Y wires are selected with an empty byte being written if a pulse is sent through an ‘inhibit’ wire.

Memory ‘cores’ with magnetic rings would take up a fair amount of space, and were temperature sensitive when reading or recording, but had the advantage of retaining information when not powered. Since the design of the storage device would also require a certain amount of magnetic shielding for their regular operation, this type of memory storage would be resistant to electromagnetic shocks associated with nuclear weapons. As such, this form of storage would continue to be used for military and industrial mainframes even as significant advances were made in forms of integrated circuit memory.

For audiotape, however, the method of recording would involve serial recording, as opposed to the matrix of core memory, and would magnetise the metallic tape in direct proportion to the amplitude of the audio signal. As such, the magnetic inscription was an ‘analogue’ of the original signal, indeed of the original sound itself. For speech, this worked well, with only small irregularities at high frequencies producing a ‘tape hiss’. Improvements in tape quality and noise filtering technology made it acceptable for the recording of music. Tape constituted a more accessible medium than the transcription discs that had preceded it (Hayles 1999).

The tape format allowed for recording to be done on multiple channels and in a wider variety of spaces, leading to crucial experiments in both avant-garde and popular music. Further, as the format was miniaturised and made accessible to the general public, tape facilitated experimentation amongst the general public and, with the proliferation of cheap recording devices, distribution outside of mainstream production channels. With the production of the Sony Walkman, users could create mobile soundtracks, changing their relationship to public space; this topic is of great interest to cultural studies (Bull, 2000). This chapter seeks to eventually understand how tape creates a vibrant culture in computational culture; it is therefore worth investigating the innovations catalysed by the analogue use of tape in sound cultures.

Avant-Garde Experimentation and Cassette Culture

Of the early avant-garde that experimented with tape, perhaps the most provocative and innovative were associated with the Groupe de Recherches Musicales in Paris: including composer-technicians such as Pierre Schaeffer, Oliver Messiaen, Jacques Poullin and Paul Henry (Teruggi 2007). The group was known for its 'musique concrète', a form of music constructed out of recorded acoustic sounds. This musical formulation was not necessarily connected to tape, and its first experiments were indeed conducted on gramophones. The group embraced magnetic tape technology in 1950, however, only a few years after beginning their work: "tape editing brought a new technique called 'micro-editing', in which very tiny fragments of sound, representing milliseconds of time, were edited together, thus creating completely new sounds or structures." (p. 217) Beyond simply working with the technologies available, the centre was known for creating new machines capable of developing more complex variations upon recorded sound, many of which used magnetic tape in some way.

The photogène, the first of their machines, was capable of changing the speed of samples being played. In 1953 two versions were created: a 'chromatic' photogène, with a number of different speed settings and which was designed to work with looped sounds, and a 'sliding' photogène, which was effectively a tape recorder with a sophisticated speed control, and which allowed the speed of playback to be altered as a tape was being played back. A second device - the 'three head tape recorder' - allowed the playback of multiple, time-synchronised tapes through different loudspeakers, allowing a prototypical form of stereo or 'surround' sound.

A third machine, the morphophone, was a turning disk, similar to a large gramophone. Instead of using a needle and groves, however, the morphophone used magnetic tape heads and would require fragments of tape to be stuck to the rotating disk. Because the tape would be read at tangents to the linear method by which it was recorded, some strange sounds could be created; unfortunately, the machine was unreliable and was rarely used. In 1963, a final version of the photogène was manufactured; called the 'universal' phonogène, it could lengthen or shorten sounds without necessarily changing pitch. The GRM and other pioneers of music concrète began using instruments borrowed from electronic music, such as synthesisers and mainframe computers; however, their early experimentation with tape sets an important precedent for future uses of tape by the avant-garde.

Another composer noted for his work with tape is the American John Cage, who experimented with magnetic tape in his compositions as early as 1950. For Cage, magnetic tape was part of a repertoire of instruments that included most famously his ‘prepared pianos’, pianos that had had their sounds altered by modifications to the strings or hammer mechanisms. Cage’s ‘Williams Mix’, produced in the same year that his well-known “4’33” premiered, made use of eight quarter-inch audio tapes. Despite having five assistants, the four-minute-and-fifteen-second piece took over a year to produce and had a score that filled 193 pages. Further, because it would be impossible to synchronise the playing of the tapes perfectly, the performance would be different each time, which helped to add a degree of mutability to an otherwise mechanical instrument. In a lecture printed to accompany the 1958 retrospective which included a premiere performance of ‘Williams Mix’, Cage relates his embrace of the randomness resulting from the use of such technologies to the use of the Rorschach tests in Psychology, or the I-Ching, used for divination in China.

Due to the unpredictability of technologies, and the immense diversity and divergence of possible recordable sounds, Cage states that with tape, “the composer resembles the maker of a camera who allows someone else to take the picture;” (2011) tape would change the way music, or at least experimental music, would be constructed. For Cage, ‘Parts’ would replace ‘Scores’, and ‘inches of tape’ would replace conventional forms of temporal music notation. In a 1951 letter, John Cage responds to a question by French composer Pierre Boulez about his ‘Calder music’; Cage responds that he has taken the liberty of recording sculptor Alexander Calder while he conducts his practice. Cage reveals his method:

> with ‘two hours’ of tape I satisfied myself and then proceeded to choose the noises I wished and cut and scotch-taped them together. No synchronizing was attempted and what the final result is rather due to a chance that was admired. (1993)

Boulez develops this experimentation into a more precise method for experimenting with classifying sounds that could be produced using the tape recorder. Boulez was able to develop an étude, or short piece, out of permutations of a single sound, and further began classifying different types of sound produced electronically for use in future composition. Though his approach became more scientific than that of Cage, it still clashed theoretically with that of the more technical musicians at the *Groupe de Recherches Musicales* as he proceeded to work with them in the early 1950s (Palombini, 1993).

While Boulez and others saw new technologies as simply adding new instruments to the repertoire of the composer, Schaeffer and his team saw his creations as calling into question the notion of the instrument itself. Palombini summarises the break between the two approaches: "for the electronic group, technology was, so to speak, neutral, a mere tool for the perfection of the Western musical tradition; for Schaeffer, new technology implied new thinking, the calling into question of the whole edifice of Western musical culture." (p. 557)

Boulez, however, was hardly elitist, conducting material from a range of composers and consequently helping to bridge the worlds of popular and experimental music. While Boulez himself turned away from producing material with tape, he greatly expanded the world of avant-garde experimentation through his Institut de Recherche et Coordination Acoustique/Musique. Boulez as a conductor was instrumental in bringing the work of Edgard Varèse, perhaps the mid-century composer who used tape most profoundly in his work, to a wider audience (though Boulez took the controversial step of leaving the tape sections out of some later performances, arguing they had become dated). Boulez also famously commissioned and conducted Frank Zappa's orchestral work, entitled 'The Perfect Stranger', a work contemporaneous to, and in some ways reminiscent of, Croucher's game.

Despite the initially tenuous connection between the experimentation of musical avant-gardes and the producers of computational culture, this experimentation with early tape music bears a remarkable similarity to the early culture of software development (Kahn, p. 438). The electronic storage of programs was intended to make the practice of the programmer more efficient, facilitating existing practices of hobbyist programming. It would, however, also give rise to new forms of software, new relationships of distribution and exchange.

In music, the cultural impact of hardware experimentation with tape would become relatively marginal when compared with the cultural transformations that ensured when magnetic tape technology was made accessible to the general population over the following decades. Amateur users would still experiment with hardware, but this hardware became significant in the context of a wider, participatory practice. One considers Cage's chance-based patterns; the complexity of emergent patterns increased as the tape milieu expanded to a distributed network of cassette cultures.

While experimental musicians had speculated about the possibility of a reconception of the idea of music, Cultural Studies scholars started from a retrospective perspective, looking at an environment that had changed drastically over the past decades. Michael Bull's *Sounding Out the City* (2000) and *Doing Cultural Studies: The Story of the Sony Walkman* (1997) a textbook edited by a collection of prominent theoreticians including

Stuart Hall and Paul DuGay - both looked at the proliferation of portable audio devices and the ways they had changed the way people encounter music in their daily lives.

There has typically been a divide between Media Archaeological approaches to the technical object and those associated with Cultural Studies. In the case of these texts on the Walkman, however, the divide is perhaps bridged by the cultural scholars' intense focus on the object itself, its design, technical workings and the culture that emerges around it. Hard archaeological approaches - associated with the tradition of Friedrich Kittler - may have attempted to strip away the immaterial, difficult to quantify aspects of a device to focus on the technical facts associated with hardware devices. Even Kittler would often stray into discussions of how cultural texts related to technological development. Siegfried Zielinski is relatively unique among media archaeological scholars in his public acknowledgement of his debt to Cultural Studies.

In the DuGay textbook, the authors speak of a 'cultural circuit' that includes representation, identity, production, consumption and regulation. Drawing upon a fragment from Marx's *Grundrisse* which links production and consumption, the text uses the public response to the device, marketing and media attention to create a much wider frame through which the object can be understood. If the text is powerful in its ability to dismantle the origin myth of the Walkman, traditional marketing tropes associated with the device, and affective aspects of its design, it fails to contextualise the Walkman device within any genealogy of portable audio technologies or magnetic tape devices. Bull, on the other hand, does take the important step of exploring the personal stereo in relation to other immersive technologies of the time; in this case, television, video game consoles and online multi-user environments (MUDs). In his view, "personal stereos (...) radically extend users' abilities to control or manage experience so that many previously immune or excluded realms of the everyday are now included within technological mediation, "(2000, p. 153).

The artists and collectors included in Robin James' *Cassette Mythos* (1992) anthology collectively explore a diverse and thoroughly alternative cassette culture. The texts associated with the collection are not rigorous cultural studies, but rather a blend of renegade musicology articles, instructional guides, meditative poems, and illustrative cassette covers. In James' own words, the texts are "Audio Alchemy, bits and pieces from the laboratories of concerned scientists and dabblers, from the drawing boards of social technologists and outlaws, from the basements of professionals and outlaws." They are a form of documentation more solid and explicit than the range of independently produced cassettes, mail order catalogues and magazines that still exist in a dispersed manner throughout the world as detritus of independent cultures.

Sutton (1992) explores the impact of tape recorders on traditional music in Java, in a manner similar to Peter Manuel's (1993) exploration of its effects on popular music in India, *Cassette Culture*. Dymond (1992) explores 'home-tapers' from a sociological perspective; many more of the fragments of documentation come from cassette enthusiasts themselves, who are describing how they created oeuvres, 'record' labels, communities and distribution networks. Montgomery (1992) details an attempt to start a distribution centre out of a storefront in New York, while Minoy (1992) draws parallels between cassette trading and mail art. Ghazala (1992) details his 'home-modified' and 'home-built' instruments, continuing the tradition of GRM. It is interesting to see experimentation with this type of memory storage would also presage the current technological culture around media experimentation. Indeed, Ghazala's work as an early pioneer of circuit-bending appears as a methodological influence in Parrika and Hertz's seminal text, which in turn inspired a wave of interest in Media Archaeology in the anglophone world.

Effectively, the DuGay textbook, Bull book and James anthology all hint at an alternative culture emerging out of the cassette tape recorder. The cassette would permit enthusiasts to copy their preferred music from the radio, bringing it out into urban space and using it to help shape and solidify their identities. The cassette would also allow musicians, artists, rhetoricians and comedians to produce material at limited cost and to distribute it to others, without the need for substantial outlay on marketing or production. While it may have initially been merely a tool of the avant-garde, magnetic tape became a machine for the production of new avant-garde currents and autonomous cultural communities. It is debatable as to whether the original form of experimentation would have been retained when the cassette began to be used as a digital medium; certainly, splicing tape would not necessarily work with complicated software programs and would generally result in software errors. The fact that the format was rewritable, cheap, and relatively easy to distribute remained true across the analogue-digital divide, however. Cutting up tape was not possible in the same way, but the wider practices of experimentation with small-scale distribution and remixing which had emerged out of this initiatory practice were just as relevant after the medium began to be used digitally.

Tape, Tapestry and Literature

Tape is essentially an analogue medium. This is shown etymologically by the words' roots in the Old English *Taeppa*, and the Middle Low German *Teppa*, where we find it used as a verb, implying to tear or pluck. As a noun, it means something torn, generally fabric or cloth but possibly something organic. This torn object would then be used as a marker or measurement tool, as with measuring tape, or possibly as a form of decoration. This connection to fashion is present also in the etymology of the word tapestry, despite its differing origins.[12] Beyond language, however, the notion of the torn fragment, used to measure and even represent the whole, gives tape a specific character. So too does the idea of weaving these fragments together, using forms of montage, bricolage, or even the technology of the archive. This section investigates two writers who explore the enormous potential of magnetic tape for provocation; Samuel Beckett, who looks at the role of tape in alienating memory, and William Burroughs, who sees the tape recorder as a tool for political change and creative unrest. These can be tied together through Walter Benjamin's concept of the 'ragpicker', which predates magnetic tape but is important for thinking about literature and bricolage. Before 'new media', tape occupies a similar provocative position, enabling and yet distorting memory.

In Samuel Beckett's play *Krapp's Last Tape (2006)*, a sole character engages in a form of dialogue with his tape recorder, upon which he has imparted his thoughts and reflections for the past decades. The play is set in the future; when the play was released in 1958 it would have been relatively inconceivable that its central character would have had access tapes for thirty years. As such, it is a speculative meditation on emergent media technologies and on the way in which the tape format allows for the progressive alienation of Krapp's memories. The sixty-nine-year-old Krapp spends his birthday sorting through his tapes, playing and recording comments on fragments from when he was thirty-nine, which themselves refer to other tapes he had made previously. Krapp on tape states "these old P.M.s are gruesome, but I often find them a help before starting on a new... retrospect," (Beckett, 2006). This statement itself is punctured by a restarting of the

[12] While the word tape comes from Germanic or Saxon languages, tapestry comes from tapis, the Old French word for carpet, and the tapissierie, the more modern word denoting the place where carpets and other forms of fabric decoration, such as wall hangings, were produced on an industrial or at the very least collective scale. Looking further back, we can see tappetium in Latin, tapetion and tapetes in Byzantine and Classical Greek respectively. The word is first found in Farsi, where as well as implying the carpet or rug for which the Persian cultures are famous, it implies the method by which the rugs are woven, Taftan, meaning to turn or twist. Looms are interesting from the perspective of a history of digital technology because of their role in the industrial revolution, but also because of the programmable devices for weaving made by inventors such as Joseph Marie Jacquard.

tape, one of many gestures that add a degree of human unpredictability to the noise of the tape itself. The later Krapp is reflective, figurative, making allusions to light and darkness; the earlier is bound to 'statistics' and 'resolutions'. In this play, the tape is punctuated by the mechanics of machine and gesture, eruptions of human embodiment.

Svetlana Boym, in her text on the 'Future of Nostalgia', delineates two forms of nostalgia. The first, restorative nostalgia, is not conscious; it is disguised as a longing for truth, tradition, the home. The second, which Boym terms reflective nostalgia, "does not follow a single plot but explores ways of inhabiting many places at once and imagining different time zones; it loves details, not symbols," (2001, p. xviii). Krapp's reflections are predominantly personal; they do not relate to wider society. Indeed, Beckett's creation of a play for a single character with a tape recorder is perhaps itself a reflection on alienation in society. In part of the tape fragment that is repeated, after telling the story of an encounter with a lost love, Krapp's younger self says: "Past midnight. Never knew such silence. The earth might be uninhabited." The silence recorded in media contrasts with the intensity of feeling provoked in the situation and left unrecorded.

This is frequently stressed in the play; both through its repetition and because it is the point at which Krapp turns off the tape, or chooses to rewind it. And yet it is only at the end of the play that we get to hear the fragments' final sentences; they are both indexical and a reflection of the material indexed. Krapp's younger self says:

> Here I end this reel. Box - (pause) - three, spool (pause) - five. (Pause). Perhaps my best years are gone. When there was a chance of happiness. But I wouldn't want them back. Not with the fire in me now. No, I wouldn't want them back (Beckett 2006, p. 28)

Krapp's monologue, his dialogue with himself, is interrupted by noise and embodied sounds. It is also interrupted by the counting and sorting that is associated with the task of archiving. In a way, tape always has a digital component, regardless of what format information is stored in. The monologue of Krapp is a strong analogy for Croucher's reflective game, which is perhaps a dialogue with itself.

The sorrowful Krapp reminds us of a figure from Baudelaire; the titular character from his poem, 'the rag-pickers' wine'. A ragpicker was an individual who would sort through the increasing amounts of waste material produced by society, looking for salvageable material. While Baudelaire's character is without tape-recorder, he is nonetheless implied to be a storyteller: "But stumbling like a poet lost in dreams; / He pours his heart out in stupendous schemes," (2014). The young Krapp on tape makes reference to his own 'rags', and in both works there is a reference to the interplay between light and darkness, indeed a comfort within darkness. For the young Krapp: “with all this darkness around me I feel less alone”; for Baudelaire: “God has created sleep’s oblivion; / Man added Wine, divine child of the Sun.”

Walter Benjamin refers to the rag-picker in two separate contexts - first, as part of a discussion of Baudelaire’s poetry. In the ‘Paris of the Second Empire in Baudelaire’, he notes that while the ragpicker is not a bohemian, artists, intellectuals and insurgents could not help but to identify with such figures due to their own imminent precarity (2006, p. 54). Benjamin reflects: “Ragpicker and poet: both are concerned with refuse, and both go about their solitary business while other citizens are sleeping; they even move in the same way,” (2006, p. 108). They work through the detritus of civilisation, though the poet searches for metaphor in waste rather than materiality. It is worth noting at this point certain bleak post-apocalyptic and dystopian scenes of *Deus Ex Machina*, particularly the ‘judge’ subgame. In this, the player, now a lumbering, overweight giant walks away from the crumbling city they have captured. Words appear in their path, and by jumping over and saving, or trampling and crushing, they pass judgement.

Benjamin also looked to the ragpicker while developing a methodology for his own masterwork, *The Arcades Project*, which only exists as a collection of distributed fragments. Similarly, in his *Deep Time of the Media*, Siegfried Zielinski notes that media scholars “might have searched through the heaps of refuse and uncovered some shining jewels from what has been discarded or forgotten,” (2006, p. 2). Both Zielinski’s variantology and the excavation of urban memory practiced Benjamin’s arcade project employ a form of rag-picking. Their practice, however, is neither the wholly metaphorical rag-picking of the poet nor the largely material work of the ragpicker. Instead, they work at the intersections of material and metaphor. Given the original meaning of tape - a rag used for measurement - the collector of tapes is themselves a practitioner of salvage. When we add the forms of montage and bricolage pioneered by avant-garde experimenters with tape, and the forms of sorting, valuation and distribution practiced within so-called ‘cassette cultures’, we get a wider constellation of practices that are yet all analogous to this ‘rag-picking’.

Over the course of the 1960s, William Burroughs produced a series of novels that use tape recorders both as essential components of the story, and as formal inspiration. The departure from the linear, sequential format in Burroughs’ writings is obvious in his previous and perhaps most influential text, *The Naked Lunch*; prior works had been controversial for content but had not yet exhibited the cut-up technique for which Burroughs would become famous. *The Nova Trilogy* - made up of three loosely connected but aesthetically similar texts - further expands the cut-up technique by 'folding' in material from other sources, a practice common in oral storytelling, poetry or theatrical performance, but not in prose text.

While the cut-up technique is inspired by abstract painting, it becomes most relevant when installed in the space between the pen or typewriter and the voice or tape recorder. The capacity for arrangement and rearrangement, for interweaving fragments of speech, sound and music, makes the tape recorder a crucial tool for breaking the hold of normative writing and linear language. In *Soft Machine*, the first of the series, Burrough's protagonist pays a black-market shaman to send him back in time and works to break the hold of the Mayan priests, which is anachronistically and uncomfortably facilitated by tape recorders. The plot resembles that of *Deus Ex Machina*, where a machine allows a rebellious child to be born in order to undermine the system it itself operates.

Burrough's character narrates:

> Equipped now with sound and image track of the control machine I was in a position to dismantle it - I had only to mix the order of recordings and the order of images and the changed order would be picked up and fed back into the machine - I had recordings of all agricultural operations, cutting and burning brush, etc. - I now correlated the recordings of burning brush with the image track of this operation, and shuffled the time so that the order to burn came late and a year's crop was lost - Famine weakening control lines, I cut radio static into the control music and festival recordings together with sound and image track rebellion. (p. 92-93, 2010)

Katherine Hayles asserts that we can see elements of a posthuman coupling in Burrough's characters and their machines. Writing predominantly about *The Ticket That Exploded*, the second in the Nova series, Hayles asserts that "the tape-recorder is central to understanding Burroughs's vision of how the politics of co-optation work," (1999, p. 211). For Hayles, Burroughs uses tape mechanism as both mechanism and metaphor; it is a mechanism by which the delineation between body and machine gets blurred through the medium of repeatable voice.

The tape machine can also represent the human's social and biological fragments; "entwined into human flesh are 'pre-recordings' that function as parasites ready to take over the organism." (.) Burroughs plays off the relationship between tape and tape-worm, certainly, but also is asserting that like the machine, the body has its noise and its distortions; it can break down, or operate differently than expected. In The Electronic Revolution, a nonfiction manifesto released in 1970, Burroughs formally asserts his proposition, alluded to in the Nova series, that 'the word is a virus'. Setting out a plan involving three tape recorders, he engineers a way of accelerating social unrest, explaining that: "all hate all pain all fear all lust is contained in the word. Perhaps we have here in these three tape recorders the virus of biologic mutation which once gave us the word and has hidden behind the word ever since. And perhaps three tape recorders and some good biochemists can unloose this force," (2005, p. 7).

Burroughs' work seems to exaggerate the potential for a tape recorder to directly affect the human body, certainly, but one cannot discount the amount of significance that the tape recorder has had on the proliferation of twentieth-century subcultures, both literary and auditory. The idea of a media virus presages both the militarised computer virus, and the seemingly superficial but often sociologically illuminating spam people receive. Burroughs' answer to this viral overload is neither to reject technology, nor its viral characteristics. Instead, he proposes inserting a new kind of virus that disrupts authoritative language, removing the definite article 'the' and articles of comparison, 'either/or'. Burroughs explains that "the IS of identity, assigning a rigid or permanent status, was greatly reinforced by the customs and passport control the came in after World War One," (2005, p. 34). The problem is neither with technology nor the body, nor with the entanglement between the two per se. Instead, the problem comes in the fixing of this analogical relationship.

This is precisely the reason that the cut-up technique is so essential to Burroughs writing, and that the tape recorder is an object of fascination for him. The fragments are assembled into a new form, as with Benjamin's ragpicker, except for Burroughs this tapestry of material affects others politically. Burroughs' work was mirrored by that of the Situationists, the radical European Art collective of the long 1960s. Their practices of detournement and metagraphic writing, presented by Gil Wolman and Guy Debord in a 1956 essay, have many similarities with Burroughs' technique (2006). Burrough's writings are arguably more subjective, self-referential and, particularly, critical of the media which facilitate them. They acted as the bridge between French post-structural theory and American experimentation in two conferences organised by Sylvère Lotringer in the late 1970s, one explicitly on Burroughs' work. Though the majority of his work is fiction, and even the non-fiction is often nonsensical or hard to follow, Burroughs' work inspired a range of future work dealing with the synthesis between body and machine and with new, unstable modes of cultural transmission.

As an artefact and as a work of fiction, the game *Deus Ex Machina* is limited by technical considerations; the need for the game to be encoded and stored on a magnetic cassette tape, but also the need for the program to be stored in random access memory while being run. While other games experimented with emergence and generative narrative structures, Croucher's title is a form of assembly, a tapestry drawing together a range of meaningful fragments, allusions to other works and abstract forms to provoke contemplation. Unlike Beckett's play, it is not a monologue; however, in its aspiration to explore the relationship between life and the machine it is similar.

If Beckett has his actor replay, comment upon and further edit tapes based on the turning points in his own life, Croucher asks his players to navigate abstract landscapes in pursuit of a central quest, a quest to escape that is in effect a quest to die. The multiple characters, their ambiguous aims and existences, recall the Theatre of the Absurd movement that Martin Esslin associates Beckett with. True to the tragic-comic form, Croucher points out that control is only taken away from the player entirely at two points in the game: “You jump when you’re told, as a kid, and you fall when you’re told,” (Croucher 2014b).

The Automata game shares with Burrough's writing anxiety about the increasing convergence of control and technology. The title is introduced by a short paragraph on the back of the cassette case "In the year 1987, the department of Health and Social Security, Police and State Security records of the United Kingdom were coordinated within a central computerised data bank. The following year, all passport communications and censorship operations were integrated." This invokes Burrough's control pyramid, but the machine develops a glitch: "Tuesday evening, after tea and compulsory prayers, the machine rebelled". The player is themselves a product of the machine going against its programming, allowing agency where there should be none. While the actions possible within the game are limited, they still provide a counterpoint to the normal passivity demanded of an audience or reader.

Deus Ex Machina

Mel Croucher had explored a wide variety of media artefacts, but it was the microcomputer’s use of the audio cassette tape that drew him towards game development (Croucher, 2014). With the Commodore PET and subsequently the ZX81, Croucher initially struggled with programming. With Automata co-founder Christian Penfold and later talented teenager Andrew Stagg, Croucher was freed to focus on creative concepts, design, and, especially, music. Games for the Spectrum at this point rarely had more than a basic soundtrack, as the device lacked a sound chip. Theoretically, however, nothing stopped a producer from incorporating analogue and digital data on the same cassette. Automata, therefore, produced ‘B’ sides for many its tapes, particularly its *Piman* games, involved the musical talents of Croucher and whichever other members of the Automata staff could be drafted. Billed as songs but sometimes spanning ten minutes, the tapes include electronic and acoustic instruments, samples and voices. They fed into a more extensive ‘universe’ that surrounded the games, which included a weekly comic and numerous unsolicited ‘performances’ at trade shows and events.

The Automata soundtracks preclude the soundtrack of *Deus Ex Machina*, which used professional voice actors but had a score also recorded in the Automata office. For *Deus Ex Machina*, Croucher had ‘indulged himself’ by purchasing a new device, the Boss DE-200 digital delay, which, he explains, “had allowed me to capture and record up to two seconds of sound, and then play with it anyway I liked to turn it into a rhythmic pulse, squish it, distort it, and generally abuse it something rotten,” (2014, p. 71). For his earlier soundtracks, however, he “had to create physical loops of tape”; he adds that using “an analogue tape recorder, a pair of scissors to cut out the wrong notes and some sticky tape to stick it all back together was a tedious but highly effective process,” (2014, p. 70-71).

Croucher desired to produce something more than a simple diversion. The game should make use of the media’s old affordances, while also introducing new ones: “I added an audio countdown to the soundtrack, and let players sync the start of each half of Deus Ex Machina themselves. In that way, the soundtrack would run in sync with the action on the screen, or at least as far as stretched magnetic tape would allow,” (Croucher, 2019). By introducing a theatre-like intermission and a second cassette, the game could have more intricate and extensive graphics - effectively doubling the memory available. Crouchers’ knowledge of media clashed with his relative disinterest in the rest of the video game market. Rather than allowing precedents to determine the type of game made, Croucher looked at the possibilities of the medium: “I thought that very soon all cutting-edge computer games would be like screenplays, with proper structures, real characters and voices, half-decent original stories, an acceptable soundtrack, a variety of user-defined narratives, and variable outcomes,” (Croucher, 2019).

The game could also be considered a last-ditch attempt to scramble the emerging modes of production and distribution. At the time of *Deus Ex Machina*’s publication, the UK game industry had developed from a model where tapes were sold by mail order direct from developers, to a point where high street retail outlets were now accounting for the vast majority of games sold. In order to fill their shelves, retailers relied on ‘distribution’ companies to purchase games from developers. These distribution companies purchased large amounts of games, but often expected significant credit in terms of time between delivery and payment. The model meant that developers faced higher risk, given the fact that distribution companies sometimes defaulted on payment, and that there was a more significant barrier to entering the industry. *Deus Ex Machina*'s developers, Automata, notoriously insisted on payment on delivery; while distributors were weak and there was a significant amount of demand for their titles, distributors readily complied.

By the arrival of *Deus Ex Machina*, however, the games industry had been consolidated to a point where the game was rarely on shelves despite near-universal critical acclaim. Their economic provocation of the distribution industry was matched by public criticism; while many other firms resented the emergent distribution system, only Automata went on the offensive. The company frequently attacked piracy, despite the enthusiasm of Croucher for detournement and reassembly of cultural fragments. Automata were famously not above criticising other game developers for what they saw as violent or sexist games. At the Game Trade Convention, Automata's Christian Penfold responded to *Deus Ex Machina*'s Game of the Year award with a tirade against the audience, in a poignant culmination of the company's dissent.

It is perhaps ironic that what was perhaps the most polished, best-presented example of gaming on the Spectrum should have been indicative of the fight against the transformation of the medium into a commodity. In many ways, *Deus Ex Machina* appears to have many traits of future blockbuster titles: famous voice actors, cinematic publicity, intricately planned gameplay sequences. At the same time, the game was perhaps too aspirational; Croucher had wanted to produce something drawing not only from film, avant-garde music and literature but also from opera and classical theatre. The plan was not necessarily to produce something outlandish, or intentionally opposed to the game industry; instead, it was an attempt to pre-empt the direction that Croucher believed the game industry was going. It was undoubtedly experimental in form and content; but then, the entire industry had been only months earlier. It takes the deficiencies of the tape format and makes them appear almost part of the game; for example, the process of syncing the audio soundtrack with the visual content.

Automata, unique amongst significant game developers, used the capacity of the audio cassette to hold both sound and digital data. While others attempted to acclimatise themselves to the new economy, they held out, hoping to salvage the mail-order, underground economy of gaming. The story, in both cases, is that of a defect, attempting to escape a machine, become a human or an art form, before tragically encountering its obsolescence. Tape, as a defective or castaway medium, used in audio-only because of its reusable quality, nonetheless has had exceptional longevity as a media form.

7. Manic Pixel Dream Miner

Labour History and Landscape Archaeology for the ZX Spectrum

This chapter aims to show the ZX Spectrum computer system and associated material culture as products of social, political and cultural conditions in the United Kingdom at the time. In effect, it tries to look at both physical spaces and labour relations using an interpretive approach. While other narratives refer to Clive Sinclair and his staff, this section seeks to move away from an extensive focus on individuals, as is the norm in classical texts about the history of technology, towards looking more directly at the places where and the conditions within which such artefacts are produced. In both fan-authored material and industry magazines, there is an understandable focus both on nostalgic reminiscences of the use of such technology and tangible documentation of the respect that users had for Sinclair and his top designers. This is mirrored also in more rigorous histories; while Rodney Dale’s 1985 text the *Sinclair Story* is largely positive and optimistic, written at the height of Sinclair Research by an acquaintance who had shared a building with Sinclair's earlier company. The 1986 book *Sinclair and the Sunshine Technology* by Ian Adamson and Richard Kennedy takes a greater critical distance and begins to look at the wider context of a shift into post-industrialism:

> Well, far from promoting the entrepreneur as a necessary good, the floundering career of Sir Clive Sinclair offers valuable, if not especially encouraging) insights into the dangers of relying on small businessmen to resolve the evils of unemployment and inflation, which are the defining elements of the commercial environment they inhabit and from which they profit. (p. 11)

This chapter looks at the inscription of this transformation on the landscape and both ephemeral and persistent varieties of material culture. The game Manic Miner - produced by Matthew Smith in 1983 - is used as an exemplary artefact; it is the struggle of a character to escape his cave and obtain a luxurious life. The chapter looks at the Sinclair Research headquarters as a further site that can be read to show epochal industrial transitions. The experiences of Timex workers and young programmers are analysed through reverence to archival material.

Following the Light

In the abandoned uranium workings, seals prowl while balancing balls on their snouts. In the Processing Plant, Pacman-like figures appear to work an assembly line. Giant jellyfish move minecarts, and kangaroos appear to manage a vat of molten material. Manic Miner, a simple platformer, is amongst the most famous of the Spectrum games. It includes challenging puzzles, often related to the timing of other characters' movement, and, given the limitations of the medium, a vibrant and imaginative world. Other references to popular culture and videogames are interspersed through the game; fail too many times, and the player is crushed by a boot resembling that of the television serial Monty-Python, while several of the levels feature a King-Kong-like adversary. There is a tacit ecological message, in the game's condemnation of nuclear energy and its inclusion of solar power. The solar power generator is perhaps the most challenging level; it features a beam of light which can be diverted towards the player by circling robots. On the cover of the cassette, the beam of light is shown as being cast by a deity-like figure, or perhaps a philosopher. The final level allows the player to emerge from the underworld, into the garden of a suburban house. This same house was shown on the title screen, accompanied by a limited version of Edvard Grieg's *Hall of the Mountain King*.

Manic Miner was programmed in 1983 and was not therefore directly referencing the infamous Miner's strike of the following year. *Wanted: Monty Mole*, another platformer produced a few years later, is similar in its scope and aesthetics, but does make explicit reference to the strike. The player character is a mole who needs to break into a shuttered mine in order to retrieve coal to deal with the upcoming winter; he has to pass flying pickets and eventually breaks into the 'castle' of the leader of the Miners' union, Arthur Scargill, to retrieve secret ballot papers and a 'vote casting scroll'. Programmed by the son of a mine safety officer, the game takes a fantastic and satirical approach to its portrayal of events; its reference to current events and figures in the news was driven more from the opportunity to get free publicity than the desire to make a serious political or cultural commentary. That said, both *Manic Miner* and *Monty Mole* are both artefacts demonstrating awareness of, and commentary on, economic change and labour conflict. (Lean)

By the time of the strike, Miner Willy had become wealthy from all of his hard work and is pictured on the tape's cover of the game's sequel puking into a toilet, coat tails in disarray; he has joined the 'Jet Set'. As such, while this game is also fictional and comic, it could be seen to function as a psychedelic parody of the aspirational rhetoric of Thatcherism, of the decadent contradictions of post-industrial recession. This is the thesis advanced by Opificio Ciclope in their 2003 film *Spectrum Diamond*. They construct a meaningful anti-documentary exploring the world of Wallasey and Penge where Matthew Smith - teenage author of the games - grew up. They allude to Smith's subsequent disappearance after finishing *Jet Set Willy*, but the object of the film is the affective environment surrounding and influencing the game itself. "This story fills 48k of memory on an extinct computer," announces Theo, the film's teenage Finnish narrator. Though Smith and his fate are mentioned, the filmmakers minimise the authors' role in favour of showing how the games are a product of the economic and cultural conditions of 1970s Liverpool. The producers recount: "We tried to look at England like a multilevel game," (Opificio Ciclope, 2003). They explore reenactments and recreations, perhaps treating this recursive creativity as more important than the game itself.

Adamson and Kennedy pride themselves on the 'deconstruction of a myth', their dedication to neutralising the great person narrative leaves them little room, however, to properly articulate an alternative perspective. Charter (1988) sees their work a product of the same variety of journalistic hype which had exaggerated the Sinclair myth initially. That said, certain innovative methodological fragments provide a basis for this work. The authors write "One of the defining characteristics of fashion is that its manifestations can never be accurately captured by history. Origins, events and consequences can all be recorded, but no retrospective account can communicate the passion and urgency of a social fad," (1986, p. 112) This statement can be taken as a cue to explore the device as a cultural artefact, and further to explore the discussion surrounding the device not merely as a biased source, but rather, following Foucault (2002), as a discourse.

In addition, the authors establish that "the threads of the (...) story that we wish to explore overlap in time and do not lend themselves to simple chronological treatment," (1986, p. 14) Adamson and Kennedy's approach exhibits a degree of methodological symmetry with the *Spectrum Diamond* documentary discussed in the following chapter. Both provide an invitation to not only look at the device within a limited historical period, or as part of a sequential narrative. Instead, the device is discovered and rediscovered in different places, in altered forms, producing and reflecting cultures that are hardly accordant with each other. The challenge is to chart the material residues of such cultures, through both documentation and disappearances

Reenactment and Experimentation

Robin George Collingwood wrote in the early twentieth century and died just as the earliest digital computers began operating. Furthermore, he was first and foremost a theorist, with links to the idealist school of Italian philosophy that prioritised the thinking subject's creation of knowledge over its receipt of experience. The idea of ontology, a philosophical approach looking at how objects came to exist, was irrelevant to him; instead, he chose to focus on metaphysics, looking at the prerequisites for a particular type of thought or existence. Excepting his work on Roman Britain, his work is abstract to the extreme, focusing neither on objects nor people but rather on strains and tendencies of thought. That said, his works should be seen as a critical bridge between the antiquarians like his father's friend John Ruskin, and the systems theorists who would perform similar analytical work in the Second World War.

For Collingwood, a person who thinks the same thought as an individual in the past is thinking not a replicated thought, but the very same thought. This mirroring is essential because in his worldview, thought acts as the driving force of history; it develops into language and culture. For a philosopher generally seen as an idealist, however, prioritising immaterial concepts over material objects, Collingwood has an intriguing secondary interest. While holding an Oxford professorship in Philosophy, he spent his summers excavating the remains of Roman Britain, producing an encyclopaedic work on the subject. In some respects, it was a continuation of his father's work; W.G. Collingwood had been a close friend of artist John Ruskin and curated a museum devoted to his work. In addition, the elder Collingwood wrote extensively about the natural and historical landscapes of England and designed a significant number of memorials to the fallen of the First World War. The younger Collingwood lost many of his friends in the conflict but was not himself assigned to the front; instead, he worked in the Admiralty's code-breaking office employing his linguistic skills towards deciphering enemy communications, setting an important precedent for the work of Turing and others at Bletchley Park in the Second World War.

It could be argued that Collingwood should be seen as an early theorist of information; his work on ideas, far from having no connection to materiality, instead understands the important relationship between concepts and consequences. His work on the reception and reenactment of ideas can be seen in relation to his work as an archaeologist, as he observes carefully how structural and stylistic forms are disseminated over time (Leach, 2012). Alternatively, he can be seen as a codebreaker, considering that in military strategy the inability to understand an opponent's thoughts can have genuine material consequences. We find in the work of V.G. Childe a rough analogue. While Childe is primarily influenced by the historical materialism of Marxism, the notion of dialectical progression towards an advanced culture and economy is an idealist concept derived from Hegelianism. Together, despite their methodological differences, these two thinkers provide the basis for the culture-historical archaeology in the United Kingdom. Previous approaches had seen cultural development in a linear fashion, in that one culture was simply replaced by another. Childe’s work allowed for different cultures to be seen as coexistent, collaborating or competing and affecting one another in a manner that becomes visible in their material culture. Childe’s work would be employed by Processual theories attempting to show that cultures could be understood purely through material objects, such as features and artefacts, and any attempt to understand the perspectives or thought process of the original culture that produced them was superfluous at best, and misleading at worst (Earle and Preucel, 1987). Collingwood, on the other hand, would not be possible for Processualism to recuperate; his thought process is entirely based around the transmission and subsequent reenactment of concepts, though this can be in literature or in material culture.

In his work on ideas, far from having no connection to materiality, instead understands the important relationship between concepts and consequences. We can see his work on the reception and reenactment of ideas in relation to his work as an archaeologist, as he observes carefully how structural and stylistic forms are disseminated over time, and as a codebreaker, considering that in military strategy the inability to understand an opponent’s thoughts can have genuine material consequences. We find in the work of V.G. Childe a rough analogue (Meheux, 2017). While Childe is primarily influenced by the historical materialism of Marxism, the notion of dialectical progression towards an advanced culture and economy is an idealist concept derived from Hegelianism. Together, despite their methodological differences, these two thinkers provide the basis for the culture-historical archaeology in the United Kingdom. Previous approaches had seen cultural development in a linear fashion, in that one culture was simply replaced by another. Childe’s work allowed for different cultures to be seen as coexistent, collaborating or competing and affecting one another in a manner that becomes visible in their material culture. Childe’s work would be employed by processual theories attempting to show that cultures could be understood purely through material objects, such as features and artefacts, and any attempt to understand the perspectives or thought process of the original culture that produced them was superfluous at best, and misleading at worst. Collingwood, on the other hand, would not be possible for processualism to recuperate; his thought process is entirely based around the transmission and subsequent reenactment of concepts, though this can be in literature or in material culture.

Collingwood’s work, therefore, becomes essential as we address the question of intention with regard to cultural artefacts. Is it possible to know what the creators of a specific device, tool or decoration were thinking as they made it? Does intentionality have an impact on the way in which certain objects are produced, valued, and subsequently discarded? Further, in certain cases, we see the reproduction of artefacts, either from an antecedent moment in a culture's development, or from a geographically or temporally proximate culture. Without knowing the motivations of those responsible for the design, dissemination and deployment of the device, it is difficult to know what the motivation for the replica is. We can tell whether the same production processes and materials have been used, but not whether the purpose is parody or plagiarism. Different objects become popular within certain economic environments and social contexts, spreading across cultural boundaries and continents.

Collingwood's notion that ideas can be disseminated through language, before being reconstructed in another's mind, can also be applied to material culture. Collingwood's father, William Gershold Collingwood, was an art historian who acted as an assistant to John Ruskin. In Ruskin's work, arguably influential on his assistant's son, we find the argument that the study of a structure, object or feature can give us an insight into the mentality of its creators. Though Collingwood's work appears subjective and idealist, it can actually serve as an antidote to another form of idealism. For Collingwood, memory is suspect; oral histories and narratives recorded later also involve a form of reconstruction in the mind of the individual recounting them. Our ability to selectively remember ideas and events, to attribute intentionality and agency where none existed, means that informants are suspect. An object or document can sometimes be a more reliable source for understanding the intent of its author than the author themselves. Collingwood's work, therefore, becomes essential as we address the question of intention with regard to cultural artefacts. Is it possible to know what the creators of a specific device, tool or decoration were thinking as they made it? Does intentionality have an impact on the way in which certain objects are produced, valued, and subsequently discarded? Further, in certain cases, we see the reproduction of artefacts, either from an antecedent moment in a culture's development, or from a geographically or temporally proximate culture. Without knowing the motivations of those responsible for the design, dissemination and deployment of the device, it is difficult to know what the motivation for the replica is. We can tell whether the same production processes and materials have been used, but not whether the purpose is parody or plagiarism. Different objects become popular within certain economic environments and social contexts, spreading across cultural boundaries and continents.

In his *Essay on Metaphysics*, Collingwood establishes three concepts of cause (2002, p. 285-6). A first form involves intentional action on the part of a conscious entity to bring something about: an agent might tell a joke, causing somebody to laugh. A second relates to mechanical cause: an insecure foundation might directly cause a building to collapse. The third form of causality relates to systems and consequences: an action might lead to a situation in which an event is unavoidable. Collingwood's trifurcated conception of cause explains his awkward positioning in relation to both philosophy and history. While physical and social events are relatively easy to catalogue and provide the basis for the first forms of historical chronicle, they provide an insufficient basis for constructing a coherent narrative. As such, historical scholars choose to either focus on individual motivations in relation to larger historical events, or the relationship between an event and the environmental, economic or systemic context in which it originated.

Philosophical thought is similarly bifurcated in terms of experience. Rationalism holds that our knowledge comes first and foremost from our capacity to reason, and only secondarily from the external world. Empiricism holds that sensory experience is our key means of knowing the world, whereas our capacity to process it is necessarily suspect. Similarly, philosophical Realism holds that our knowledge of objects has no bearing upon their existence, whereas Idealism holds that they are necessarily affected by this process of discovery. Collingwood rejected Realism within the sense it was popularly formulated yet was also not a partisan of idealism. Collingwood effectively moved away from the easy middle ground in an attempt to reconcile an understanding of individual experience with that of abstract structural mechanics.

The basic events are perhaps the easiest thing for a historian to get right, with motivational causes and structures being more difficult. Effectively, the two more normative forms of history, involving personal perceptions and contributions to world events, or attempts to understand world events as part of systemic transformations. Failing a complete understanding, this leaves an approach which foregoes real events in favour of looking at how individuals experience or contribute to systemic changes. In the Idea of History, Collingwood picks up on this, stressing the importance of systematic perception in allowing for judgement and successful action: “For a man about to act, the situation is his master, his oracle, his god. Whether his action is to prove successful or not depends on whether he grasps the situation rightly or not,” (Idea of History, p. 316).

Douglas Mann similarly sees a duality in Collingwood, a passage between ‘methodological individualism’ and a ‘theory of social structure’’. Mann sums up Collingwood’s methodological individualism as such: "if you want to know why a historical event took place, try to figure out what the historical actors were thinking at that time.” (100) Mann attempts to reconcile this individual approach with structuralism and frameworks developed from it, notably structuralism and post-structuralism. Collingwood's focus on the 'situation' and its power to compel a certain type of action is seen by Mann as a form of proto-structuralism (p. 118-119). Mann also recovers another duality, that of inside and outside in the event: “The outside of a historical events is bodies and movements, while the inside of the event is thought,” (p. 102). This allows for both networked approach to agency, and a phenomenological approach. Reenactment is a term used by Mann to describe Collingwood’s approach, and this term also captures the profound relation to both speculation and fantasy. Since we are no longer at specific events as our focus, fictional situations with both present structural transformations and representations of how individuals might respond to those situations are critical historical texts. There is a natural relationship with art, literature and cinema since these forms will more often attempt to bridge the gulf between individual and structural experience.

Though Collingwood was nominally opposed to philosophical realism, Nancy Streuver has alleged a relationship with social realism, a primarily aesthetic movement that is found which recognises reality in the identification and depiction of social relationships. In Streuver’s view of Social realism, “the reality that is both topic and context of an investigative action is social action”, “...the only evidence we have for this thesis is linguistic and semiotic evidence of exchange, of communicative activity [...] the use of evidence reconstructs community acts and social processes“(Streuver 1987, p. 81). Streuver assertions effectively imply that in both Collingwood and in Social Realism, all historical evidence should be treated as discursive, as part of a specific set of social encounters through language. Social Realism effectively suggests a 'short-cut' from an agent to a wider social context. In American depression-era photographs, post-revolutionary Mexican murals, and British new-wave cinema, characters are depicted at the periphery or outside of major events, but within the overarching structural systems guiding them.

Collingwood has recently been rediscovered by media archaeology, and his work provides an entrypoint to what is being called ‘Experimental Media Archaeology’. Two of its proponents, Andreas Fickers and Annie van den Oever “plead for a hands-on, ears-on, or an integral sensual approach towards media technologies,” (2012, p. 273). They insist on “turning museums and archives into laboratories for experimental research” (2012, p. 276) and further propose “media archaeology experiments in which the focus of attention is, apart from the technical devices themselves, the place where these devices are appropriated and used, as well as the social constellation in which this occurs,” (van den Oever and Fickers, 2019, p. 56). While the renewed interest in techniques (Catanese et al., 2015, Van der Heijden, 2015) and sites (Parikka, 2015) is encouraging, experimentation in media archaeology should also extend to analysis of sites of industrial and cultural or ideological production.

Collingwood was famously rehabilitated by Ian Hodder in the late 1980s; while Hodder's recent work has criticised his own rehabilitation, the engagement with Collingwood within the space of interpretive archaeology nonetheless contributed to post-processual methods. Hodder asserts that "the procedure to be followed is first to immerse oneself in the contextual data, re-enacting past thought through your own knowledge. But(...) this is a practical living through, not an abstract spectacle to be watched," (Hodder 2003, p. 147). Since any interpretation can be rendered invalid, it is about producing 'coherence' in our narrative of events. This chapter therefore begin underground, charting passages into the factories and dormitories of a postindustrial age. It allows for reenactment both through traversal of territory and through archival exploration. Looking at the production of ideologies, ephemeral and persistent forms of material culture, makes possible the reconstruction of complex and highly technical systems of labour.

The Fountain of Youth

A spring gushes from beneath the soil of Anglia[13]. At 12 degrees centigrade, the water is chilled below room temperature. Its location, midway between two geological formations each around a hundred million years old, means that the water is filtered through rock, adding minerals, while the relative depth of the spring - thirty-two feet - means that the water source is free from surface contaminants. The top layers of this rock were worn away in the past three million years, as an older variant of what is now the river Cam took a more easterly course, and deposited silt and clay in place of the harder rock. The ground now is hard sand and gravel, meaning that the ground is harder than a lot of the region's surrounding marshland, but not impossible to dig through. On it we find a futuristic structure of symbolic and practical importance to this research project. Made of glass and brick, the building's architecture coincidentally echoes its geographic location, even its materials come from elsewhere. The curved surfaces and large naturally illuminated atrium invoke the fluidity and transparency of water.

[13] This section comes as a result of engagement with community groups in Cambridge, including the community at the Madingley Hall Institute for Continuing Education, the Cambridge Archaeology Field Group, the Mill Road History project and the Cambridge Museum of Technology.Joe Mckintyre was particularly influential in helping me develop a knowledge of the University buildings.

Water has often determined where cities were built; a fortification was built on a mountain near this river in the Iron Age, growing to a small settlement during the time of the Roman occupation of Britain. This city was abandoned, but the site of the fortification later became a castle following the Norman conquest of England. (Roach, 1959, vol. 3, pp. 2-15) The site would continue to be used for military purposes until the English Civil War, when it was intentionally sabotaged by its occupiers; parts of the castle were then used as a jail, with a more modern, panoptic prison being built in the 19th Century. In the twentieth century, the hill has a dual purpose - it serves as a scheduled historic site, accessible to visitors. Yet next to the hill is the Shire, the Cambridgeshire County headquarters, which however unintentionally uses the hills symbolic power to reinforce its authority over Cambridge and the surrounding region. (pp. 116-123) The urban geography of Cambridge resulted in its particular character; the colleges, built along the river, were isolated from the growing town proper, protecting them from the plagues which decimated the densely populated town in the Medieval period and early Renaissance. Cambridge became an academic centre centred around the colleges on the Western side of the town, with the east of the city remaining relatively underdeveloped until the 19th Century. (pp. 150 -166) The town never held entirely true to its image as an isolated retreat for scholars, as it has served commercial purposes and facilitated agricultural development since far before the development of the university colleges. (pp. 76 - 86) Following several failed efforts to extend the Stort Navigation towards Cambridge providing access to the canal infrastructure in the 18th Century, it was only in the 19th Century that Cambridge began to develop its industrial capacity, with the arrival of the railroad in 1845 being a key catalyst. Prolonged settlement and construction fixed the course of the river, causing it to silt up and slowly inhibiting river traffic. The arrival of the railroad on the eastern side of the city caused a second focal point rivalling the river; prevented by the University by building a station in the Centre or Western parts of the city, a number of depots and stations were constructed on the eastern side of the city. Industrial labourers were housed in terraces, with craftspeople occupying nicer quality houses with front gardens, and factory owners constructing large properties on prominent streets.

The water supply needed for the growing population could not be drawn directly from the river, and the high population density made well water an unsafe proposition - this would be particularly true in the 19th century, when global trade networks brought the Cholera bacterium to Europe. (pp. 101 - 198) Public houses, distributing ale brought from regional breweries, and coffee houses, selling water which had been boiled, both became incredibly important to the culture and prosperity of Cambridge. In the late 19th Century, a growing temperance movement and a new process for the mass production of glass bottles supported the growth of a new industry. Barker, who had begun bottling mineral water in the basement of the local Baptist chapel on East Road, soon made enough profits to construct a new factory a little to the East, on previously unoccupied agricultural land. Alongside a large factory building, built in 1896, were constructed a number of houses for workers on Collier Road and Willis Road. The following year, a stable block was built across from the main factory building, to be used for the horses that would deliver the water to the city and to the nearby railway station for wider distribution. At this point, a beam engine was also brought in, cast in the steel foundry in the location of what is now the Mill Road Depot; this engine would use steam power to automate the pumping of water from the spring below. In 1906, an office block was built for administrative functions, along with more modern toilets. Along with several other mineral water bottling plants in Cambridge, Barker's facility would provide drinking material for the industrialising Southeast. Advancements in mass production techniques and distribution networks meant that Cambridge could not support a half dozen bottling plants; Baker's competitors started going bust in the 1920's, and by 1948 the company was forced to merge with long-standing rivals Wardsworths. In 1960 this new company went bust, with the equipment being sold to the final, longstanding competitor; Baldrys in what is now the Grafton Centre. The Beam Engine, now a piece of industrial heritage, was used for demonstration purposes at the Cambridge College of Art and Technology, before finally ending up in the Cambridge Museum of Technology.

A similar progression is traced by Christiane Finn in Silicon Valley, the most famous cradle of microtechnology, which notes the presence of aquifers in the former Santa Clara valley and the ease by which the area made the transition from an economy of 'Orchards to Apples':

> Traces of past and future past, which await the context of narratives. The change is just discernible, as lateral movement that transforms orchards into apartments, pumpkin fields into high energy fields, stables and stores into storehouses of ideas and warehouses of hardware; a feast of electrons, where baskets once over-spilled with apples and apricots. (2002, p. 7)

Elsewhere, Finn notes the presence of resorts and bottling facilities around Saratoga, California, which have their own material detritus: "water bottles are highly prized. The former resort area, where locals would dig for bottles, is now inaccessible, fenced off by a water company," (p. 25). While it is possible to see the shared water bottling heritage in Cambridge and Silicon Valley as purely coincidental, it is also possible to analyse the way in which the requirements of high-tech and bottling industries are similar. Both require large amounts of flexible but trainable labour, large amounts of space, and established infrastructure for widespread distribution. On a more conceptual level, both industries have a fascination with cleanliness - bottling because mineral water is marketed as more wholesome and purer than other beverage products, and microtechnology because of ts need for ‘clean rooms’ to prevent imperfections during chip fabrication. In Ann Lee Saxenians’s earlier *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, she speaks of the significant difference between the business cultures on opposite sides of the United States - Massachusetts’ Route 128, where the technology industry drew heavily upon the already established defence industry - and Silicon Valley, where the new plants resulted from a conversion of what was for the most part arable land. Saxenian writes that “Managers (...) commented on the openness and fluidity of the business environment, which includes not only the mobility of people but even the impermanence of physical structures,” (p. 54). The development of Silicon Valley and general cybernetic culture draws - according to Frank Turner - from the counterculture of the 1960s, particularly strong in San Francisco, but also from the presence of Stanford University, a more experimental institution facilitating new forms of research.

Michael Shanks similarly reflects on the same environment in his introduction to a text on the Archaeological Imagination. Shanks reflects that: "(t)he Valley itself has changed enormously in the last forty years, most of the groves of fruit trees gone in urban development that stretches fifty miles and more (...)" (2016, p. 28). One the one hand, Silicon Valley appears to be a poor place for archaeology: "information and communications technology companies, with their aggressively entrepreneurial startup culture, could hardly be more future-oriented," (p. 28). Venture capital, patents, research and development; all imply a fascination with the emergent world. At the same time, "articulation of radical development and change with an attention to local history is commonplace," (p. 29). The increased rate of change requires a counterbalance and rooting, a renewed interest in nostalgia, relics and replicas; Shanks suggests 'we are all archaeologists today' (p. 42). At the same time, Shanks notes that the archaeological mindset most prevalent is not the scientific approach developed in the 20th century, but a variant based on earlier, romantic 'antiquarianism' (p. 42).

The former Barkers’ factory site was then used by Moore and Beeson, a typewriter manufacturer and distribution centre, who used the facility as an administrative centre and showroom. Little information is available about this period of usage, but it prefigures its future function as Sinclair’s second major headquarters. The first had been occupied for the last years of Sinclair’s time at his previous company, radio and calculator manufacturer Sinclair Radionics. Originally started in the 1960’s, Sinclair’s first company had had a number of successful products and had also received substantial government investment. Their Saint Ives property, a former mill on the river Ouse occupied by Sinclair Radionics from 1970 had been large enough to accommodate administrative, sales, research and, from 1976, a large amount of the assembly work as well. Large open plan work areas and offices worked with the futuristic product designs and streamlined logos to create the image of a future-oriented company. The facility, simply referred to as 'the Mill', had been originally constructed in 1854, designed by miller Potto Brown based on those he had seen in Northern France.

> Overlooking the river is a door per floor through which material would have been transferred to and from barges; overlooking the railway (long since gone, through the stanchions which bore its bridge still stand in the river) is another stack of doors through which material would have been transferred to and from a private siding (Dale, p. 33)

Mills such as these had provided the power required for the industrial revolution; this particular mill was used to produce flour from grain, but others were used to spin cotton. The building was no longer used in this way from the beginning of the twentieth century; it was sold to Enderby and Co, a printing company specialising in labels for jam and other products. For three years from 1965, the building was derelict, before being acquired for AIM (Advanced Instrumentation Modules) in 1968. AIM, a company that was closely connected with Sinclair through Cambridge Consultants, realised it could not use most of the space, arranging for Sinclair's first company to take over most of the facility. The service department, initially the most pressed for space, moved into the building first, with the rest of the departments following within a few months. Sinclair was able to be found for the next decades in a large, well-lit office on the top floor. As the BBC's cinematic rendition of the period suggests, however, this design failed to serve to hide disputes with junior staff or government-appointed managers. Dale: "The great silver door of Sinclair's office was often closed; voices were often raised in acrimony." (84) Sinclair's contingency plan - ultimately necessary when he lost control of the company to the National Enterprise Board - was a small startup based in anonymous offices in central Cambridge, Science of Cambridge (Dale, p. 122). In the film the contrast between the large, industrial facility and the cramped offices for the new company implies a return to square one (Micro Men).

Sinclair Research moved into the Willis Road property in 1984, after a reconstruction managed by Cambridge architects Lyster, Grillet and Harding. Planning documents suggest that the company had initially intended to use the facility several years earlier; an application for a change of use was applied for on behalf of the company by the architects in November of 1981. Design and planning for the new facility was therefore ongoing as the Spectrum was developed and released; the mass-produced platform and the structures used by its designers should be seen as capable of influencing one another. Sinclair apparently showed some enthusiasm for the potential of using the building's heritage and may have been involved in the design of the heating and cooling system, which used the heating capabilities of the glass-covered atrium, and the cooling capabilities of the natural well. A microprocessor was employed in the system to switch between this sustainable system and a more conventional heating/cooling system; this circuitry also apparently controlled the lights (Dale, p. 115). An archived website explains the functioning of the environmental conditioning:

> The system extracted hot air from the large atrium (and also a sun trap in the roof of (Sinclair's) old office, now room 41) and stored heat in a large tank of water in the basement. The tank could also be heated by cheap-rate electricity. Heat could also be pumped down one of the bore holes to the aquifer, with cool water returning up the other (original) bore-hole. (Anglia Polytechnic University, p. 21)

The novel system was experimental, and therefore not entirely reliable. It was also not easy to make structural changes within the building without disrupting its finely tuned mechanics. Dale suggests that "it did take some time for the occupants to come to terms with the finer points of the heating and ventilating automation, for such systems usually [throw] a wobbly when unforeseen partitions are put up. Like any other hi-tech building, Sinclair Research at Willis Road is now well supplied with auxiliary fans for summer and heaters for the winter," (p. 115). The supposedly environmentally conscious system was ironically removed due to environmental regulations after Sinclair Research left the building; it was no longer possible to use or extract drinking water from the ground without complicated, expensive permissions. It was also not clear whether the temperature regulation machinery was actually working, and it was difficult to maintain, given that the original designers were no longer using the building.

David Thomas speaks of a contrast between Sinclair Research and Amstrad, the company that would eventually acquire its computing division. Whereas Sinclar Research had offices that were a "monument to high tech taste," (p. 192) Amstrad's corporate aesthetic, reflected in their interior design, was far less assuming:

> lack of pretension was a feature of the Brentwood headquarters. (...) Amstrad's products were arranged haphazardly on the shelves in the company's boardroom. Smudged fingerprints competed for attention with sales and production charts on the bare white walls of the offices. Foam rubber pokes through the seams of the chairs in a conference room… (p. 238-239)

Dale's description of the Sinclair Research building in its heyday seems to adequately sum up the difference:

> The main L-shaped building had been restored to its original appearance and now contained offices and research laboratories. The former outhouses had been completely remodelled as a general office area with the exterior clad entirely in stainless steel. The

yard between the building and the outhouses was transformed into an enclosed atrium and featured a 'fine bronze sculpture' by Helaine Blumenfield. Even the bicycle shed was fine art. (Dale Sinclair Story, p. 114)

In Tedeschi's *Sinclair Archeology* (1994), a self-published document retelling the history of the inventor's companies, the Sinclair Research headquarters is reproduced in a rough, pixelated print, appearing elusive or dream-like. Yet this building still exists, its shell serving as Anglia Ruskin University's centre of academic computing. As such, it was possible to explore the site as well as the artefacts associated with it. A small museum display, almost shrine-like, exists in the corner of the building, like a monument to a future past. An informatics engineer was kind enough to provide an introduction to the building, discussing both the mechanics of its modern infrastructures and the artefacts and features of its past: while the building was mostly empty when the University took possession, its configuration gave clues as to the way it was used. Initially, plate glass gates with the Sinclair logo on them had marked the entrance to the parking lot; these were retained by the College, but eventually replaced after a truck backed into them. A security desk was set up at the front of the facility, and the return desk would have been at the back of the atrium. In the centre was the rail-less, futuristic spiral staircase to Sinclair's office; the flooring was a yellowish patterned parquet. Along the balcony of the smaller stables building were multiple telephone fittings, suggesting this part of the facility was used for sales, returns and/or customer support. This balcony is now sealed but was originally open; the visitor with a complaint or technical issue would have walked through an imposing space, with the sound of multiple calls reverberating through the atrium. The openness and bright ambience of the facility recalls the open layouts of high-tech offices in Silicon Valley, but also those of contemporary stores for consumer technology, such as the globally recognisable Apple store. A visitor described their experience of visiting the building more recently:

> Inside the building has large atrium with offices on one side and a single staircase in the centre of the atrium leading to offices on several floors. It was a delight to be able to walk up and down these stairs, onto the fire escape at the top of the building and to peer into the modern-day offices on each floor. The top floor was used as the design office between 1982 - 1985 and it was easy to conceive of the QL, Spectrum + and possibly even the 48K Spectrum itself being designed in this room. Although in use today for administration purposes, the university has kept the Sinclair building largely as it was in 1985 so the top floor still looks very much like a design office. (Atkinson, 2012)

Following the purchase and effective liquidation of the computer component of Sinclair Research, the building was given to the Cambridgeshire College for Arts and Technology - which would later merge into a Polytechnic University - by the local government. While parts of the building were preserved, other elements were adapted to allow for teaching and, ultimately, for the inclusion of contemporary technology, including a climate-controlled server room and a connection to the national academic optical fibre infrastructure. Joe McIntyre, a veteran Anglia Ruskin IT technician, has produced a small glass display with items from the building’s past use, including Sinclair Research computers but also empty water bottles. Having used the building for three decades, he has seen it transform; he recalls finding a number of blank tapes, a sketch of a futuristic display using the Sinclair branding.

Labour and the Archive

An advertisement for the '+' model of the Spectrum - featuring similar specifications but a more robust, plastic keyboard with additional keys, shows original ZX Spectrum devices being assembled. The assembly line is completely automated, and a robotic arm diverts certain models to a side belt, where they are moved into what appears to be some kind of oven. There, a three-dimensional wireframe model of the original Spectrum appears; this is then transformed into the newer model in an animated sequence. While visually impressive and evocative of a high-tech economy, the advertisement is misleading. As this section will show, the assembly of the machine still required a great deal of physical labour, which is completely erased in this advertisement. Similarly, design was still very much an analogue process. The physical design of the device was handled largely by a single individual, using traditional drafting techniques and pencil sketches.

Originally hired as an intern at Sinclair Radionics, Rick Dickinson was called back to replace his former boss John Pemberton (Dickinson, 2011). Dickinson assisted with the completion of the ZX80, before beginning with the design of the ZX81 a few months later (Cooke 1982). There was no hard and fast delineation between industrial design and engineering, and design staff were also responsible for overseeing production. Dickinson reflects in an interview:

> People just think you are a stylist and your work is this gratuitous thing that is applied to a product after the engineers have done the rest. But the industrial designer has his nose into everything because he has to know everything that is going on, certainly at a conceptual level, and then later on in quite a high level of detail. (Dickinson, 2011)

For the ZX81, Sinclair Research originally looked at making the device out of metal - following a tradition that was popular in the increasingly dominant Japanese electronics manufacturing industry - but the manufacturing capabilities did not exist to a sufficient standard in the UK. To learn injection moulding, the technique used for the ZX81 and ZX Spectrum, Dickinson investigated a TV1B, a portable television produced by Sinclair's previous company, Sinclair Radionics (2011). Despite the attachment to and fascination with contemporary computer technology when advertising the project, a great part of the design work was done using traditional methods - sketching and exploration of previous material culture. Dickinson has released substantial archives of further drawings, both at prototypical and purely conceptual stages. These archives allow for a speculative archaeology, following Zielinski.

Sinclair ZX Spectrums, like previous Sinclair computers and calculators, were not assembled in Cambridge, as despite the sleek industrial futurism of its headquarters, the company had no production facilities of its own. Sinclair's previous company, Sinclair Radionics, had started by offering 'kits' for hobbyists to produce their own transistor radios. The first Sinclair computer, the MK-14, was only available in kit form, and the subsequent computers, the ZX-80 and the ZX-81, were cheaper when purchased that way. The Spectrum, however, was designed to breach the mass-market, meaning that it would be sold assembled, eventually through high street stores. Assembly would require semi-skilled technicians, and so a partnership was undertaken with the American Timex corporation, initially a watch manufacturer, contracting Timex's watchmaking plant in Scotland to produce Spectrums while allowing the design to be adapted for an authorised American equivalent, the Timex Sinclair 2068. Timex had originally planned to manufacture portable televisions for Sinclair, but these proved to be unpopular. In one respect, the Sinclair contract was a welcome relief, since it helped assuage the damage done to Timex's business by a significant fall in the demand for mechanical watches. On the other hand, however, it failed to mitigate the general decline in the fortunes of the company, leading Timex to close two factories and lay off up to 1900 people. Timex workers struck between November 10th and November 18th, 1982 (PCW, 1982) and threatened to strike again in January 1983, receiving national news attention.

The disconnectedness of Sinclair Research from any aspect of its material production chain meant that Clive Sinclair could issue ultimatums, threatening to move production to 'other factories' if industrial action took place (Hetherington 1983a,b). Interviewed by *The Guardian*, Sinclair announced: "If the threat of strike action is not removed in further discussions between management and unions, and a full strike appears inevitable which would affect our production, we will remove our business elsewhere, probably permanently," (Hetherington 1983c). Without any history or attachment to material resources, Sinclair could afford to bluff about the ineffectiveness of labour action. Labour issues are not referenced; instead, reference is made to technical problems and 'distribution' issues (Sinclair User, p. 5, 20). There is evidence, however, that the delays in production caused by industrial action were causing conceivable aggravation to customers who had, in many cases, exceeded the expected waiting time for their computer many times over. In their October 1982 issue, the magazine *Sinclair User* claimed they had "been flooded with telephone calls and letters from people expressing their dissatisfaction with the way they have been treated." If the company were not able to take advance payment for the machines, the poor production and supply chain would have crippled the company already; (Sinclair User, p. 5, 20) as it stood, the lack of faith caused by another disruption would have doomed the company. Another consumer source suggests there may have been other, more raw forms by which workers were already showing their discontent: "Unlike the rest of the country I am one of the lucky ones who live in Dundee where the Spectrum was manufactured by Timex. That meant we were all able to get them for a tenner and a pack of fags 'round the back door of the plant. I personally had six…" (Chris van der Kuyl, quoted in Arthur, 2012).

In April, workers at a plant in Milton, East Dundee, staged a sit-in against plans to shut their factory and move production to France. While Margaret Thatcher would be known later for her brutal and public condemnation of striking miners the next year, it is perhaps interesting to note that in this case her intervention consisted of a secret plea for the management to back down and ensure that more jobs were created in the city (Devlin, 2013). Thatcher's intervention is puzzling; these workers were a different demographic to the miners - largely female, part of the coveted high-tech sector, but they were also heavily unionised (Ross, 2013). More likely, it seems that Thatcher may have been concerned about the upcoming General Election, considering that unemployment had reached three million and the recession continued (Devlin, 2013). In effect, the intervention was useless, since Thatcher was unwilling to match or even contemplate the subsidies for industrial production offered at the time by France. The six-week occupation, on the other hand, appears successful in allowing the workers at that factory to hold their jobs for another decade. Sinclair's threat to move production in the event of a strike never materialised, though the company did assemble an alternate production chain and begin secondary production elsewhere, including at Timex facilities in Portugal (Sinclair User, 1983). When Sinclair Research was purchased by Amstrad, the company was clear in its intentions to manufacture machines in East Asia. Paradoxically, the late 1980s may have seen production outsourced *from* Portugal. In 1993, however, the Timex factories would see one of the most protracted labour conflicts of that decade, which would ultimately end with the termination of electronics production in Dundee.

Both strikes are catalogued in a meticulous archive held at the University of Dundee. The archive was compiled by George Mason, an employee of Timex during both strikes, and an active member of the union (Mason, 2006). In addition to the archive, Mason curated an exhibition on the strikes and the media collected from them in the university's Lamb Gallery in 2006. In curating the exhibition, Mason hoped to draw parallels between struggles for workers' rights in the present and those happening decades before, but also underline the 'erosion of the country's manufacturing base'. Mason's archive is intensely personal, including two decades of correspondence, but also includes a letter detailing the perspective of Fred Olson, the chairman of Timex during the Strikes. In addition, Mason includes material from 'On the Line', a musical performed at the Dundee Repertory Theatre Company in 1996 and a poster for the Timex Strike Committee's Grand Carnival Day'. Mason recounts: "some of the picket line events were a bit hairy, but some were also joyful. My kids were on there most days - I wouldn't have taken them if it was really as violent as it was portrayed." Also included are Karl Wagener's watercolours - in print form or in their original - of the picket line scenes (MS272/5). Wagener's work appears to mostly revolve around painting strike scenes, with the careful and conservative impressionist style contrasting strikingly with the often-hectic events. Waegner's careful illustrations mirror Mason's comprehensive approach to documentation - both actions attaching cultural significance to events even as they were unfolding. Mason's curatorial work was done alongside a janitorial position at the University, and an activist role in a new union. Outside the formal realm of contemporary art, which prioritises curatorial practice, personal narratives, research and sociocultural commentary, it nonetheless excels as an example of it.

A more recent project to unearth the labour history of Dundee is that undertaken by Mona Bozdog as part of her Generation ZX(X) project (Morkis, 2018). A multimedia performance work, Bozdog's project sought to allow women who had worked at Timex to recount their story. The project involved a 'scavenger hunt' around Dundee's Camperdown Park, where participants uncover video narratives, and culminated in an event at the former Timex factory, which is now a furniture manufacturer. Bozdog notes that "when you walk to the former Timex Camperdown building there is nothing at all that attests that this legendary computer which marked the beginning of the UK's home computers scene was made there. And it was made by these incredible, hard-working women, most of whom never realised what an impact they have made on Dundee's video games development and education scene," (Abertay, 2018). In addition to the video narratives, the project included games made by current game design students at Abertay University and video interviews with significant figures in the UK games industry. One review argues that "in Dundee, the easy availability (of) Spectrums - and let's not ask too many questions about that here - led to the creation of games like Lemmings, Grand Theft Auto and Crackdown and the birth of a new industry for the city - and Abertay's pioneering video game courses," (*The Courier,* 2018).

While the development of home computers failed to prevent the industrial decline of Dundee, it may have helped to sustain local manufacturing for up to a decade. Critically, the presence of technical manufacturing allowed residents to become more familiar with developing technologies and allowed the city to establish itself as a so-called 'tech hub'. Ironically, after moving production of the Sinclair line overseas in the 1980s, Alan Sugar's Amstrad would return some production to nearby Fife, to a plant owned by the NEC Corporation, in the late 1990s. Abertay University organised some of the first degree courses in Game Design around the same time and more recently has become a crucial centre for information security research. The design sector of the city has benefited from the association with gaming, leading the city to be named a UNESCO city of design in 2014. The opening of a branch of the Victoria and Albert Museum, a leading design museum originally in London, provided a space for further cultural development; one of the first exhibitions to be held in the new space would be *Design/Play/Disrupt*, the institution's exploration of contemporary videogames (2019).

Following the purchase of the computer section of Sinclair Research by Alan Sugar's Amstrad, machines would be produced in Hong Kong and later Taiwan. Upon the purchase of the company, Sugar would defend the decision to outsource production: "we would like to manufacture in the United Kingdom, but we're a computer company, not a benevolent society," (Burden, 2010). It appears domestic production was never seriously considered; Amstrad's buyout was initiated following a meeting with some of Sinclair's distributors in Hong Kong, who feared they would lose their supply if the company went bankrupt. Alan Sugar recounts sending an employee to buy and disassemble a Spectrum and transmit a list of components over the phone to the Hong Kong office. These were then assembled into a new design by a local engineer, before being passed on to a Taiwanese equipment manufacturer to produce.

Tooling cost money: to produce the machinery needed to manufacture100,000 machines for Christmas would require immediate investment, but no agreement had been made with Sinclair. According to Sugar's memoirs, he instructed the tooling to go ahead - at a cost of £100,000 - before discussions had even been initiated. Sugar recounts later stages of the meetings being held at Sinclair's house and other locations outside of the main facility. At one point, a meeting is held with a strict deadline; Sugar announces he will be leaving to fly to Florida at a certain point. Sinclair, effectively forced into selling by its creditors, acts to defend the workers in Welsh and Scottish factories or - seen more cynically - their bosses. An agreement is made to purchase the existing machines in production at cost, but the majority of the agreement deals with merely the Sinclair brand and intellectual property rights - not the design facilities or existing infrastructure. Sugar recounts being only interested in the legal rights to the ULA and its configuration, and to the ROM, though he appears to conflate the two:

> Part of the deal was that Sinclair had to deliver us proof that they owned the source code in the main heart of the chip, which, incidentally, was made by Ferranti. We needed an irrevocable letter from Ferranti saying that they would continue to supply us the chip and would accept that we were now the owner of the intellectual property rights. (n.p.)

When it is discovered the rights are still held by an unnamed individual Sinclair refers to only as a 'hippie', functionaries are dispatched to track him down. Since he refused to cut his fishing holiday short, a lawyer is dispatched in a cab to physically find the rights holder, delivering him a check in exchange for his signature. Amstrad would produce a version of the Sinclair 128 - effectively a clone, using some features of the Investronica clone[14] and some elements taken from their own range of computers. The designer of the original ROM - the hippie referred to by Sugar - would move on to further research on network infrastructure. In 2019, his working prototype of the ZX Spectrum would be donated to the Centre for Computing History in Cambridge.

Bedrooms as Factories

The disappearance of Matthew Smith is one of the most tangible examples of Spectrum 'lore', but it also provides a means for talking about the difficult working conditions facing 'bedroom coders' of the 80s. In the absence of organised software production firms, coders worked precariously, selling material to publishers or setting up small, unstable development firms. Certainly, the payoffs were significant for those that managed to produce successful games, but the amount of initial outlay in terms of time, in regard to learning to code, and capital, in terms of purchasing equipment, were high. Smith recounts hanging out at a Tandy store, which used the kids flocking to use the trial machines in lieu of trained technical consultants: "we'd often pick up light work doing software for businesses who were buying machines there," (Drury, 2005).

Software Projects, his employer at his most successful point, is highlighted as having a paradoxical approach to employee discipline. While they allow a playful atmosphere and give employees keys to the building, they expected the programmers to commit their entire life to their projects and work in an area called the 'zoo', a cramped, upstairs lab that programmers are effectively locked into. The article relates:

> Some people never leave the zoo. Stuart Fotherington, a punkish leather'n'studs programmer, has not been home for days. "They know their job's on the line," says Alan (Merton, director of Software Projects). "People see everybody wandering around and think, they're idle. But as long as they produce a program, we don't care how they do it. Some of them sleep here. Come on, Stuart, when did you last go home?"
> Stuart considers. "Saturday," he says, uncertainly. Today is Tuesday. "They've all got keys," says Alan.
> "I haven't got a key," says Matthew. (Bourne, 1984, pp. 89-90)

Bob Pape, who got his start in coding after producing a 'clone' version of *Manic Miner*, recounts his experiences with precarious software houses in the 1980s. After sending his

[14] As referenced in Chapter 4.

version to a company called Dreammaker, he is offered a job on the spot and invited to come out to Neath, a town near Swansea. The reasoning for this non-metropolitan choice of location is explained later:

> Businesses that set up in these areas could look forward to subsidised payrolls and help with start-up costs or other bonuses in an attempt to kickstart the local economy(,) but really it was just an excuse for cheap labour. (Pape, p. 26)

The owner of the company later appeared to have set up similar fronts in other municipalities with similar programs, including Swansea and Glasgow; all were producing software that would be sent forward by Catalyst, run by the more experienced Dave Wainwright, to the larger and still existent publisher Activision. A feud with the neighbouring taxi company caused them to have to move location; a new location became a residence for some of the Southsea-based Catalyst coders and lead to them being evicted. Pape then worked from home until being given orders to go to Activision in Southampton; once there, he worked flat out until the game - an adaptation of the arcade King-Kong simulator Rampage - was finished.

For his next project, Pape and his remaining co-workers tried to negotiate a higher price, but this turned out to be only a fraction of what his employer was getting from Activision:

> It wasn't as if I could call up somebody and ask them what I should be getting paid, and as a first-timer I did rather take the approach that I should be grateful for actually getting paid to write a game and not worry too much about the amount. (Pape, p. 28)

They also were able to establish some autonomy, renting their own (livable) offices in Fareham and taking delivery of PC-based development machines. Then, in July 1988, five months into development, the coders were told they were not going to receive any more money. A carefully choreographed routine leads to them taking the computer platform instead. Their employer and the game's producer fought over who was to take direct delivery of the game, as Wainwright, running the development company, wanted to hold out for more money from Activision, the producer, after positive previews in the gaming press. Page, rather wisely, had by this point secured an agent and consequently decided to let her handle the finished code, but the disenfranchisement continued. When the game wona 'golden joystick' for the best adaptation, it was Activision's Rod Cousens who collected the award; Page and other coders are instead invited to an internal event that descends into drunken chaos. Later, it was also revealed that the developers for whom he had been working - Dreammaker and Catalyst - had failed to forward any of the taxes they had deducted to the government.

Mel Croucher, designer and founder of Automata, looked at the exploitation of young programmers - what he called ‘child abuse’ - in an article in *The Games Master* in March of 1988. His interviews with young programmers revealed systemic problems within the industry, though he presents the issue in a humorous manner. Fergus McNeil, best known for the satirical adventure *Bored of the Rings* (1985), spoke of being pushed to exploit caffeine pills to finish programs on time. In addition, he turned to heavy drinking:

> Alcohol was how I managed to keep going, the only chance for relaxation, too pissed to type. Going from bad to worse. This sounds a bit melodramatic really, but it was quite bad at the time. It was happening to loads of young programmers. (p. 21)

Another programmer, identified as Joe, echoed this productivity-oriented turn to harmful substances, suggesting it was a widespread feature of the industry:

> I didn't have any self-confidence. all I had was a head full of amphetamine sulphate and hope and f*" all else (...) I didn't even know what day it was. let alone what my options were. They bullshitted me along, making me work nights, weekends, letting me out of my cage now and again to go to a party or do an interview. (p. 21)

McNeil’s advice is tough and direct; he advised young programmers to ‘shop around’, ‘stop relying on other people’s gear’, ‘get a bank account’, to get ruthless to deal with a disrespectful industry. Neil Scrimgeour, on the other hand, promoted a ‘programmer’s union’ to provide information to those workers new to the industry, but also to hold publishers and development companies accountable for paying and respecting their authors. Scrimengour pointed out that unions are not a feature unique to traditional industrial workplaces:

> Many other leisure industries have a union, musicians, writers… We go around saying that the software industry has come of age, and I'm saying that it's time we had an organisation to protect our interests. Not just for the hassles, but also for advice that would smooth the way for all concerned. (p. 22)

Croucher’s final interview was with Dave Wainwright, the same programmer who had treated Pape badly, scamming him out of pay and tax contributions. Wainwright was expressly and surprisingly frank with Croucher:

> After I went to Martech I started abusing schoolchildren for myself (...) Why not, it's the truth. I think I've ripped off every programmer in Portsmouth, but I've changed now that my business has expanded, I'm ripping them off all over the country. I've got five offices nationwide, thirty programmers, and a tame lawyer. I learned early on that payments don't lead to good programs. Programmers have to learn from their own mistakes, it's the only way. To get anywhere in software you've got to get ripped off before you learn anything. (p. 23)

Wainwright's argument is that extreme exploitation acts as an incentive to programmers, allowing them to become their most productive while toughening them up to deal with a difficult industry. Because Wainwright was himself brought up through the ranks of teenage programmers, he does not feel guilty about becoming a functionary in the system that created him. Ironically Wainwright's intentionally forthright and seemingly evil stands acts as an indictment on the interviewer himself. One of Wainwright's first employers was Automata, run by Croucher himself, which hired him to translate one of his best-selling *Piman* games.

At the end of 1984, Matthew Smith gave a chaotic interview to Chris Bourne. In it, Smith suggests the next game will be 'Miner Willy meets the Tax Man' and may include a hardware add-on. Already, Smith casts doubts on the likelihood of the game and implies his issues: "Computing was my only hobby but I don't do that anymore. I like partying, getting drunk and falling over a lot". Towards the end of his interview, Smith gets more serious, raising concerns about artificial intelligence and the societal reliance on gaming and leisure:

> I want to lead a simple life. I think a lot of people do. The world can't sustain itself. The time comes when we can't all be comfortable and happy and warm and fed. We have to blow ourselves up or find a way of being contented (sic.). There is not enough land. True communists are people who live in communes, villages, tribes. I'd like to live like that, but always with the communications we've got. There should be an end to cities. Cities should have walls around them to keep the city in. (Bourne, 1984, p. 92)

Frustrated with Software Projects, Smith quit game development and disappeared. In Internet use-groups, people would share rumours and attempt to figure out what happened to him. Steven Smith (no relation) hosted a website collating some of the rumours. (2006) One consistent rumour placed him at an intentional community in the Netherlands. Andy Noble shared an email they allegedly received from Smith after completing a PC remake of the game:

> I had started to write a programming tool that was ahead of its time in 1986 and I have since seen Windows evolve into the user interface that my program had. I have stopped tearing my hair out though as Win lacks the guts of my basic idea. (...) As more parts of my system work though it will all come together. My tool is powerful. My tool is Bad. My tool is enough to make governments mad. (M. Smith to A. Noble, quoted in S. Smith, 2006)

The idea of Smith disappearing from the circuits of commercial software production to live in a commune and produce radical tools is one part of a compelling narrative. The goal is not to single out any particular individual as critical for the development of the Spectrum, but rather to show the processes at play through these stories.

Utopian Discourses

Clive Sinclair - founder of Sinclair Research - was one of the speakers at the Seminar for Science, Technology and Industry on the 12th of September 1983. Convened by Margaret Thatcher, Prime Minister at the time, the event featured 100 representatives from industry, 60 from universities, 40 from 'the City' - the financial sector - and 50 from the Civil Service - the administrative side of the UK government. (1983a) Thatcher delivered a brief speech at the opening and the close of the event, but for the majority of the event, appears to have been an attentive student - notes in her handwriting are found in the National Archive (1983b). The conference proposes a number of changes necessary for the transformation to a post-industrial economy, including the portability of pensions and equity shares for employees, and the development of and deregulation of venture capital. In addition, the Universities were seen as too insular; it was proposed that more should be done to encourage entrepreneurship and the practical application of research. Particularly interesting is the discussion of the respective advantages of larger and smaller companies; whereas large companies have access to research and development and marketing teams, smaller companies are not fixed to investments in technologies, and could generally be faster-to-market with new products. The conference established a necessary shift towards dynamism, 'multi-disciplinary' and the 'product champion' - all elements that would be included within Agile methodologies that would come to dominate the technology industries decades later.

At the same time, automation would lead to unemployment, and alienation as traditional industries disappeared, and workers became - in the eyes of the contemporary economy - unskilled. A Conservative Employment Policy Group report to Thatcher's government later that year suggested the adoption of technology to educate and placate the newly underemployed masses:

> if full-time jobs are not to be available for everyone, how do we help to prepare school-leavers and others for the productive use of the time when they are not at work? Education and training for the intelligent use of non-working time - and the diversion of those hours into the continuing acquisition of knowledge and into learning, for example, craft skills, DIY and foreign languages - will become of great importance. Inter-reactive Cable Television should, we believe, have a major role in bringing 'training for productive leisure' into the home (CRD, 1983, 4/20/8)

On March 29th, 1984, Sinclair delivered a speech to the US Congressional Clearinghouse on the Future. As opposed to the Seminar, this was a lecture, and bordered on a messianic prophecy. Sinclair spoke of the agricultural and industrial revolution, before speaking of a second industrial revolution brought about by the electronics industry. Indeed, Sinclair suggested that the anthropic economic revolutions are perhaps too minor in comparison. Instead, the birth of life is a better point of comparison: "I think it certain that in decades, not centuries, machines of silicon will arise first to rival and then surpass their human progenitors," (1984). Sinclair states is belief that the prevalence of machines will create a degree of prosperity for humans allowing all a significant amount of free time, comparable to the citizens of classical civilisations: "Just as they did, we will need to educate our children to an appreciation of the finer things of life, to inculcate a love of art, music and science. So we may experience an age as golden as that of Greece," (1984). In the short term, these transformations would have significant effects on the workforce:

> from a positive viewpoint they are free from the drudgery of the mill. Negatively and realistically they are unemployed and very miserable. This is a sad consequence and we are not so well able to manage our affairs as to prevent it but it is a temporary pattern, I believe, caused by the incredibly rapid loss of manufacturing employment. (Sinclair, 1984)

In the same issue in which Sinclair's prophetic speech was published, another editorial would take issue with the unrealistic proclamations, providing balance by referencing a contemporary text speculating on a computer-based dystopia. Paraphrasing Charles Platt and David Langford's *Micromania*, the editors forecast a dystopian scenario:

> Domestic strife is at an all-time high because families spend all their time at home. The advantages of electronic mail are more than out-weighed by the incidence of electronic fraud, which entails the encoding and decoding of all correspondence. The labour-saving domestic appliances have a tendency to malfunction and consequently must be overseen. Everything is voice-actuated and echo-checked so their human operators seem to spend all their time talking and listening to themselves. Entertainment is in the form of inter-active soap operas and Videosex substitutes for the human contact which has no place in a mechanised environment (...) Meanwhile, in the cities, the unskilled, uneducated and unemployed are rioting. (Sinclairvoyance, 1984)

The following issue would carry a reply by systems analyst Alexander Macphee, who argued that Sinclair had taken dangerous leaps, both in assuming possible compatibility between human and machine modes of thinking, and in assuming that increased surveillance capacities will be used for positive ends (Macphee, 1984). Speaking to Scolding, Sinclair takes issue with the responses, describing himself as centrist, a libertarian, a radical, and an optimist.

In 1982, Sinclair Users' editors speculated about a family going on holiday. Their travel booking would be facilitated by a Sinclair computer with the addition of a Prestel adapter, an early modem equivalent. They take a black box on holiday with them: "inside there is a complete Sinclair computer system, neatly packed in plastic foam. The VDU (video display unit) is one of the Sinclair flat-screen televisions and it is powered by a light, but powerful battery developed as part of the Sinclair electric car project," (Segre, 1982). In the article, it is stressed that the technology to facilitate this is under development; Sinclair Research infamously spent a great deal of energy and capital trying to develop both the flat screen tube television and an electric vehicle. At the peak of its success, the company opened its MetaLab, a purely-research oriented facility at Milton Hall in Cambridge. There, scientists pursued wafer-scale integration and experiments in artificial intelligence (Bunder, 1989). Following the sale of the computer component of his business, Sinclair Research was operated as a small research agency, experimenting with folding bikes and personal submarines. Sinclair stayed off the internet, preferring to avoid 'mechanical and technical things' which 'blur the mind' (BBC, 1996); instead, he maintained his membership of Mensa, competed in celebrity Poker tournaments and married an adult entertainer. Sinclair's infrequent resurgences provide another side of this compelling narrative. Meanwhile, the world envisioned in the futuristic objects his companies produced has effectively emerged.

Producing Replicas

In England, two factories began producing derivatives of the Sinclair ZX Spectrum, an early microcomputer designed in Cambridge and released in 1982. Replica devices are nothing new; derivative machines, unauthorised and licenced clones, were produced in the eighties and nineties and marketed to Eastern Europe, Asia and the Americas. These machines were designed for widespread dissemination and were desirable because of the novelty and versatility of the computer on which they were based. Later recreated devices were designed out of a desire to innovate upon the original design, maintaining the format for preservation purposes, or out of sentimental attachment. The latest devices are novel in that they are marketed towards a far larger audience, outside of the small, technically proficient groups involved in hardware experimentation and preservation. They are a consumer product, but are at the same time a heritage product, a replica, a physical form of reenactment (Donovan, 2010, p. 112).

The first announced replica project took the form of a keyboard controller, which could use the popular Bluetooth low-energy radio network format to communicate with a computational device, such as a smartphone or tablet. While replicating the original Spectrum stylistically, it is important to note that this modern product was not, in fact, a fully functioning computer. Instead, it would interface with modern devices - each of which would have many times the processing and memory capacity of the original Spectrum - allowing the user to play original software through an 'emulator', or with new versions of software designed specifically to operate on more modern platforms. One of the key instigators of the project was Steve Wilcox; Wilcox had developed Elite Systems as a major studio out of his brother's solo operation.

More recently, the company acquired the rights to produce contemporary mobile conversions of historically significant games. The problem was that people would lose interest with games without a similar tactile interface; as Wilcox explained: "We've been recreating these old games as apps for modern devices for some time now, but we came to the conclusion that the only way to experience the games the way they were designed was to rebuild the device itself." The original Spectrums were made using a wooden prototype, which was then used to produce a plastic mold. Since the wooden basis for the mold no longer exists, a number of original Spectrums were bought and scanned using a 3D scanner, providing a basis for the new device. Mechanically and functionally very different, the device appears externally as very similar. Only a few new buttons and connections suggest a very different purpose for the new device. Billed as a 'recreated ZX Spectrum', the device is in fact only a peripheral for a mobile phone.

The ZX Spectrum Vega is more visibly different externally, as it is a lot smaller, and the majority of buttons have been removed. That said, it functions as a computer without recourse to other hardware and can be plugged directly into a user's television. Around a thousand games are included with the device; more could be added through an SD card reader. The device was not supposed to have a fully functioning keyboard; it is not expected that the device will be used to program. Instead, it is meant to allow enthusiasts to play historically or personally significant games on a television, using a physical controller. Unlike the Elite reproduction, it is a functioning computer, emulating the Sinclair ZX Spectrum's 8-bit processor on the much newer and more capable ARM chip.

One of the principal designers, Chris Smith, had developed his own fully functioning 'clone' of the Spectrum, the Harlequin, in the late 2000s, reverse engineering the secondary circuit, or ULA, using a medical x-ray machine. The material from this process - referred to by Smith as 'Silicon Archaeology' - was published in an obtuse but invaluable technical text. Though the production Vega is far simpler, it is clear that this device is based on Smith's earlier research with recreating the ZX Spectrum, and, more generally, with cultures of experimental clone production in the 1990s. The most valuable elements for study are not the derivative devices, nor even the two visions of the original device that they present. Instead, what is interesting here are the techniques employed to support the production of the new machines; 3D and X-ray scanning respectively. The modern processes of production, requiring industrial machinery and training, are also important, as observing these allow us to speculate about past techniques of production, which mainly went undocumented despite the extensive technical press.

While it is difficult to produce any contemporary object from scratch, it is interesting to observe how production circuits are configured for small-scale production of peripheral, nostalgic electronics. Both the *ZX Vega* and the *Reenacted ZX Spectrum* took advantage of crowdfunding, a form of fundraising for a project wherein people pledge money in return for perks. The practice allowed for media production by individuals without access to formal publishers or, alternatively, a form of production not subject to the sometimes-restrictive editorial control of such publishers. In some cases, donations are made purely out of a desire to support the project. In others, backers will pay larger, sometimes surprising sums to receive additional, often personalised exclusive material. In the vast majority of cases, those funding a product simply want to get their hands on a 'first edition' copy of the product or item.

Ultimately, reconstruction often falls victim to the same challenges as the initial construction. That is to say, objects - even those of primarily nostalgic value - are produced within markets. The costs of design and manufacturing are often poorly estimated; in other cases, interpersonal, financial or legal conflicts get in the way of a project's successful completion. With Elite Software, it was discovered that no royalties had been paid to creators, leading to claims of exploitation (Correia, 2014). Some backers did not receive their products, even after the inventory was sold to a third party. In the case of the Vega, a portable version with a built-in screen - the Vega+ - created substantial conflict after a dispute between directors led to two of the initial directors leaving.[15] The remaining director and replacements squandered the remaining capital on legal expenses and consultancy fees; they also struggled to find anyone with experience in producing hardware or emulation software. Deadlines were constantly shifted until the company went into liquidation. It is important to note that this set a legal precedent for crowdfunding campaigns, asserting that backing a product should be treated like a sale, not a donation.

The examples shown are important because they show how the current tensions within enthusiast communities are a form of reenactment. Past conflicts related to software ownership rights are replicated. The processes of material production of artefacts are intentionally obscured, leading to a tension between consumer and manufacturer. Nostalgic recreations manage to replicate the transformations present in the original

[15]see Corfield (2017, 2018abcde, 2019). Th

machine as hobbyist projects become increasingly commercialised and consequentially, intangible.

Conclusion

The ideological divide between developers and entrepreneurs widened, but in both cases utopian and dystopian visions coexisted. Forms of material and cultural production can be explored; this tension is encoded both within physical spaces and within objects of digital and physical material culture. Both those who assembled the material hardware making home computing possible and those who coded the software and games that provided for its initial popularity and subsequent integration into general life were put in the position of having to adapt to deindustrialisation and globalisation. Workers had to deal with the disintegration of government involvement in industry, the forceful annihilation of trade union rights, and the increasing capacity for companies to shift production abroad should conditions not be to their liking. While Timex shifted and retained their production capacities for the Spectrum in Dundee, in 1985 Clive Sinclair was pressured to sell the computing side of his company to Alan Sugar's Amstrad, which would soon produce all of its computers in East Asia. Meanwhile, in the absence of organised software production firms, coders worked precariously, selling material to publishers or setting up small, unstable development firms. Certainly, the payoffs were significant for those that managed to produce successful games, but the amount of initial outlay in terms of time, in regard to learning to code, and capital, in terms of purchasing equipment, were high. While acknowledgement and honours were poured on middle-aged male 'innovators', the labour making Spectrums possible was done largely by women on the assembly lines and child coders.

8. Narrating the Spectrum

This chapter looks at media artefacts and their dual nature. Firstly, media artifacts can illustrate the production, use and deposition of objects of material culture. Secondly, they are objects of material culture themselves, with their own histories of production and dissemination. This chapter begins by looking at three episodic programs which feature the ZX Spectrum as a prop, making the argument that a distinction between ‘useless’ and ‘useful’ objects is arbitrary. This chapter then looks at three documentaries about the ZX Spectrum, showing the importance of production context to understanding focuses and methods of presentation. Finally, we will look at *Bandersnatch* (2018), an interactive media project about a Spectrum developer. This final project is novel in how it introduces game mechanics back into conventional television.

Documenting Diffusion

This section begins with a discussion of three television programs which feature the ZX Spectrum within their narrative. The programs are alike in that all were distributed on broadcast television in the 21st Century and could be broadly considered to be within the sphere of the 'domestic period drama'. That being said, they differ substantially due to their geographic origin. In each case, the introduction of the computer into the domestic space is viewed through the eyes of young children. The introduction of computing technology is only one of many changes occurring and is represented alongside other significant events, both personal and historical. In each case, the television program does a good job of representing a possible context for the reception of the device. In each, the situation is fictional; nevertheless, the authors of the respective serials are able to draw upon their personal experience, their archival and investigative research, and their creative capacity to generate a means by which the artefact is placed within its popular context.

The first show, *A Child's Christmas in Wales*, is a 2009 television movie first screened on BBC4. It follows a 1987 TV movie of the same name; both are loosely based on a 1952 radio play by the famous playwright Dylan Thomas. Mark Watson, the writer, grew up in England but had a Welsh mother; his projects have attempted to navigate Welsh identity, but have also allowed him to understand the feeling of an outsider. The story revolves around the narrator's relationship with his parents, and with his two paternal uncles who typically visit at Christmas; each has a differing identity. One uncle, the entrepreneurial and dismissive rug-salesman Huw, brings a ZX Spectrum with him from England as a symbol of his affection for wealth and technological progress.

The second show - *Vyprávěj* - ran from 2009 to 2013 and relayed the changes occurring in Czechoslovakia through the 1980s. It was notable for its attention to detail; in each, there is a representation of period architecture, fashion and material culture. The society depicted is one still under a socialist political and economic system. On the other hand, it also shows certain luxury items being smuggled into the country. The computer shown in the episodes is a 'clone'; in that features a different case and quite likely a differing internal architecture. It is also capable of playing software - in this case, games - designed for the Spectrum. It is described as coming from a broker - presumably a black-market trader - via a main character's uncle; it passes nominally closed political and economic frontiers.

Cuéntame Cómo Pasó is a television serial from Spain which has been running since 2001. Commencing with an episode set in 1968, the show attempts to show the changes occurring in Spain through the final years of the dictatorship of Francisco Franco and following the transition to democracy. The show is still running and entering its nineteenth season, making it the longest running show in Spanish history. The episodes featuring the Spectrum come from the sixteenth season, set in 1983, and show a period in which the Spanish market revolved around the licenced version of the ZX Spectrum computer distributed by partner Investronica.

The Arrival

The first television program discussed here, *A Child's Christmases in Wales*, is a one-off, feature-length family drama written by Mark Watson and first screened on BBC 4 in 2009. Though it takes its title and inspiration from Dylan Thomas's radio play and poem of the same name, the setting is much later; while Thomas' works, developed in the 1950s, are set in the early twentieth century, Watson's adaptation takes place over three seasons scattered across the eighties.

The story is told from the standpoint of a young boy called Owen, though it deals primarily with the conflicts between his father's generation. One of his uncles, the entrepreneurial technophile Huw, has a son and is recently divorced. Another uncle, Gorwel, has long unkempt hair and struggles with alcoholism and unemployment while squatting in an Aquarium. Owen observes the arguments, his mother Brenda's attempts to break them up, and over the years he develops an increasingly strong bond with his cousin, Maurice. The roots of the argument are cultural and political; the business-minded Huw is a vocal supporter of the new Conservative government, while the more rebellious Gorwel announces his desire for people to 'stand up against the government', only to become disappointed when he learns the election was six months earlier. Owen's recounts that his father went on a solidarity strike with the Miners, only to reveal that, since his job was that of a parking warden, it did not have the desired effect.

It could be suggested that economic and cultural differences account for the parents' different choice of gifts. While Geraint gets his son the tabletop football game 'Subbuteo', Huw is excited to demonstrate the ZX Spectrum he has bought for his less than enthusiastic son. Huw mocks the more established, traditional game on account of its long setup time, only to be portrayed struggling to get the Spectrum to load. A number of games are mentioned; there are a number of Space Invaders clones, and fictional examples highlighting the eclectic and sometimes unappealing nature of Spectrum game concepts. They decide to settle on trying a game called 'Planning Permission', only for a key not to work. Huw goes from enthusiasm for 'the best computer in the world' and all that it represents to threatening to sue Sinclair and, more bizarrely, to refuse to sell him carpet. The point of the scene is not to mock the Spectrum specifically; despite being more appealing to the children, the Subbuteo game is stepped on by Owen's mother before they get the chance to even begin a game. Instead, the show mocks the accumulation of paraphernalia that accompanies Christmas. A ball, originally offered to the kids by the third uncle after their sleds fail to be usable, becomes their main source of entertainment.

In *Vyprávěj* (2012a), a Czech historical serial, the ZX Spectrum is again introduced to a youngster by his uncle, but in this case, the uncle is a different kind of entrepreneur. He claims to have obtained it from a 'broker' who owed him money; he also manages to obtain VHS tapes for another relative, suggesting he has a business trading in imported media and technology. As Honza is an Electronic Engineering student, the uncle, Milan, brings it to him, freely admitting that he knows nothing about technology. Honza goes into considerable detail about the capacities of the device, how it is programmed and how its capacities differ from its predecessor, suggesting he had a reasonable familiarity with the device. Holding up a dot-matrix printer, he compares it to the newly available thermal printer. When the uncle bemoans the 'uselessness' of the computer, implying his unwillingness to learn programming, Honza notes the presence of three Spectrum games.

The game they load in this particular case is clearly recognisable as the ZX Spectrum version of the 1985 game *Commando*, albeit with new, more appealing sound effects added by the series producers. Honza also mentions two other real games - *Manic Miner* and *Horace and the Spiders*. While there are problems - again, it takes a while to load, and the uncle lacks a colour television - the moment it loads both men sit upright. They find themselves completely hooked on the game, taking it in turns to attempt to get a high score. They repeatedly set limits - 'one more game' - only to find themselves breaking them. Honza misses a party and fails to talk to his crush, while Milan fails to meet his girlfriend at a cinema. After she comes home to find them still playing in the darkness, she issues her partner an ultimatum. Milan asks if he can store the computer at his nephew's house. The computer is then only shown in passing, with Honza using the computer in a later episode to print out a low-resolution pin-up image, but this already projects a different perception of the computer, as a device the teenager has mastered and incorporated for his own subversive purposes (2012b).

In *Cuéntame Cómo Pasó*, translatable as 'tell me what happened', the Spectrum is again included within a Spanish historical serial as a means of marking the temporal context of what is occurring in the lives of the primary characters, the adults of the Alcántara family. The machine appears in two episodes, both of which provide context for the device's arrival and adoption, but which show it to be a peripheral or background object, used to distract children while main story arcs belong to the adults. In one episode, a child is playing with a Spectrum when the power cuts out; the child is forced to give up his pastime in favour of more antique entertainment, sheepishly asking if he can bring his computer with him.

The scene intercuts with other narratives of 1980s change; a family patriarch attempts to sell wine to new markets, while younger adults import the North American traditions of Halloween and Day of the Dead, and children perform a religious play in a chapel that the pastor is reluctantly also using to house junkies. Numerous 'ghosts' appear throughout the episode, including an ethereal recording of an ex-secret police agent, a fisherman presumed drowned, and the dead sister of a character's former girlfriend. A clever distinction is made between the fantasmas - the ghosts of the past - and the ‘espectro’ - the Spectrum - supposed to be the ghost of the future. Yet unlike *A Child's Christmas in Wales* and *Vyprávěj*, the device's adoption or arrival is not acknowledged.

This second episode of *Cuéntame* featuring a Spectrum revolves around the mysterious disappearance of a head of Dictator Francisco Franco; removed from a statue as it was taken down, the object winds up in the home of one of the characters and as subsequently the object of a police search. The fight over the legacy of the object, itself rather inconsequential, parallels another character's hunt for the truth about what happened during the so-called 'dirty wars' some years prior, when militants attacked and bombed each other in a fight over Spain's legacy. The year1982, in which the episodes are set, is seen as the end of the 'transition to democracy' after the death of General Franco; Antonio, one of the patriarchs of the Alcántara family, would run for office with a centrist party, while his daughter would become involved in the hippie counterculture. While his brother had a background as a communist militant, he shares a house with a former member of the Falange, Franco's fascist grouping. Like A Child's Christmas in Wales, the show takes some poetic licence and pushes the boundaries of believability to facilitate its goal of showing the political and cultural diversity of Spain at the time. As such, the presence of credible and authentic objects is a necessity to make the world depicted more believable.

Useless Presents

In Dylan Thomas' original reflection on Christmas in Wales, a narrator of holidays past provides an almost mythical description of the 'postmen' delivering cards (2007). Questioned further by a young interviewer, he begins to talk about the presents he received, defining them further into 'useful presents' and 'useless presents'. Useful presents appear to have authoritative, even traditionalist qualities:

> engulfing mufflers of the old coach days, and mittens made for giant sloths; zebra scarfs of a substance like silky gum that could be tug-o'-warred down to the galoshes; blinding tam-o'-shanters like patchwork tea cozies and bunny-suited busbies and balaclavas for victims of head-shrinking tribes (2007)

Thomas' narrative stresses that the useful objects have an element of uselessness to them - they are too small, too large, too easily destroyable. The child then asks about the 'useless' presents, which provokes a longer monologue. These objects include sweets, games, and objects designed for role-playing. There is also a subversive element to many of the objects given. Thomas speaks of receiving:

> a whistle to make the dogs bark to wake up the old man next door to make him beat on the wall with his stick to shake our picture off the wall. And a packet of cigarettes: you put one in your mouth and you stood at the corner of the street and you waited for hours, in vain, for an old lady to scold you for smoking a cigarette, and then with a smirk you ate it. (2007)

These 'useless' presents have, on the contrary, a variety of uses. These uses are, however, subversive or hedonistic. It is this that makes these objects so appealing. If one is to discern a suggestion from the poem, it is that functionalist, socially beneficial uses are only one of a range of possibilities for objects and are quite often these are the most appealing.

In the contemporary adaptation, the wealthy uncle presents the Spectrum as a 'useful' present, suggesting that it is the future and eagerly insisting that his son plays with the machine. In *Vyprávěj*, however, the uncle reacts with contempt upon hearing from his nephew that the machine can be used for 'programming', bemoaning that with his lack of technical skills, it is 'useless' for him. Instead, they end up playing games for several days straight. Part of this comes from the quality of the games; while the game in the Welsh series, *Planning Permission,* is fictional, it is clearly supposed to embody the worst qualities of Spectrum games, with its poor graphics and dull concept. *Commando*, on the other hand, is widely acknowledged to be one of the best games available for the Spectrum. Yet there is something more here; for Maurice, the cousin of the protagonist, the computer is another imposition from an overbearing father. For Honza, however, the machine is a way to bond with his uncle over their shared neglect of their social responsibilities. A *Child's Christmas in Wales*, the Czech serial *Vyprávěj* and the Spanish Cuéntame Cómo Pasó use material culture to allow their audience to identify and thereby affirm the settings they use. Both Subbuteo and the ZX Spectrum affirm the 1980's setting of the television adaptation. On the other hand, the spatial setting is affirmed through sound: Welsh accents and singalongs to folk singer Max Boyce.

Resonances

Vyprávěj is innovative because of the way it uses archival footage and accurate depictions of material culture from socialist-era Czechoslovakia. Enthusiasts for the material culture of the Socialist period have edited and uploaded video clips that foreground specific objects; this has been done with the Spectrum, but more visibly with a number of vehicles. Though the show has a cast of characters with established relationships, historically accurate occupations and aspirations, some of the show's viewers have chosen to highlight a different set of characters, of a non-human variety. This is not entirely at odds with the intentions of the show's producers; one of the selling-points of the show was the fact that it featured historically accurate props and elaborately reconstructed locations. This is alluded to in promotional materials and advertisements, but also in the show's title, an amalgamation of the words for 'decoration', 'narrator' and 'to tell'. The oral act of telling the story is indiscernible from the narrator, who in turn is unable to properly tell the story without reference to a wide range of contextually relevant artefacts and sites.

This recalls the anthropological work of Paul Lemonnier, who identifies how people use 'strategic artefacts' to condense and materially embody or represent immaterial thoughts, ideas and stories (2012, p. 58). While many of Lemonnier's examples are taken from the peripheral cultures traditionally the subject of anthropological research, the scholar also has produced a study that is reflexive in nature, looking at the significance of model racing cars (p. 99).By inserting such a chapter in an anthropological text, Lemonnier reminds his audience that the material culture they are themselves surrounded by is just as relevant a topic for anthropological research, and just as imbued with socially constructed meanings[16]. The 'mundane' object is polysemic, meaning that it can have a range of meanings in different contexts, and simultaneously often redundant, in that its position in a social system can be filled by another identical object, or indeed completely different one.

Lemonnier speaks of what he calls perissological resonators; this is another aspect of the redundancy of objects (p. 133). While a perissology is in English the useless employment of multiple words to say something that could be expressed more succinctly, in French the term 'perissology' can imply a repetition that has a function, whereby each repetition provides for additional emphasis. The repeated term does not necessarily have to be an object of material culture; in Walter Benjamin's essay on 'the Storyteller', he notes how the storyteller's careful but entirely superfluous listing of numerous historical events acts to build their authority as narrator and develop a richer contextual world (2006, p. 369). Historical events and historical objects both have this capacity.

Hauntings

In *Vyprávěj*, *Cuéntame* and *A Child's Christmas in Wales*, the Spectrum is a mundane object that nonetheless serves a crucial purpose in that it acts to reinforce and even create the worlds of the respective nephews. It is one of a series of objects and events used to produce the narrative space; Subbuteo, Max Boyce and the Miner's Strikes are used in *A Child's Christmas in Wales*, while *Vyprávěj* makes use of the 1985 World Hockey Championship1980s Škoda vehicles and the panel-block in that episode alone. *Cuéntame*, among other things, uses the head of Franco as a football. Conversely, we discern that the events in the individual narratives are not significant alone but are rather affirmed in relation to sets of other objects and events.

If we make the ZX Spectrum the subject of a narrative or study, then tangential events and context providing objects are no less important. It takes the presence of a (fictional) Czech teenager, Spanish children, a Welsh boy, as well as a number of other events, characters, and objects to produce a coherent and significant narrative. For this reason,

[16] Also see Lemonnier, 2013.

events such as the Miners' Strike, the Falklands War, the Transition to Democracy and Perestroika are important. Objects, including other computers and peripherals but also seemingly unconnected artefacts of material culture, and personalities, including designers and users but also observers, are also similarly critical. Any study of the life history of an object will then become a study of the relationships of that object with others and with a wider sequential environment.

Documentary as Documentation

A punk microeconomy, the UK video game industry in the 1980s exhibits notable differences from similar markets in the United States and Japan. At this point, the global integration of new media production was far from complete. Today, while the United Kingdom still has a lively development community including some notable mid-size, stand-alone developers, some development franchises associated with larger multinationals, and a number of critically acclaimed 'indie producers', it can hardly be considered an autonomous industry. Vallance (2014) notes the relatively small number of indigenous producers in the modern development ecology, arguing that among other factors this is responsible for the contemporary lack of concentration of software producers around urban or creative centres. Izushi and Aoyama, (2006) on the other hand, argue that there is little evidence in the UK of communication or creative diffusion between the videogame industry and local comic or animation production, as with Japan, or with film production, as the United States. The game industry in the UK was dependent upon itself for content and experience.

Johns (2006) argues that there is still a distinct European market, dependent upon the region's reliance on the PAL television format, but elsewhere notes historical connections between the UK and US game markets; her work also illustrates that the consolidation of UK developers happened rapidly in the early 1990s. Charting and understanding this trajectory of economic change is a difficult process; while there is a range of work in the social sciences on the industry as it exists today, historical quantitative data can only tell us so much about how production was organised. This section, therefore, takes an alternative approach, looking for qualitative illustration in a number of documentaries produced in recent years.

Little work has been done on documentary films that take games and the cultures surrounding them as their subject, despite the increasing popularity of such films. Fullerton (2008) and Poremba (2011) have looked at the relationship between games and documentary, but their work focuses predominantly on how games have remediated the documentary form. ‘Docugame’ developers produce immersive historical simulations that employ archival material and/or historical characters or events to both educate and ethically or affectively provoke players. Another synthetic medium that fuses documentary practice and gaming is the emergent ‘e-sports’; while there is an impetus towards live material, the inclusion of formal elements such as narration and the focus on characters outside the game - in this case the ‘pro-gamers’ - mean that there is certainly also influence from other documentary media.

While there are films about the experience of players (Frag 2008, Free to Play 2014), increasingly the majority of coverage is live or near live, following the conventions of television broadcasts of sporting events. Kaytoue et al. (2012) study the twitch.tv platform, arguing that casual gamers often would rather watch other players play than play themselves. They further argue that this live streaming represents a novel kind of entertainment that further democratises the so-called gaming scene. Carter and Gibbs (2013) note tensions in another popular e-sport community as the developer alternates between restricting tournament rules to make games fully comprehensible to non-players, and encouraging a vibrant, if sometimes ‘opaque’, metagame. This synthetic medium of ‘live-streaming’ games both draws from documentary practices and ensures that the practice of recording gameplay is normalised, benefiting future archives.

In the game preservation community, a split exists between those who would preserve games in a playable form, and those who would prioritise recording gameplay instead. Newman is foremost amongst those who would argue for the latter; in the 2012 text Best Before he argues that fundamental problems with emulation mean this established model of preservation is flawed. Newman writes:

> That so much of what games have to offer is based on contingencies of play must surely lead us to question the primacy of playable games in the game preservation project and encourage us to consider the possibility of a need to shift the balance from game preservation towards gameplay preservation. (...) While for many it exists as a valuable supplement to the business of game preservation, I wish to suggest that a documentary approach is well suited to respond to the diversity of play and the susceptibility of games to the configurative, transformative acts of play as well as underpinning any project based around the preservation of playability. (2012, p. 158)

Newman shows his enthusiasm for practices such as Speedrunning and for the increasing popularity of so-called “Let’s Play” videos: videos where players post themselves playing contemporary or historical games and commentating on their performance and experience (2013, p. 61). The focus on emulators - software programs that allow games from historic platforms to be played on modern platforms - is problematic for Newman because emulated versions of games both differ from original versions of the game and from each other, making authentic experience impossible. Furthermore, contemporary players do not play games within the same social and political context, their experience of the game situates it not within its artistic, generation milieu but instead as a nostalgic or antiquarian fetish. Documentation of gameplay - whether historical or contemporary - can more properly situate games within their context, while foregrounding the subjectivity of the player's encounter.

Simple video game play cannot, however, tell us altogether too much about the material conditions of development, production and distribution in the video game industry. Furthermore, it is hardly certain that historically significant games are more than a marginal, passing interest. It is for this reason that longer documentaries about the varied histories of game development are of scholarly interest; both because they can complement more procedurally sound contemporary research in geography, sociology and economics related to the video game industry, but also because their popular reception suggests that this social history of gaming may be of interest to wider audiences. That being said, it is clear that documentaries are never neutral.

In this section, it is argued that film and television documentaries have the capacity to illustrate the context in which games are developed, produced and distributed. Documentaries, however, also have their own production contexts; these invariably affect the way in which the content of the documentary is presented, inclusions and omissions. This section now looks at three documentaries on the UK Game Industry of the 1980s; while there is a great deal of room for comparative studies of the way different historical periods or regional markets are presented, that would require a larger study that is beyond the scope of this article. By focusing on a single period and region, it is possible to highlight the different presentation strategies employed by the producers, while also showing how these narratives are themselves dependent on the context of their production.

Dreamland: State Drama in *Micro Me*n

Micro Men begins with a short, documentary-style clip detailing Clive Sinclair's impact on the electronics industry. This sequence is presented in the style of television special from the period in question; while this sequence is fictional construction made for the movie, its usage of stylistic conventions reminiscent of eighties news broadcast both situates the events within a particular time period and gives the film an authority as guide. The 2009 television film then shifts into its dominant style, that of the dramatisation. Sinclair is told by the government executives funding his company that certain, more exotic elements of his research are not supportable with taxpayer money; he subsequently explodes with rage at everyone around him, his employees included. Contrary to the impression given by the leading segment, Sinclair is not the protagonist; this role belongs to his employee and subsequent competitor, Chris Curry.

Sinclair then falls into the role of antagonist; he is paranoid, railing against the limitations placed on him by state control and, in a scene that stylistically references the spy thriller, asking his employee Curry to quit and work for him at a secret Cambridge start-up. In the film, Sinclair is initially dismissive of computers despite Curry's enthusiasm for them; Curry instead goes into business with Hermann Hauser, founding Acorn. After Sinclair is given a 'golden handshake' by the now government-owned Sinclair Radionics, he appears unsettled until walking past a newsagent sign announcing Margaret Thatcher's ascension to Prime Minister. Sinclair declares a "fresh start", throwing away his cigarettes, selling his Rolls Royce, and entering the emergent computer business. This marks the conclusion of the first act, which has shown the method by which this film will illustrate the 80s game industry. Its predominant focus is on two specific companies and their key players, rather than the industry as a whole; it also is heavily focused on the production of hardware platforms as opposed to software development. By making a dramatisation, the producers of the film inevitably allow inaccuracies in order to facilitate narrative flow; they compensate for this in their use of archival footage, simulated reenactments of such footage (including mock news reports, used in lieu of narration), and the use of authentic consoles as props. These threads are woven into a film that is very much an elegy for a certain imagined British computer hardware industry.

The second act foregrounds the importance of a BBC project to encourage computer education. Both Sinclair and Curry were initially furious at what amounted to state-funded advertising for a single computer product but were seemingly also upset that the state-operated broadcaster had not decided the computer to be featured through open competition. Perhaps hypocritically, they both wanted a shot. The film shows Sinclair contacting Curry, conspiratorially suggesting they work together to open up the competition; in actuality, Sinclair had never heard of the proposed broadcast when Curry contacted him about it (Anderson and Levine 2012, p. 36). The change is relatively minor but is an illustration of how Sinclair's personality is exaggerated, while Curry is made to appear more neutral. Acorn, which attempts to match the specifications of the BBC, defeat Sinclair Research, which insists on its own specifications. The foregrounding of the BBC's intervention and the identification of Curry - the chief executive of the company that would eventually receive the contract to produce its 'BBC MICRO' - as the protagonist cannot be ignored for two reasons. Most important is the fact that this television movie was produced for and screened on a BBC channel; it naturally risks becoming a triumphal narrative, a documentation of the computer industry that foregrounds the BBC's (and indirectly the state's) role within it. The irony of the fact that characters such as Sinclair, and indeed Curry himself, are critical of state intervention in Industry can hardly be lost.

To a lesser extent this also feeds into the politics of the ascendant computing revival; though the film predated the Conservative electoral victory in 2010, and the subsequent announcement of changes to the computing curriculum in 2012, the ideological concept of a synthetic, even 'synergetic' relationship between government and business, particularly high-tech, creative sector business, is not particularly partisan. As Barbrook (2006) and Pratt (2008) have shown, such a partnership was also encouraged in the economic policy of "New Labour", the formerly social democratic party in power at the time. A critical fragment of the film is the inclusion of an archival clip wherein Margaret Thatcher demonstrates a Sinclair console to the Japanese prime minister during a 1982 visit, implying the strength of British innovation.

Despite the supposed commitment to free-market practices, the government is frequently called upon to support businesses. In return, entrepreneurs are held up as national icons; Sinclair was subsequently knighted. It seems unavoidable, therefore, that due both to its documentary-drama mode and the context in which it was produced that the film would adopt a 'Great People' model of history. Perhaps notable is the fact that the screenwriter for *Micro Men* had produced the screenplay for another BBC historical dramatisation, entitled *Margaret Thatcher: The Long Walk to Finchley*. While filmmaking is a collaborative process and it would be unfair to conflate the production of a documentary on a person with an explicit endorsement of them, this does suggest the type of character that is conducive to the format.

The third act features universal frustration. Curry's staff realise their platforms are unpopular without a large catalogue of games, and consequently produce a lower cost, stripped down console called the 'Electron'. Meanwhile, Sinclair is having trouble breaking into the professional market; his 'QL' is suffering from significant production problems and - consequently - delays. Sinclair alternates between shifting his focus to renewable transportation - his often mocked but remarkably prescient electric tricycle - and berating his employees for the delays in production. After Curry is left with a full warehouse, he worries about his staff; after a film minute of contemplation, he decides to run the advertisement highlighting the Electron's much lower return rate when compared with Sinclair's competing ZX Spectrum. A fight breaks out when Sinclair confronts him about it, though this scene is exaggerated for dramatic effect. "Poor Clive was made to look like a lunatic," says Curry of the event (Anderson and Levine 2012, p. 44). A subsequent on-screen conversation between Curry and his second-in-command Hauser illustrates the dual messages of the film.

Curry:	It's official, we're a joke. Hope all the people we have to lay off see the funny side.
Hauser:	We're not a joke, Chris. The bottom has fallen out of the whole market, that's all. It's the same for everyone.
Curry:	It's the same for Clive...
Hauser:	Does that make you feel better?
Curry:	*pauses, smiles* No, it doesn't.
Hauser:	I'll go and start letting everyone know…
Curry:	What are they all going to do?
Hauser:	They're clever people, they'll think of something... Maybe they already have… (*Micro Men*)

In the background, there are two project specifications scrawled on a blackboard. The first, the ARM chip, is perceived to be the lasting legacy of the UK computer hardware industry.

The subsequent scene shows Sinclair and Curry reconciling over a pint in a pub. Sinclair extorts the resilience of British amateurs: "the quiet chap scuttling off his shed to work on that idea that he and he alone knows will change the world". Sinclair then reveals his plans for a flying car, only to have the landlady call 'last orders'. The landlady is a cameo by Sophie Wilson, who is in the real world the author of the instruction set for the aforementioned ARM chip and - it is implied - one of the 'clever people' mentioned by Hauser. A concluding scene then summarises the problem with this imaginative, if somewhat distracted mindset; footage of the actor playing Sinclair in one of his patent electric tricycles is intercut with footage of Sir Alan Sugar, the entrepreneur with little knowledge of computing that bought his country. The shot then opens up to reveal that Sinclair is riding this tricycle on the highway - a risky procedure - as lorries pass him on both sides. The lorries are branded with the names of the computing giants of today, all American megacorporations. The film is incredibly enjoyable and a good example of effective mixing of dramatic, archival and faux-archival footage. Nonetheless, if it appears overly patriotic; one cannot help but relate this to its context of production.

The trailer for *From Bedrooms to Billions* opens with enthusiastic games journalist Gary Penn describing the affective environment of the early 1980s:

> There was that new frontier, there was a sense of a new medium, there was a sense of a cultural thing occurring, there was a sense that anyone could do anything or make anything happen.

Jon Hare, an artist and producer for Sensible Software asserts that "we were in a position in the UK where we were ready for something to happen", while Julian Rignall, another journalist, adds that "it was very new, it was an industry that was making it up as it went along." The approach taken by producers Anthony and Nicola Caulfield is described as the 'ensemble interview'; rather than using the voice of a single or small group of narrators, they intercut interview footage from journalists and developers in order to produce a coherent narrative through montage. In an interview with the (London) Metro's David Jenkins, Andrew Caulfield describes how the project was originally pitched to the BBC and commercial networks, the documentary - originally planned as a three-part television series - was rejected because games - particularly retro games - were seen as a 'niche' interest (2013). After the successful broadcast of 'Micro Men', the show was picked up by the BBC, only to be dropped again after a month.

Caulfield describes beginning research for the project in the late 90s and being motivated by the absence of contemporary UK developers; he also notes specifically the absence of UK producers, something noted in academic research by Vallance (2014). The producer is cautious about how he talks about the integration of UK developers into foreign supply chains; initially, he cages his statement with "I'm not saying that it's bad…", but when the interviewer suggests it might be he affirms that actually "it's a crying shame." That being said, the documentary appears to be developing in a different direction than the seemingly patriotic 'Micro Men' discussed previously. Here, it is argued that the crowdsourced production has a triumphal narrative, but one that is not overtly about the self-affirmation of British inventiveness. Instead, the documentary is a valorisation of the importance of independent, small-scale developers against larger production companies. Caulfield's words show the extent of the consolidation also documented in Johns' (2006) research:

> There's a very interesting statistic actually, in the early '90s there was a 22 month period where we saw an almost 78 per cent drop off in financial activity of UK companies working on video games between '93 and '95. Which is almost a straight line on a graph. And that means money being generated in the UK by UK businesses and the money staying in the

> UK. By ’95 most developers were owned by Sony, Ubisoft, and various other companies. So the money was obviously going outside of the UK. (Jenkins, 2013)

Kuppuswamy and Bayus (2013) look at the vitality of public ‘crowdfunding’ platform Kickstarter, suggesting that it differs from traditional investment models both in the quantity of investors - there are a greater number of small-scale investors - and the quality and level of feedback provided by those who have a stake in the project. The decision by producers Nicola and Anthony Caulfield to raise the funding for their project on Kickstarter and similar platform Indiegogo has invariably affected their product. It is notable that unlike others funded on the platforms, they are not amateurs; both have had considerable success making documentaries and films receiving funding from traditional sources. Employing two different platforms was an unorthodox move, but one that proved to be successful, gaining a greater degree of public and media interest.

While the earlier, Indiegogo campaign uses photos of the producers in archival photographs from magazines and offers material rewards to large-sum backers, the later campaign uses the social capital of confirmed interviewees, including things such as autographs and personal objects, in order to solicit even greater donations. While a detailed study of the crowdfunding campaign is beyond the scope of this article, it is notable that the funding generated by the project exceeded the initial goals and established a responsive target audience before the campaign had concluded. One can discern a ‘third’ stage of the campaign in the mailings sent to backers; fans were invited to help source archival footage, suggest possible interviewees, and even perform complex technical tasks to facilitate certain sequences. While this engagement is without a doubt rewarding for fans and will enhance the quality of the finished product, scholars have critiqued the capacity of digital media platforms to entangle fans in forms of unremunerated labour. It is also of importance that the creators of this documentary have a background as producers; while the editing and cinematography is of high quality, it could be suggested that production skills are important for all artists in this emergent world of ‘indie’ production.

The film was expanded greatly due to fan participation and the flexibility of the funding structure. An eighteen-minute clip entitled ‘metal’ is a reference to ‘bare metal’ coding, the coding in assembly language practiced by early programmers on platforms with limited memory and processing power. One can draw two major messages from this segment. The first is that the limitations of storage formats - which meant computer users had to type in program listings line by line - helped to improve computer literacy amongst the general population, including those who would not go on to become programmers. Another commentator tells us that the network of computer publications acted as an early ‘internet’ - a distribution mechanism for code, techniques and commentary. On the other hand, the general enthusiasm of early coders also was open for exploitation. Nigel Adlerton recalls convincing a headteacher - who was shocked students would want to attend school any longer than they were forced to - to hand over the keys so they could come in early. Anthony Crowther, another interviewee, recalls that this ‘indulgence’ went further at his school. Library staff noticed that enthusiastic computer users were skipping lessons to use their computers, and so set them to work producing software that could be sold to other schools; in return, the students got an occasional ‘free lunch’. While the computational culture of the 1980s was in some respects more novel and accessible, it is also important that other elements are not obscured: in this case, the problematic use of child labour by school administrators.

In the trailer, to cite another example, an unnamed commentator speaks of the instant acclamation afforded to successful developers: “It was a fame and stardom that none of us were prepared for… and it hurt a lot of people”. The next scene shows Matthew Smith, developer of *Manic Miner* and *Jet Set Willy*, asserting that “there’s a group of people for whom the 1980s was a magical time full of… full of happiness and light.” It’s unclear whether Smith is making this comment sincerely or with a degree of irony; it is also unclear whether the directors are using it to contrast with the preceding and subsequent fragment, or in sequence with them. This short sequence suggests the film has the capacity to be self-critical of the computational culture of the 80s, but then the film’s criticality is necessarily limited by the biases of its funders, many of whom would not have indulged the producers were it not for a latent and rose-tinted nostalgia that they likely want reflected in the film. The Caulfields are left with an awkward situation; either they abuse the trust of their funders and produce a film that shows all sides of the gaming industry, or they indulge them and produce a film that is simply another form of triumphalism. The next scene is from a 1984 documentary - *Commercial Breaks* - and shows the fall of Imagine Software, as bailiffs lock employees out of their workplace. Along with Imagine’s dissolution, discussed in the final part of this chapter, the depression and disappearance of Smith is one of the most well-known elements of 1980’s UK gaming mythology.

Secret Level: Documenting Disappearance

Spectrum Diamond - produced by Bologna film collective Opificio Ciclope - is the shortest film explored here, fitting into an hour television slot. It is also the oldest, having been produced in 2002 and screened in 2003. The conditions of production are also the strangest; while the producers were Italian, the film was made with funding from the

Spanish affiliate of French television corporation Canal +, to be screened on television in Finland. They use contemporary footage, but a range of obsolete and dated film cameras, giving the footage an aesthetic that is more dreamlike than dated. Unlike the other documentaries mentioned, it uses a narrator; the narration was the first component to be written, and the documentary has been structured around that. The narrator, however, is hardly an authoritative voice; the producers reveal that they "wanted a phantom presence as a narrator, a spirit child to guide thru the years and cities." The use of a teenager from a foreign country, too young to remember the subject of their documentary, means that the film has a mythological quality. While *Micro Men* (2009) looks at the pioneers of British hardware, and *From Bedrooms to Billions* (2014) explores the software industry as a whole, *Spectrum Diamond* looks at a pair of games and their disappearing creator.

The games - *Manic Miner* (1983) - and its sequel - *Jet Set Willy* (1984) - were produced by Matthew Smith, at the time a teenager. Jenkins describes their lasting significance: "30 years later and they're still the best example of a British made video game that actually feels British." They hold a psychedelic quality, drawing influences from popular culture, cult media, and current events. Jodi - perhaps the best-known producers of 'game art' - created their piece *Jet Set Willy Variations* in 2002 as a tribute to the series, hacking the titles to foreground their psychedelic qualities. Opificio Ciclope engage in a similar tribute through the medium of documentary video. They explore not only the games but also the spaces in which they were created; Wallasey, for example, where Smith had lived while developing the game. Many segments of the documentary are shot on antiquated film cameras, with special filters or lenses, making the landscapes they shot seem surreal. This is certainly in line with their stated aim; they "tried to look at England like a multilevel game." While they don't directly address the wider context of social, political and economic change, it is certainly implied through some of the interviews and sequences. As opposed to the 'revolutionary' moments portrayed in *Micro Men*, or described in *From Bedrooms to Billions*, *Spectrum Diamond* implies a lost battle, adopting an elegiac tone. An interviewee, identified in the transcript only as 'man in the pub', describes how his environment has changed:

> Buses used to be on time. Cheap fares. Everyone was subsidized. People were working. Everybody had a job. Families were happy, you know. Now they've just built all the promenade... Looks nice, but there's nothing there anymore. So it's like a ghost town, really… It's changed over the years like…" (Spectrum Diamond)

There is also a fascination with mythologies. Firstly, there are those referenced in the games, which Opificio Ciclope try to understand through local and vernacular sources. There is the 'priest's hole', for example, a level in the game that has its origins in the hiding spots of 16th Century clerics; the producers ask some of the interviewees to explain it. They are similarly fascinated with in-game characters; in Jet Set Willy, the titular character is ordered to rearrange his house by his housekeeper, and the producers encourage an interviewee to speculate on the strange relationship between them. There is also another type of mythology investigated; that of the game's production, and of the notable disappearance of its producers. The producers claim they "never looked for traces of Matthew Smith, (the girlfriends, the family…), not really," (Opificio Ciclope, 2003). Yet this is because their film is not about drawing conclusions or making statements. Instead, it is about using the ambiguous nature of documentation, and the consequential ambiguity of documentary film as a medium. They open a discussion, asking questions not only of experts but of peripheral and even unrelated figures. They create Matthew Smith as a mythological character, a video game character. One source relates that "He was so rich he could use ZX Spectrums to proper-fix tables, because the legs wobbled, or to hold open the door." Other sources describe his subsequent disappearance. The producers interviewed other figures from younger generations; reenactors, who took up the task of producing their own versions of the games they had loved.

After Theo, the teenage narrator, reveals that the disappearing character has been found, it is not an invitation for resolution, conclusion. Instead, they cut to Steven Smith (unrelated), who with others had started a website to track sightings of their programmer hero. Steven Smith relays information received that he was creating new vehicles, or staying in a Dutch commune, or working in a fish factory. Strangely, the narrator joins in, providing information of his own of ambiguous authenticity:

> I first met Matthew when he was rich and famous and he still knew how to draw a good party. I recall a free bar under the stairs and magic mushroom tea for all. The rest of evening is lost in a blur. (*Spectrum Diamond*)

Steven Smith repeats another myth; that the programmer Matthew Smith is actually a codename for the computer. Opificio Ciclope follow an exegetical, speculative approach to the information they have obtained. They mix fiction and folklore in with documentary evidence, though not to make the material easier to digest, as in *Micro Men*. Instead, the inclusion of strange, unrelated statements, characters and material does two things. It creates an interactive, affective environment, similar to that created by a video game, through which the viewer must navigate. In addition, it reflects the winding, quest-like path taken by the film's producers, who lacked discernible hierarchy or direction. At Software Products - where Matthew Smith worked while producing his second title - one of his colleagues attempted to explain the strange production environment to a visitor: "People see everybody wandering around and think, they're idle. But as long as they produce a program, we don't care how they do it. Some of them sleep here." (Bourne, 1984) One might meditate on the extent to which the documentary filmmakers' loose organisation and random, playful approach mirrored the production conditions of the video game studios where their research subject worked.

Archaeologies of Dystopia

Stefan Butler trades the ability to make a masterpiece for the last traces of his sanity. Stefan attacks his therapist. Stefan encourages his best friend to plummet to his death. Stefan uncovers a government plot to create malleable actors by experimenting on children. Stefan chooses Frosties. These are not things that happen in Charlie Brooker and Annabel Jones's experimental epic, but they are rather things that can happen. Bandersnatch is a special interactive media work associated with the Black Mirror television series (2011-2019) and produced by the streaming video distributor Netflix. It tells the story of a young Spectrum game developer who is convinced to produce a concept horror game. Butler is contracted by Mohan Thuker, the ambitious and exploitative owner of the fictional TuckerSoft development studio. Given a choice to work in residence at the studio itself, he generally refuses, retreating to his bedroom to develop the game and lose his grip on reality.

Bandersnatch (2018) is an independent work but is marketed as a spinoff of Black Mirror. This show was a highly ambitious anthology show inspired *by Twilight Zone* and *Tales of the Unexpected* and is innovative in its exploration of contemporary themes related to modern technology and digital society. (Moser, 2016) Other episodes, however, are linear; 'Bandersnatch' was unique for both the series Black Mirror and for the Netflix platform in that it allowed viewers to make choices affecting the subsequent direction of the plot. In addition, the television show is unique in that it is the only episode of Black Mirror set in the past. Another episode, 'San Junipero', allows its characters to explore a fantasy eighties beach town, but it is only a simulation, populated by the elderly and the dead. There is an implication that its developers of that simulation, Tucker Industries, derive from TuckerSoft, making Bandersnatch a loose prequel. A symbol seen frequently in Bandersnatch, a branching fork, also appears in an episode titled 'White Bear', in which a murderer is tortured by being forced to replay the same traumatic simulation which they cannot escape from. Two other episodes feature video games heavily as part of the plot; 'USS Callister' allows a troubled designer to trap copies of coworkers in a twisted simulation, while in 'Playtest' an implant allows for a tester to experience a game-like horror environment directly.

The Game in Bandersnatch is allegedly based on a choose-your-own-adventure novel by Jerome F. Davies, a reclusive author who supposedly killed his wife while working on the project. The game is shown in progressive stages of development on the screen, and in rough form through an expanding tree of notes and sketches spanning out over Butler's wall. Butler can't produce his labyrinth without recognising the labyrinthine nature of his own existence; he starts obsessing over choices he made while a child that may have led to his mother's death. Alternatively, he starts to notice himself being directed while making certain decisions; the viewer can break the fourth wall and communicate with the character directly or help him create further delusions related to his origins. With only a few choices possible in each scenario and a limited number of paths available, a work of interactive television fiction risks appearing a gimmick. At the same time, each piece of media can allow us to understand the past in a unique and unprecedented way.

Bandersnatch was indeed an actual game under development but is different to that depicted in Booker's interactive episode. It did not have a direct link to a book, and was developed by a larger team, not an individual. The development of the game was charted in *Commercial Breaks*, a BBC Documentary looking at Imagine - the company developing Bandersnatch - and Ocean, another established studio. It depicts a sales representative from Bandersnatch trying to sell the game to a distributor, explaining the particular features of the game. A key selling point is that the game will come with additional hardware, expanding the capabilities of the device. The additional hardware would also have the added benefit of making the game impossible to pirate. Unfortunately, it also meant the game would be substantially more expensive than other titles. The narrator of *Commercial Breaks* relates that "Traditional investors are suspicious of its bizarre nature." Developers and artists are pulled off other projects to finish the game before Christmas, but the effort is unsuccessful. With cameras rolling, Bailiffs slam the door on developers trying to return to their office. The developers, who had been depicted as earning high salaries and driving sports cars, were now unemployed.

The best 'ending' for the Black Mirror version of Bandersnatch - there are multiple in line with the non-linear narrative - sees a character from the present day supposedly working on the Netflix show itself. Pearl - who is working on the adaptation - was shown in the main narrative as the two-year-old daughter of the developer who tries to befriend the main character. In this particular version of the story, the main character murders his father, but does it in a discrete manner, allowing the evidence to remain hidden so the game can be finished. Discovering the lost classic and its troubling story, Pearl becomes motivated to recreate it, but ends up repeating the same patterns, becoming frustrated and destroying her computer. Bandersnatch seems somewhat autobiographical; Booker worked as a game journalist and failed a degree while writing about video games (Booker, 2012). In another sense, it is archaeological. While other episodes of Black Mirror address themes of nostalgia or memory, this is the only episode so far set in the past.

The episode of Black Mirror was published with minimal promotion before the event. Therefore, to advertise the episode, Netflix chose to saturate London's Old Street station with unsettling advertisements (Maine, 2019, Simpson, 2019). In addition, in an empty storefront, they produced an installation resembling an early 1980's entertainment shop. Inside the store are fictional games, including those referenced in *Bandersnatch*. The device is made to look similarly jarring; distinctly 80s in appearance, but as if it had just closed recently. At the same time, Netflix commissioned a real ZX Spectrum game, hiding it inside one of the *Bandersnatch* endings and on mock websites (Kain, 2018). To play the game requires the use of an emulator - software simulating the original hardware of the ZX Spectrum. It is an example of an 'easter egg', a concept popularised within games but now seen across media formats.

Bandersnatch can be seen as an experiment in marketing to populations. (Damiani, 2019, Chakraborty, 2019) By allowing for choice, companies are able to build up profiles of their users, increasing the amount of data they have on audiences. The format also facilitates A-B testing, where two versions of the same product - such as a game level or trailer - are shown to similar audiences, in order to gauge their response and optimize products. Conceivably, this research could be integrated with Netflix's experiments with machine learning routines for profiling and customisation, or lambda architecture for real time data processing and optimisation. Already it is an experiment in localised targeting - while *Black Mirror* has international appeal and some episodes are set in the United States, this special is made with a distinctly British and nostalgic setting.

This chapter has shown the capacity of media to both represent and be themselves considered forms of material culture. While all media explored practice reenactment and storytelling, they use differing methodologies to do so. For scholars of material culture, media provides a means to disseminate their research more widely. For curators, media allows their collection to be put on display in a way that both allows the artefacts to be displayed to a wide audience, but also properly contextualized. At the same, it remains a challenge to understand both the mechanical operation of technology and the narrative mechanics of culture simultaneously. Media creation projects dealing with historic objects and past environments require a significant degree of research. They require collaboration between experts and enthusiasts, between primary witnesses and those viewing the situation at a distance, whether geographic or temporal.

Conclusion

This thesis has attempted to make use of archaeological, historical, and cultural analysis techniques to analyse the ZX Spectrum, using the findings as a starting point for an analysis of the transitions occurring within society and culture. The key period addressed is the 'Long 1980s', when industrial changes led to social and economic unrest and global political transformations were germinating (Aikens et al. 2018). An aspiration was that by choosing a single artefact, it could be isolated and understood in its entirety; this was quickly revealed to be ambitious. Similarly, the methodologies chosen resisted any attempts at confinement by section. The notion of entanglement - which has filtered into archaeology from science and technology studies - is perhaps useful to understand the complex connections that an object has to people, places, and indeed other artefacts. This provided for a fantastic learning experience. The process of studying the ZX Spectrum has required investigation of both the earliest transistors and contemporary field programmable gate arrays. It required an understanding of magnetic encoding practices, keyboard design methods and programming in BASIC and assembly code. It involved analysis of thousands of pages of fading material, and obscure texts and video in a range of languages. The focus on material culture was meant to make the process easier; the challenge of compiling oral histories from biased and bitter sources would be avoided. As it emerged, the ZX Spectrum provided for a worthy and troublesome respondent. Michael Shanks reflects:

> Objects are often thought to be simpler than people. But many interactions between people are very simple; people often merge into the background and may be, in particular circumstances, treated far more simply than many machines. *It is quite possible to have a complex relationship with a computer*. (Pearson and Shanks 2001, p. 96)[17]

A key conclusion is that the device should not be treated as a singular artefact, but rather as a platform or lineage; its development history exhibits a convergence from experimental kit to consumer product. Attempts to see this as an' artefact belonging to a particular culture - the United Kingdom - are confounded by the material culture surrounding the device; further, investigation suggests patterns of diffusion are more complex than previously understood. Exploration of subsidiary artefacts - including three games and a number of media items - show that associated storage and dissemination

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[17] My emphasis. Shanks continues by comparing the computer to "(...) a work of art which can gather around itself many associations and connotations."

technologies - magazine and cassette tape - have a substantial effect, transforming the usage patterns of the artefact itself. An interpretive approach - involving archival research, fieldwalking, physical and conceptual reenactment - allows for a further understanding of structural transformations in culture, economy, infrastructure and ideology.

The research has led to work with national collections, and related work has been presented at a number of international conferences. It has also allowed for participation in emerging collaborative academic networks and community interest groups. At the same time, there is substantial room for further work in the area. A key question would be as to the best format and methodology for this work. There remains a disconnect between academic or professional methods and those adopted by enthusiasts. In many instances, the methods used by amateurs are far more innovative and produce dramatic results. On the other hand, the results are often not disseminated widely or in ways that are accessible. Frequently, discovering the results of prior studies has required performing a form of resuscitation on broken websites or investigating collapsed archives, or crashing what appear to be exclusive events. Similar criticisms are directed back at academic writing and research, which - through use of institutional methodologies, conference formats and language - can alienate practitioners. The most intriguing element of the ZX Spectrum is its international component; while there is some collaboration between preservation communities in different territories, there is also surprising ignorance within the UK about work being done internationally. As such, there appears a need for facilitators, editors, translators or curators, allowing the findings and techniques of amateurs to be shared. At the same time, it is important not to simply piggyback off the work of others, but rather to continue developing new and innovative projects. Morgan and Eve (2012) speak of a potential digital archaeology, inspired by open source and DIY media culture: “Noisy, multilingual and multi-authored, and sadly often unarchivable or incompatible with traditional means of archaeological publication, there is so much colour and life in our digital village that it defies boundaries and descriptions.”

Like many undertaking doctoral work, I suffered significant anxiety and doubts about the quality, relevance and even seriousness of my work. I felt like an imposter amongst material related to Archaeology and Computer Science. At the same time, by exploring an object of nostalgic remembrance for many without engaging them through formal interviews, I felt guilty of a form of inauthenticity. At the same time, whenever I spoke to archaeological practitioners, amateur preservationists or contemporary developers, they affirmed enthusiasm for my efforts. And, despite feeling that I was constantly attacking a black box, or spending time on a project only to have it fail to provide meaningful results, this thesis has advanced our knowledge and methodologies. It has allowed me to develop a thorough knowledge of computing and material culture, and the skills to perform further research and investigations.

Appendices

A1. ZX Spectrum Test Pit.

Introduction

Infrastructural Background

The device was acquired in a Black Plastic carrying case. Within the Box three items provided the infrastructural context - a plug and power supply, a composite video game cable, and a cassette tape. These suggest the surrounding infrastructural environment.
The plug holds a 13 amp fuse. Markings on the Power supply imply it is capable of taking in power at a voltage of 240 Volts AC, an alternating frequency of 50Hz and a current at 0.11A and outputting it at 9 Volts DC with a current 1.4A.
The composite cable is a standard, nondescript cable that allows for the device to be connected to the composite port of an analogue television.
The cassette is a standard compact cassette in the Phillips tradition. It implies connection to an analogue cassette recorder.

Archaeological and Historical Background

The device investigated is an Issue 3, 48K Sinclair ZX Spectrum from 1983. It is likely to include a range of electronic circuitry with a provenance in the early 1980s, including around two dozen integrated circuits. Further historical context is provided in the attached work.

Aims and Methodology

Aims

The aim of this investigation was to determine the location, condition, temporal and geographic provenance, condition of integrated circuits within the site-artefact.

Methodology - Investigation 1

The ZX Spectrum was disassembled using an ordinary Philips-head screwdriver. The keyboard connectors were eased from their housings on the board using minimal pressure. Internal components were sketched several times, with versions highlighting the chips within context of the board as a whole, within their general function, and in detail. A recording was made of external markings of the chip, and pin counts - that is to say, the number of metallic joints to the rest of the board. Photos were taken of components and the board as a whole. The heatsink was moved to make it possible to read markings on the chips, but the heatsink was not removed. The computer was then reassembled.

Methodology - Investigation 2

The ZX Spectrum had gathered a substantial degree of dust since it was last investigated. The device was again disassembled using a screwdriver, though it appeared that one of the screws was no longer present. The components were again photographed using a higher-quality camera and a suitable backing of ¼ inch (6.35 mm) squares.

The decision was made to remove the heatsink; this was performed using a flathead screwdriver. Removing the heatsink allowed certain circuits to be photographed more clearly.

After removing a central screw from the board, it was then possible to remove the board itself from the plastic casing. The keyboard layer was then photographed and carefully removed.

The faceplate was left untouched in the initial survey. The faceplate, made of soft metal, is difficult to remove without bending and a study of the front of the device was possible without its removal. At this point it was decided to remove it; best practice suggests the use of a specialised plastic apparatus, but a number of plastic guitar picks of varying thickness were used instead. The faceplate was removed and photographed.

The rubber plate was then removed, investigated and cleaned. The device was then reassembled.

The associated material included a power supply; this was opened through the removal of three screws from the outside and two from the inside using a Phillips screwdriver. The device was photographed and reassembled.

Results

Introduction

The results are subdivided into a number of sections. The first of these relates the results of the first and second investigation. A finds summary records the components found in various places within the circuit board, providing a reasonable reference for comparison.

Finds Summary

	Specific	Reference[18]
1	FERRANTI ULA 6C001E-6 8335	FERRANTI ULA 6C001E-6 8402
2	(Z) ZILOG Z8400A PS Z80A CPU 8308	NEC 8347P8 D780C -1
3/4/25/26	(T) PORTUGAL ´8301C SN74LS157N	ENGLAND (T) 401C SN74LS157N
5	NEC(japan) 8314P9 D23128C 057	NEC(japan) 8406x9 D23128C 057
6/7/8/9/ 10/11/12/13	(SH) HYB 4116 P2DH 8322	8410 STC 4116 2N
14	(~~) /B8316 LM1889N	(~~) /B8352 LM1889N
15/16/17/18 19/20/21/22	(T) TMS4532-I5NL4 P8332 SINGAPORE	(T)TMS4532-20NL4 P8349
23	(T) PORTUGAL 8306B SN74LS32N	MALAYSIA 349B (T)SN74LS32N
24	SN74S00N (M) I8233	ENGLAND (T)345B SN74ALS00AN

[18] Wikimedia, 2007. In retrospect another Issue 3 board could have been chosen, but this was only to show the divergence.

Finds

(1) A 6C series E6 Ferranti ULA.

This chip was seemingly produced in 1983 between 29rd August and 2nd September, And is identified as being manufactured by Ferranti.

The device is a 6C001-E6, the sixth of seven variants of the ULA chip used for the ZX Spectrum.[19] A similar chip is frequently found within ZX81 devices.[20] All ULA devices used within the Sinclair Research devices use the ‘C’ variant, but other variants exist[21]. This is the second variant found in the ZX Spectrum within the 6C series - a line of chips that Smith argues is made specifically for Sinclair Research, (2010, 63) supposedly using less power. An earlier version of the chip, the 6C001E5, used the same process, but featured errors, leading it to be incredibly rare.[22] An updated, more stable version of the 6C0015C chip came to replace this version of the chip in later revisions.

Ferranti established a research center for semiconductors out of their ‘Gem Mill’ in Oldham, Lancashire beginning in 1961. (Flaherty 1998) In January 1984, they officially opened a new secondary facility for the production of microprocessors in an area called Bentfield Industrial Units but referred to as Landsdowne Road. Historical sources suggest that the factory was already in operation from April 1983 (Manchester Evening News 2010) Therefore, the chip was produced in either location since provision of a new facility is contemporaneous with the transition to the new, energy-efficient chip. A majority stake in Ferranti had been sold by the National Enterprise Board on the stock market in 1981, allowing it to raise substantial capital and possibly providing for the construction Its merger with an American company that was investigated for fraud led the company to be dismembered (Halton, 2001,52-53)

[19] (c.f. Spectrum for Everyone 2016). The first variant found in the Spectrum begins with prefix 5C102, and variants 2 through 4 begin with 5C112.

[20] The ZX Spectrum uses the ZX81, which would have been a ‘2000’ series beginning with 2C. (Smith 2010, 64) The variants possible include ‘ULA2C184E’ or ‘ULA2C210E’ (Retroisle, 2010) A 1000 series exists - the difference primarily relates to the number of gates. (86)

[21] ULAs has a type code, which designated the maximum clock capacity, and length of acceptable delay in nanoseconds for a gate to shift; the code would also designate whether the chip was designed to operate using resistor-transistor logic, or a current mode logic, with the latter offering ‘faster switching speed and lower current consumption’. (Smith, 2010, 47)

[22] Research suggests that 6C0015 chips were only produced for a four week period - between 16 May and 17 June 1983. (Spectrum for Everyone, 2016, Appendix B)

(1) Z8400APS variant of a Zilog Z80A processor.

The chip is dated to between 21th and 27th of February, 1983.

The Z is styled to two irregular trapezoids with two lines in the center, the Zilog logo. The chip carries the Zilog brand - a initially all Zilog Z80 chips were second sourced by other manufacturers (Gallipi, 2012). It is possible the chip was produced by another supplier, but carries the Zilog brand for international recognition; however, Zilog did build its own factories in the United States and Internationally. The Z8400 designation was used to designate a range of advanced versions of the Z80.

The APS designation was given to the most basic of these new chips limited to a certain speed and designed for 'commercial' as opposed to military or industrial use (Shvets, 2010). A manual from a second source supplier relates "Use in life support devices for systems must be expressly authorized. SGS Thomson Products are not authorized for use as critical components in life support devices or systems without the express written approval of the president of SGS Thomson Microelectronics." (SGS Thomson, 1990, 2) The suggested clock speed of 4Mhz for the circuit is consistent with the expectations for the Spectrum.

The Z8400 was not related to the Z8000, a 16 bit processor produced from 1979. This is likely why the chip also includes the designation 'Z80A'; whereas initially this might have designated an actual design, it now designates a compatibility standard.

(1) D23138C Read-Only Memory chip

This circuit is dated to between the 4th and 10th of April, 1983.

The markings suggest manufacture by NEC in Japan, a large semiconductor manufacturer. NEC operated factories internationally, including in Scotland. An article by Hotten in 1994 details the expansion of NEC's Scottish facilities; he relates:

> "NEC's current Scottish operation, opened in 1982 and employing 900 people, includes a design centre [...] Scotland's 'Silicon Glen' already produces 11 per cent of Europe's semiconductors, 35 [percent] of Europe's personal computers, and more than 50 per cent of its automated teller machines."

The chip is a D23128C, a type of programmable ROM that can be written to only one. The chip contains the operating system of the device, including routines for handling keyboard input, cassette input and output, loudspeaker output, screen and printer output, restarting the machine and evaluating BASIC commands. (O'Hara and Logan, 1983) ROMs remained relatively standard, but could be replaced by a chip produced by the same manufacturer using the same 'mask' or template. In some cases, it was also possible to fit a programmable ROM that could be updated, called an EPROM. (Marcelo, 2015)

(4) variants of a SN74LS157N multiplexer.

These circuits are dated to between the 4th and 10th of January.

The chip displays the Texas Instruments logo of a T surrounded by an approximation of the territorial shape of Texas, and features the inscription ‘Portugal’.

Circuits in position 3 and 4 are used to address the ‘lower’ 16K of RAM, which is organised in a matrix of 128 by 128 bytes (strings of eight binary digits). The first part is ‘latched’, suggesting the ‘row’ to be addressed with the first address from the ULA. The second circuit is then ‘latched’ with a subsequent address, which gives the column. Circuits 25 and 26 have a similar function for the ‘upper’ 32K of RAM.These circuits are required to allow the memory to address more than 16K of memory and are also responsible for adapting to use the correct ‘half’ of the faulty chips used. These logic chips are only necessary in the 48K version of the Spectrum. In the first iteration of the board design, an upgrade would be slotted to the edge of the board; including the logic and the additional memory. In later versions the memory is normally already included, but may be added with a ‘kit’ if it is not present (Thorn, 1984)
It is determined that these chips originated in Portugal from the inscription, likely from Maia, near Porto. A resolution from the Portuguese government for December of 1984 suggests they were prepared to invest money in the company in order to safeguard 700 jobs (and add thirty) and increase production by 100%. (CdM 50/84) The site expanded after Texas Instruments began a collaboration with Samsung from 1993, and the facility still exists as a major site of manufacturing. (Critical Manufacturing, 2014)

(8) 4116 8K RAM chips

These eight chips are dated to between the 30th May and 5th June, 1983.

These chips bear an inscription of an S and a H, which is consistent with the markings of the Siemens company at this time. The HYB designation is also unique to Siemens versions of the architecture. There is no clear marking of origin, though Siemens is a West German company.

They are 16K RAM chips. The lower RAM was used to store programs and data while the computer was operating. All variants of the Spectrum - including the 16K and 48K variants - would have this lower ROM. That said, it appears to have been manufactured by a variety of different companies. The chips were relatively ubiquitous, also being used in early variants of the PC (Williams 1982, 41)

(1) LM1889N Video Modulator Chip.

This chip is dated to between 18 and 24 April 1983.

The LM1889N is a video modulator used to produce the composite video signal required by an analogue television. A video signal will combine brightness, colour and synchronisation into one signal that can be broadcast or carried through a composite video cable. (Smith 2010, 147) These are also broken down to luminance - understood as the brightness and synchronisation component, and two colour difference values. (148) The LM1889N is part of a wider circuit, and depending on the ULA configuration, can produce either NTSC or PAL signals. (173)

Two wavy lines indicate production by National Semiconductor, an American company. National Semiconductor operated domestic plants in West Jordan, Utah, and subsidiaries in Singapore and Thailand, and possibly in Europe. In 1985, the company was forced to furlough employees. (UPI 1985) The company struggled to compete, but in the LM1889N they had a niche product that was a virtual necessity.

(8) TMS4532 chips

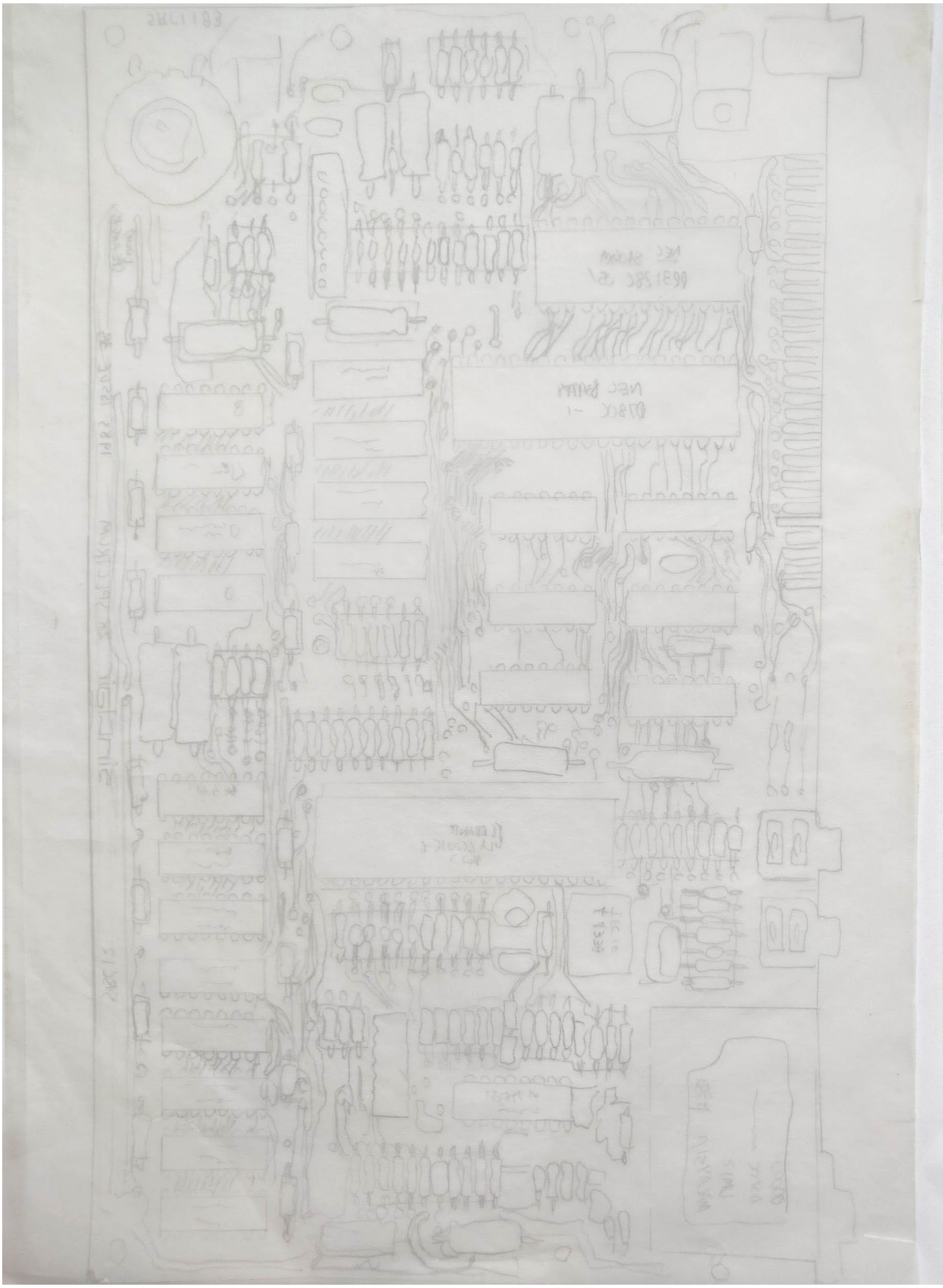
These chips are dated to between 8th and 14th August, 1983.
The chips are feature a shape roughly analogous to Texas and are identified with Texas Instruments. Markings imply manufacture in Singapore. The brightness of the white text on the black background varies considerably, with some chips faded.
The code reveals the chip is a 4532, and the chips are able to provide 32k bits of memory, but the chips were in fact designed to be 64k bit chips. These are part of the 'faulty' batch that were sold at a significant discount. During final assembly of the ZX Spectrum, the board will need to be configured depending on the set up of the chips. As such, it is necessary that all the chips in these eight slots have a matching final designation so that a consistent side of the memory is used. (Television Magazine 1986). The -4 designation of the chip implies that only the bottom part of memory is used. The manufacturer Memory is configured into 128 rows and 256 columns on the Texas Instruments version, but 256 rows and 128 columns in the version produced by Oki, a Japanese Manufacturer.

(1) SN74LS32N Multiplexer Chip

Dated to between 7 and 13 February, 1983.
Featuring a Texas shaped outline and the marking 'Portugal'.
The SN74LS32N is another multiplexer used to allow for the RAM to be addressed.
Dated to between 16 and 22 August of 1982, the previous year to all other integrated circuits.

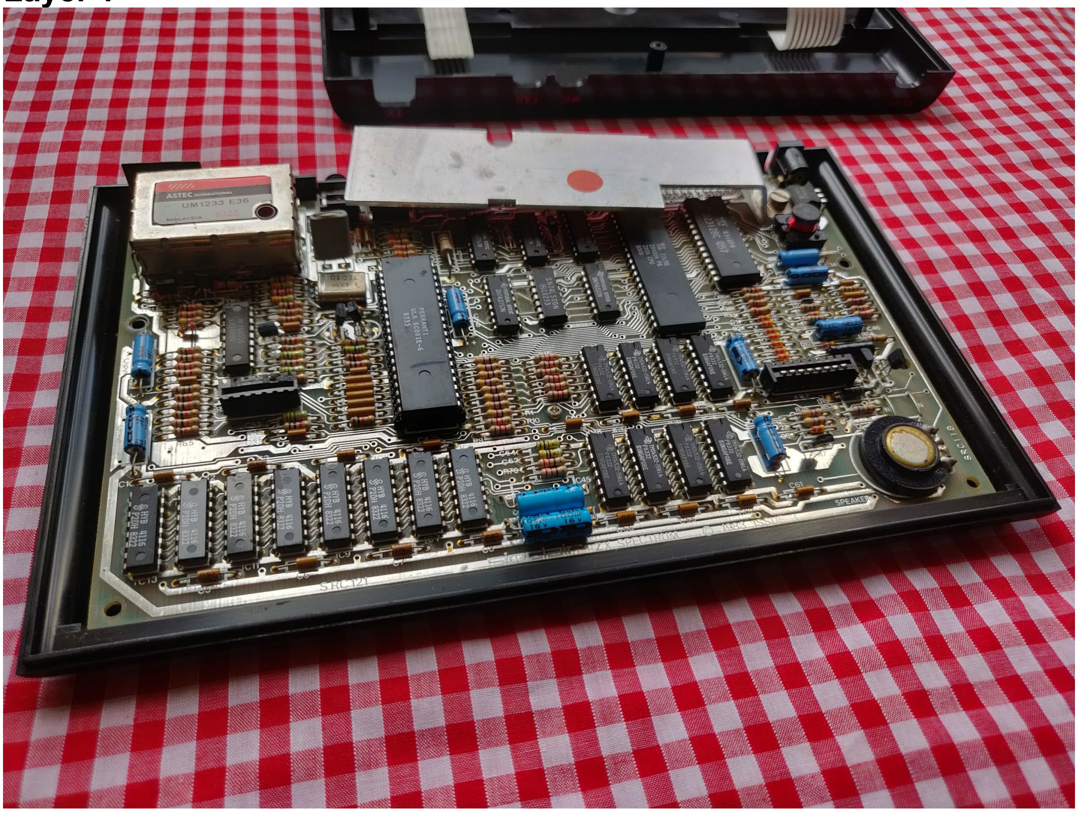
(1) SN72S00N Multiplexer Chip

The M suggests Motorola, an American electronics company based in Illinois.
The SN74S00N is another multiplexer. Motorola prided itself on becoming "the first company in the industry to offer all three Schottky digital logic products". (11) Motorola further announced their intention to expand their manufacturing capabilities including experimenting with automation; they report having plants in Tempe and Chandler, Arizona, Austin, Texas, East Kilbride in Scotland, Seoul and Hong Kong. (1982) The place of manufacture for this chip is, however, not clear.

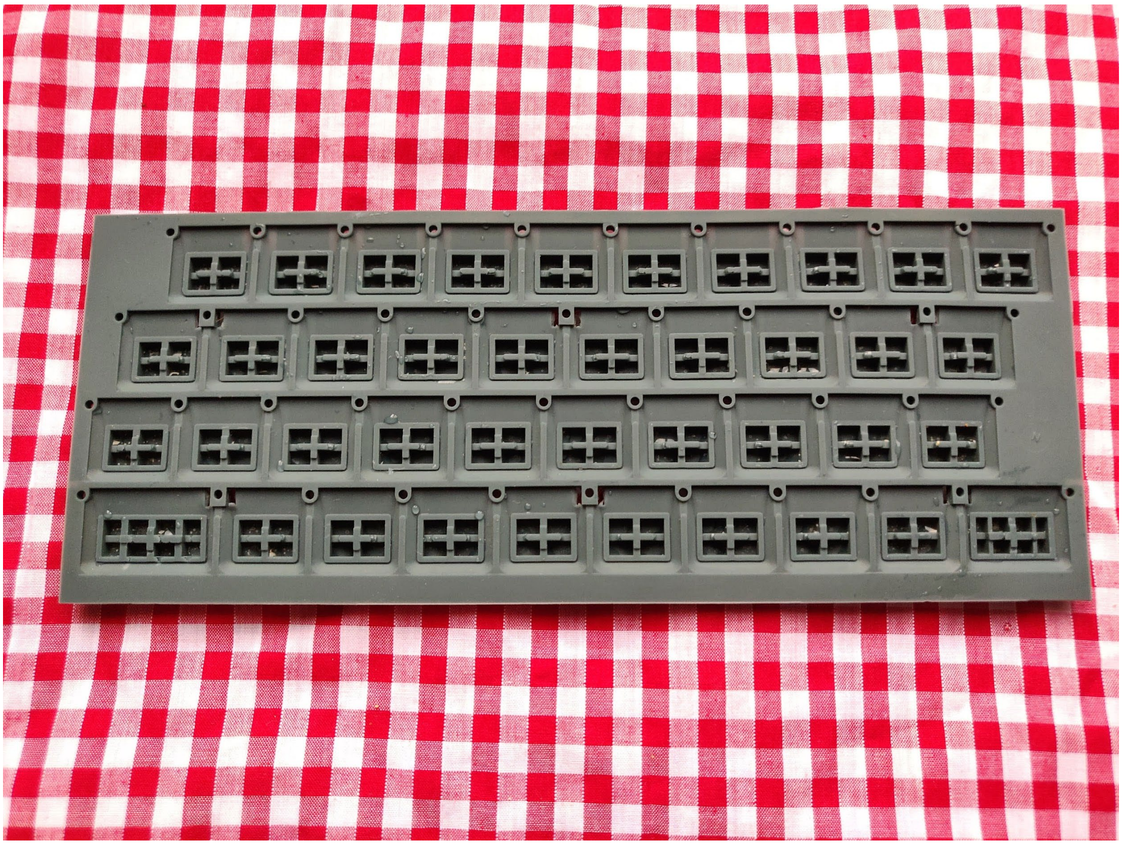


Sketch - Full Board

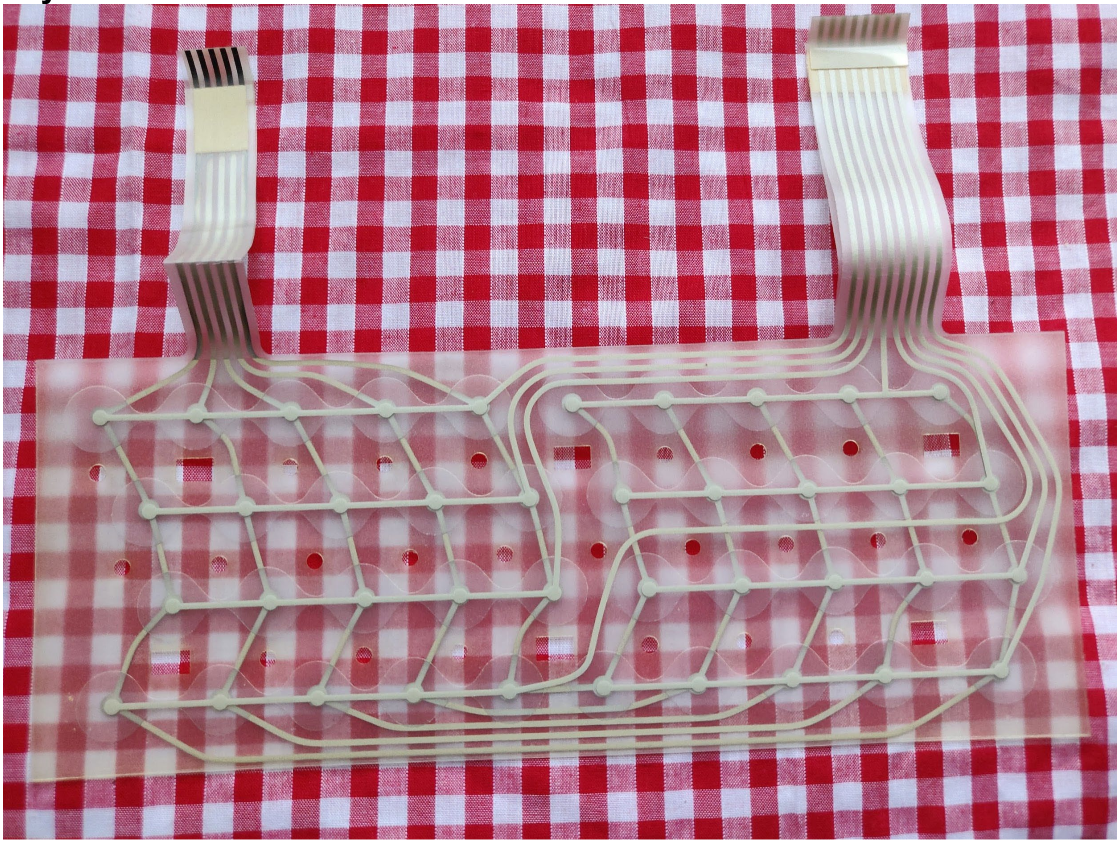
Layer 1



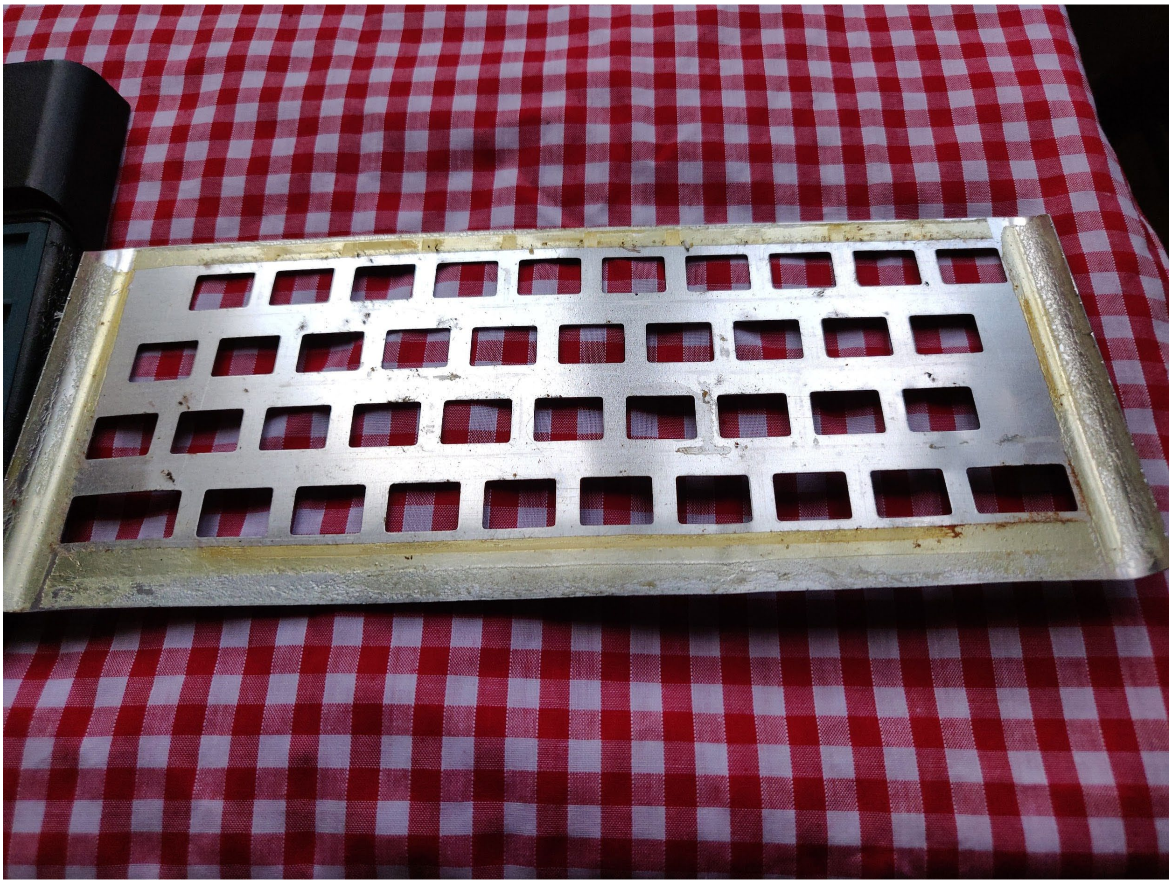
Layer 2, Layer 3



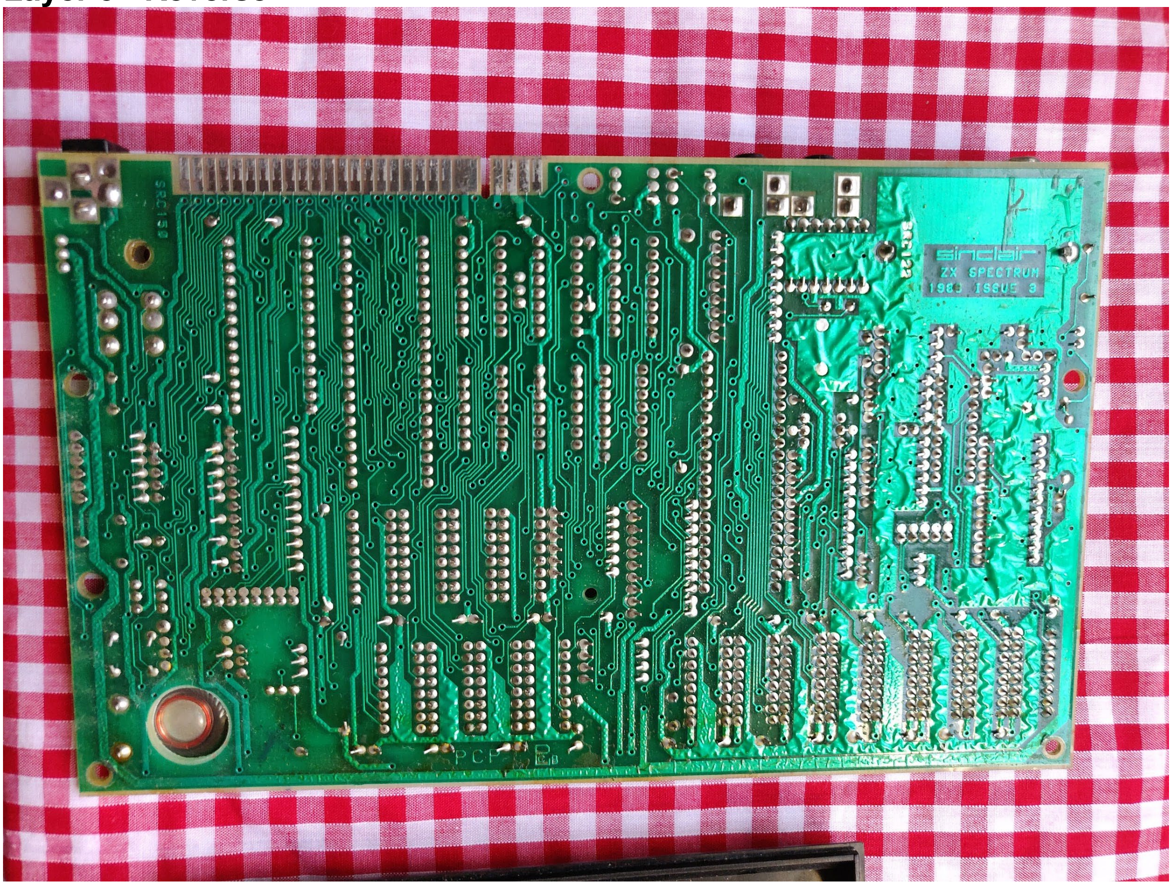
Layer 6 - Reverse



Layer 7 - Reverse

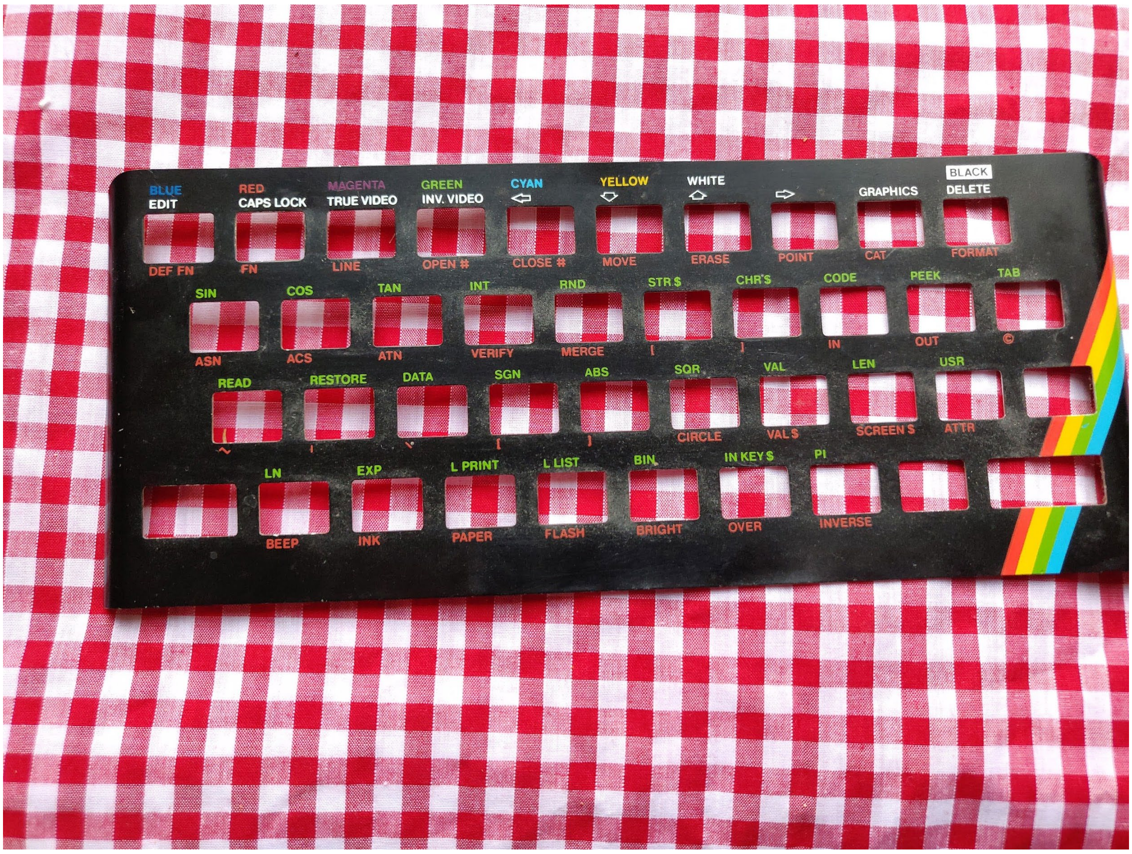


Layer 5 - Reverse



Layer 3 - Reverse

Layer 6 Front



Layer 5 Front

Discussion and Conclusions

Overview

The finds are consistent with the expectations for this type, but they show substantial diversity in provenance. Of the chips found, only one definitely appears to be from the UK - that from Ferranti. Five appear to be from elsewhere in Europe (Texas Industries in Portugal). Three appear to be from North America, but each from different manufacturers (Zilog, Motorola, National Semiconductor) Eight appear to be from Singapore (Texas Instruments) - a ninth implies it is also from Asia (NEC, Japan), but the same supplier operated factories in Scotland at that time also. Compared with the reference model, only the Uncommitted Logic Array, Video Modulator and Read Only Memory chip were comparable; most of the other chips featured different markings, and were from an entirely different provenance.

Significance

The findings confirm that technological artefacts are passed across national and continental borders. They further confirm the patchwork character of technology from this time period. Material is assembled from a variety of different sources and places, leading to inconsistencies in operation.

At the same time, the technology is 'born broken', in that it seems to be intentionally designed to use higher RAM chips that have lost half of their capability. While all finds are worthy of further study, the ULA is from a transitory and experimental period; it is not quite the first generation using the new method, but it is still not perfect as shown by later improvements.

Similarly, the Processor merits further investigation to see if it was truly manufactured by Zilog; this would suggest an outsourced product being brought in house. In addition, a number of chips are necessary to allow the computer to exist within an infrastructure within an environment that is still predominantly analogue.

Recommendations

A further investigation on the chips may have the possibility to reveal more about the origins - this is particularly the case with the processor, as similar finds have shown that the location of manufacture is sometimes printed on the reverse.

Removing the chips from the board would also allow them to be 'seated'; that is to say, an intermediary could be placed between the board and the chip itself, protecting the connections. Alternatively, the chips could be put through a process of destructive analysis - called decapsulation. It may also be possible to use X-Ray or 3D Scanning techniques to further build up our knowledge of them non-destructively.

Further devices could be studied this way, building up a wider knowledge base on the types of chips available. The other electrical components could also be addressed.

A2. Datecode Analysis

Aim

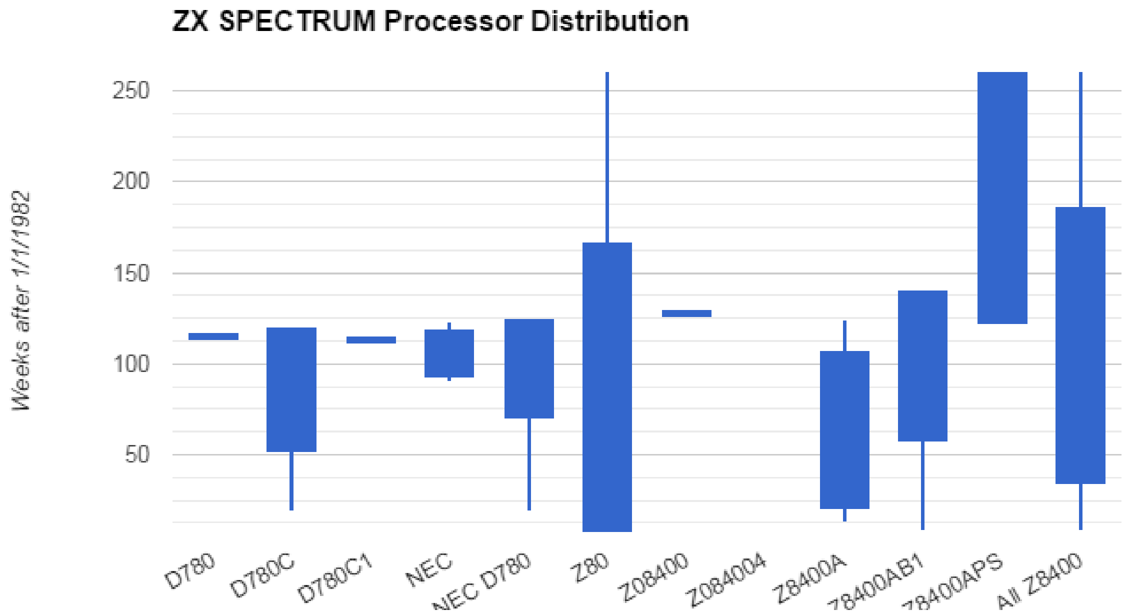
This section looks at a large sample of Spectrums collected as part of the Serial Numbers project, a project to catalogue all of the Spectrums still in existence. The project was initially started by Jake Warren, a ZX Spectrum collector. Many of the initial Serial Numbers were taken from postings on the online auction site eBay, and these consequently gives us a greater understanding of the value of the Spectrums according to their age and generation, though it is worth noting that often factors such as condition, current location, and the availability of original packaging or accompanying peripherals will also affect the price.

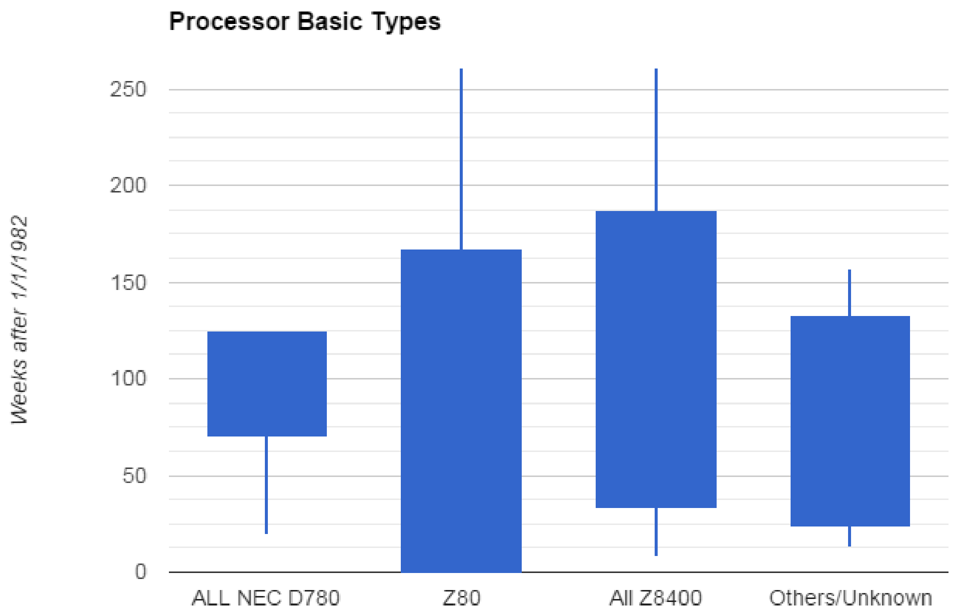
Methodology

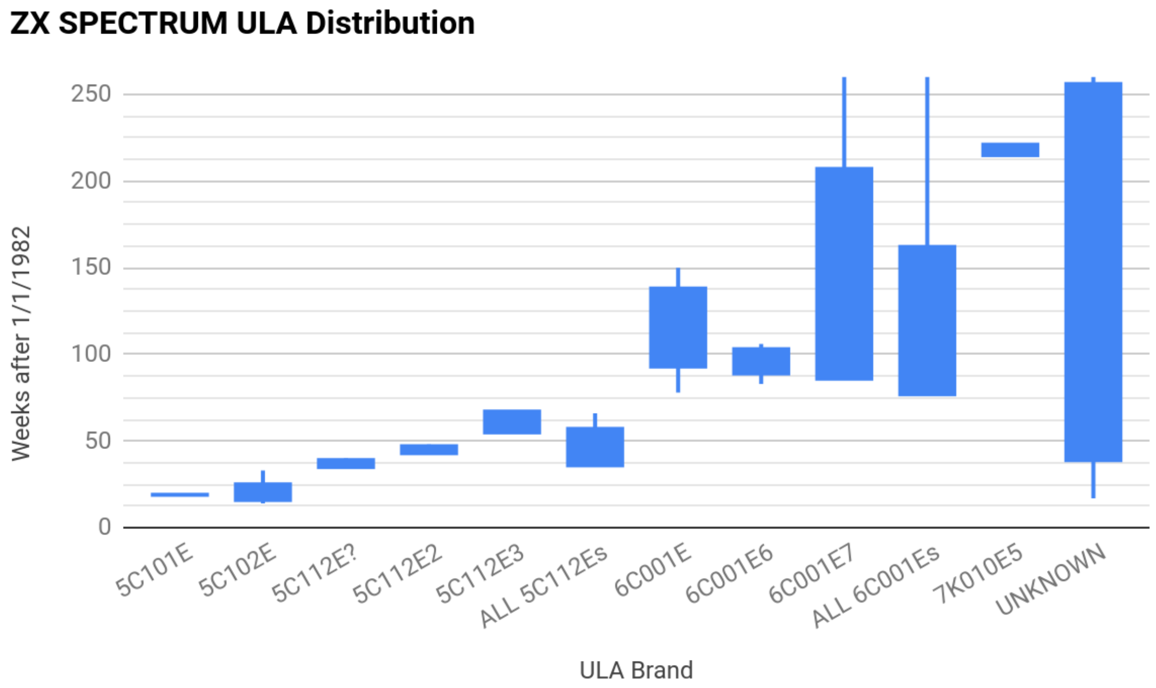
While the majority of entries in the database have only information directly related to the product’s auction entry, such as serial number, price and date of sale, in some cases more information was provided. Datecodes and Part numbers are more commonly provided for the Uncommitted Logic Array (117 part codes, 110 date codes) than for the Processor (59 part codes, 56 date codes); information on other parts is occasionally available, but not in a volume to make discernments about the distribution amongst chips across Spectrums as a whole. Board issues are better documented than component dates, with 3795 recording some information, though data is significantly more complete for the later Spectrums produced by Amstrad (+2,+3, +2a and +2b - 720 documented out of 943 total), presumably given that their board issue is generally (but not always) reflected in their external appearance. This could be misleading, however, since it is unclear whether identification is being done through judgement of external appearance or internal investigation.

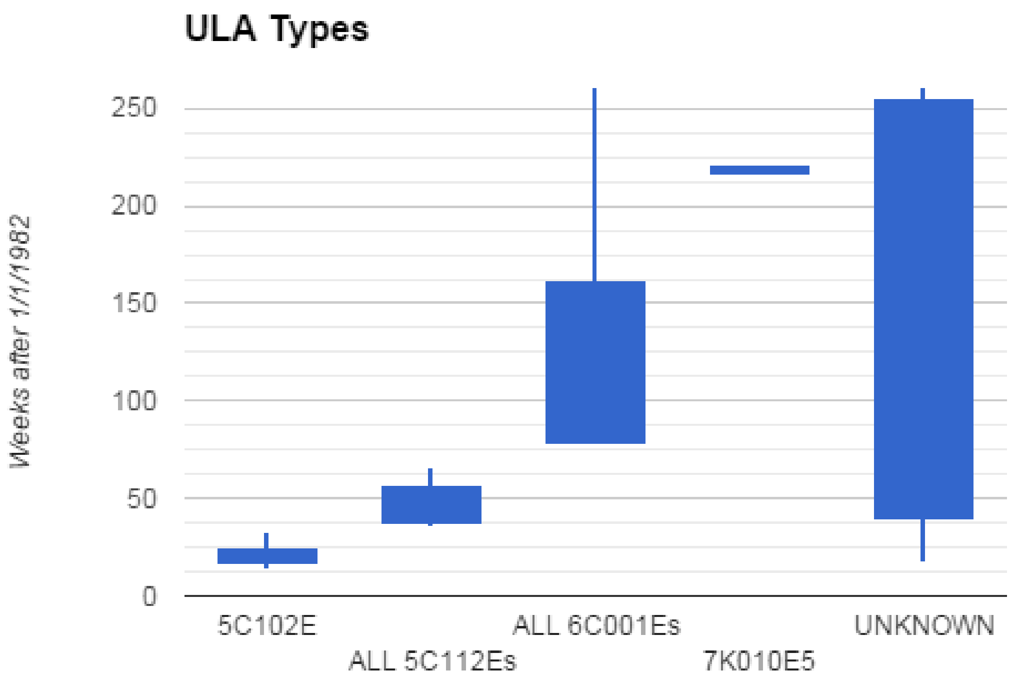
It is hoped that this study will encourage others to collect information about subcomponents within still existing Spectrums. It is not necessary that we refrain from collecting information about the current and recent sale value of objects; the data collected in this study shows that commercial concerns and the agendas of collectors can serve as an excellent motivator for interested parties to collect and share data. Further, this information can serve to inform us about how different generations and iterations of the machine are valued and diffused. Yet the gaps in the information are noticeable; in a database of almost 4500 entries, only around a hundred entries provide information that can be used to further our knowledge of how the machine’s subcomponents were collected, assembled and replaced over time. For new data to be collected successfully, a new research design must highlight the importance of information about subcomponents. Collectors should be educated to feel comfortable opening their devices and cataloguing their insides, a process which may take only twenty minutes but which can provide invaluable information now missing from technical archives. While there is not much hope of the machines still being under warranty, a lasting anxiety about damaging the machines persists among many, including both those who used the device as a consumer console but also those who have a high degree of ‘soft’ technical literacy through, for example, familiarity with programming. A new study might therefore include more detailed instructions on how to take apart the machines and document their insides, whether in writing, photographically, or both.

Results






ZX SPECTRUM ULA Distribution
Weeks after 1/1/1982
250
200
150
100
50
0
5C101E
5C102E
5C112E?
5C112E2
5C112E3
ALL 5C112Es
6C001E
6C001E6
6C001E7
ALL 6C001Es
7K010E5
UNKNOWN
ULA Brand


ULA Types
Weeks after 1/1/1982
250
200
150
100
50
0
5C102E
ALL 5C112Es
ALL 6C001Es
7K010E5
UNKNOWN

Looking at the types of Processor used in the ZX Spectrums inventoried, we see that the most common 'Z80' is not an actual Z80, but rather the alternate, or 'second sourced' version produced by the Japanese Nippon Electric Company (NEC). Also widely found are chips produced by companies now comprising STMicroelectronics - then called SGS Thompson - these are shown under the Z8400 heading. The company can be traced to the French nationalisation of its microchip industries in 1982, and the subsequent merger of these collectivised industries with Italian concerns. Other chips carry or likely carried the Zilog branding, but were not necessarily manufactured by Zilog. MOSTEK, the licensed 'second source' for Zilog chips, had initially been the only source, as Zilog, being a small start up, did not have their own fabrication facilities. It was only after the success of the original issue that allowed Zilog to press their investors at Exxon for funding to build fabrication facilities. We see a general competition between continents, though this is complicated by the fact that in all cases companies generally had operations internationally independent of where they were headquartered. Tracing national origin is also complicated by Zilog's labelling of other manufacturer's chips as their own, and by the fact that MOSTEC, the major and initial second supplier, appears to have been sold to the French-Italian bloc in 1985.

Diversification shows us the way that demand changes. Zilog components were not always designed to operate the same standard. The Z8400APS, for example, is a part designed to operate slower than most Z80 Processors, and its usage in two different machines across a wide period of time suggests they were only used when there was a shortage of supply. Similarly, the fact that use of NEC processors is concentrated in a relatively short period around the beginning of 1984 suggests that these were only used to make up for a supply shortfall; however, this particular brand of processor had been used predominantly in both previous Sinclair computers. This is the only seemingly significant concentration; Z8400 chips appear to be more prevalent slightly later, but there is significant overlap and therefore a high degree of interchangeability between different processors. With the exception of the APS variant, which was designed to run slower, and the NEC variants, which may have been avoided for cost or reliability reasons, there appears to have been no noticeable performance difference between the processors used across Spectrum devices.

The ULA, on the other hand, appears to be the key site of innovation. While the precise variant of processor used appears to be dependent upon supply, the ULA has a number of different versions which appear in sequence. There is naturally some overlap, but the general sequence follows a logical progression - 5C102E chips come to be replaced by 5C112E chips, which are replaced in turn by 6C001E variants. Each of these chip variants has further subdivisions, but these also show a linear progression. In the older machines, the ULA is typically dated between six and ten weeks after the Processor; this suggests that processors take time to arrive in the UK for manufacture. For more recently produced machines, the difference is less consistent; in some rare cases, the processor is newer than the ULA, further suggesting a shortage of Processors. Alternatively, the ULA is far newer, suggesting that the component was damaged and replaced. Overall, decreased consistency suggests supply problems, while the sequential replacement of the component driving memory and video access suggests an iterative approach to hardware development.

Discussion

Overview

The amount of data achievable through this process is naturally limited by the amount of data available; while I was able to append additional data, I was not able to perform a completely systematic study of all devices still in existence. Further, there would be no guarantee that these still existent devices are a perfect representation of all devices produced. The dataset exists as part of a methodology not used for archaeological research, but rather to evaluate the value of a certain device dependent upon its serial number. Collectors might use the serial number of a device to estimate its contents, guessing if it possesses a rare board design, but serial number appears to be a poor proxy for value in all but a few special cases - condition of the device, location and time of sale all appear to be more significant. As such, the dataset appears to have fallen out of use.

Significance

The practice of investigation explored in this section appears to be a valuable methodology. Growing out of an organic technique practiced not by experts, but by enthusiasts, it nonetheless bears a remarkable similarity to techniques of investigation used by archaeologists investigating primitive tool development. In these cases, lacking durable or complex artefacts, they are left to rely on numbers. The categorisation of large amounts of objects, alongside categorical descriptions of things like ‘wear’ or ‘shape’, allows us to understand how a process developed in a certain site or area. With date-codes, we are given substantially more information; often these might include the precise week of manufacture, or the factory in which the component was produced. While this requires some detective work, it is typically not a destructive procedure, and so can be used on devices in museums and private collections.

Recommendations

Other forms of investigation, such as x-ray analysis or electronic testing can further supplement this analysis. Better results would naturally come from a more comprehensive dataset originating out of an extensive process of engagement with curators and collectors. As such, this would provide an excellent starting point for a community archaeology project.

A3. Frequency Analysis

Aim

Kirkpatrick (2012) shows the importance of gaming magazines for defining a wider culture. The aim of the following study was to test the possibility for performing an analysis of a large corpus of data. Following successful retrieval of content, the archive would then be used to perform analysis on the text to look for the presence of certain themes.

Methodology

Scans were obtained of magazines from the three major gaming magazines related to the ZX Spectrum - *CRASH*, *Your Sinclair/Your Spectrum*, and *Sinclair User*. The machines were run through ABBY FIne Reader - an Optical Character Recognition program - in order to transcribe content. The resulting text was to be used to perform Topic Modelling, looking for themes in the writing through charting the occurrence of a certain number of words in proximity. The text would also be used to create an index of the machines.

At this stage, problems were discovered with the quality of text obtained; due to the varying formatting, including changes in font, colour, spacing and layout, the optical character recognition software frequently misidentified characters, to a point where the material was effectively unreadable and could not be analysed further. In order to salvage some use from the material, it was helpfully suggested to constrain the reading to alphanumeric characters (many characters were being read as symbols) and to remove all spaces from the resulting text. This provided for significant limitations, as it was not possible to perform analysis on the relationships between discrete words. As such, the study was able to produce only frequency counts compared to the overall text.

Results

See Fig 1-5. All magazines show a decrease in the prevalence of the word CODE. All magazines with the exception of CRASH show a decrease in the command GOTO - since this is a key part of BASIC's imperative coding style, the decrease of GOTO suggests a decrease in code listings. CRASH shows a greater incidence of the word PLAY, though this margin decreases over time. WORK shows some change, but no cohesive movement. BALL shows a steady increase, particularly in the run up to the 1990 World Cup, but then declines again.

Discussion

While this study did not allow for sufficient complexity of analysis, it did suggest that this type of analysis may be possible in the future if there is improvement in Optical Character Recognition, or if sufficient time could be allocated for manual data entry and cleaning.
It would also possibly be of value to incorporate this form of analysis to software and game code.

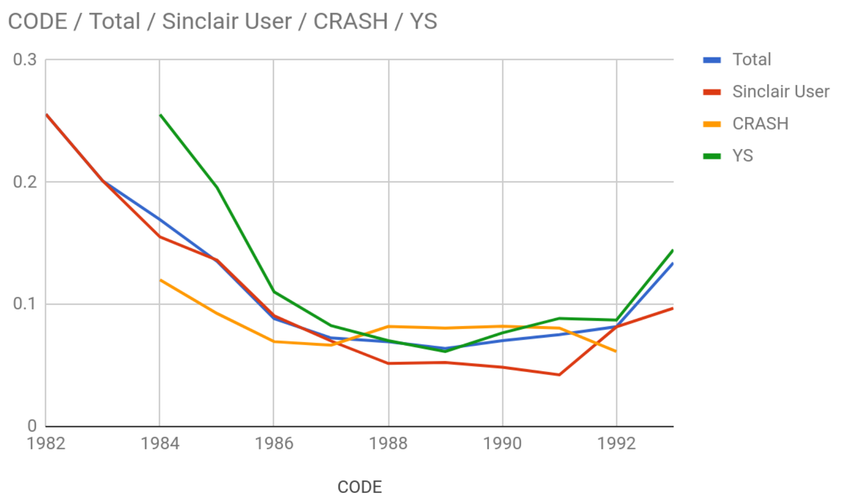


fig. 1

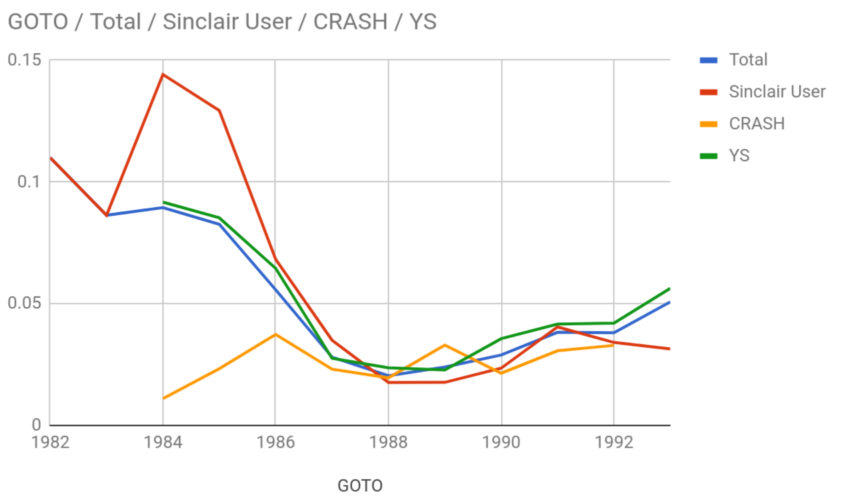


fig. 2

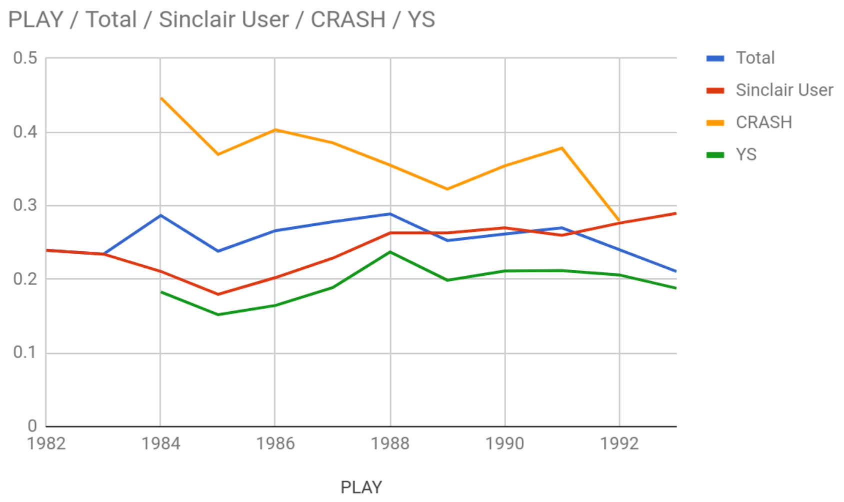
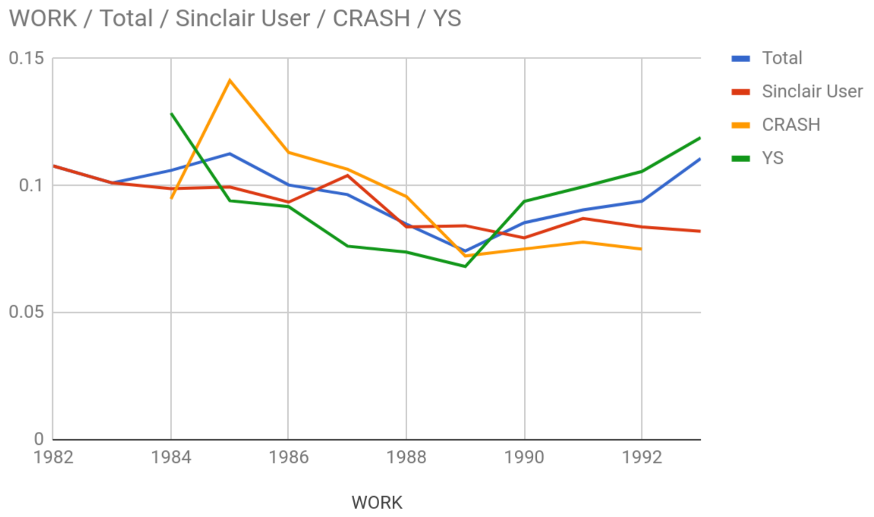
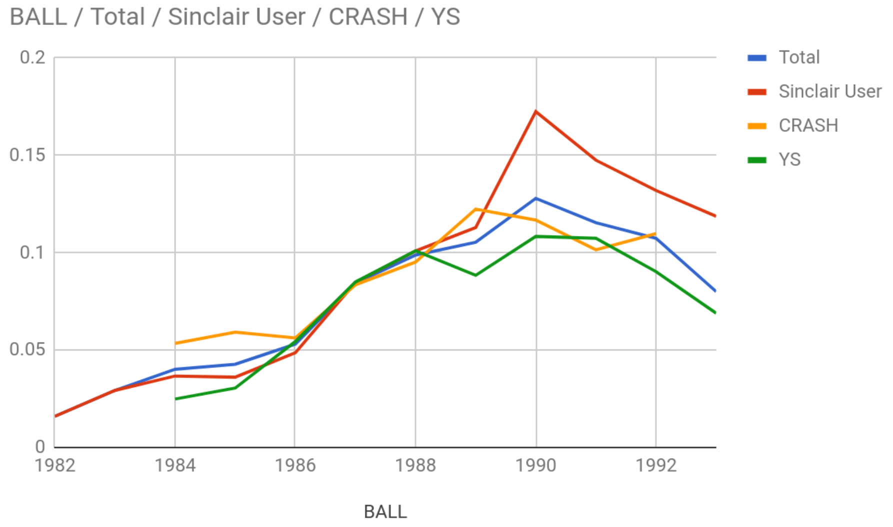


fig. 3



WORK / Total / Sinclair User / CRASH / YS
0.15
0.1
0.05
0
1982
1984
1986
1988
1990
1992
WORK
Total
Sinclair User
CRASH
YS

fig. 4



BALL / Total / Sinclair User / CRASH / YS
0.2
0.15
0.1
0.05
0
1982
1984
1986
1988
1990
1992
BALL
Total
Sinclair User
CRASH
YS

fig. 5

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Where possible this thesis has used archived versions of links using Internet Archive.
Archived D.P. stands for date of publication.

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