Materiality and Making in Experiential Ecologies

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Abstract

This practice-based thesis aims to inform new kinds of creative art and design practice that are engaged with the production and critique of new technological artefacts and systems. The core focus of this research is the role of materiality in making-processes as part of an ecology of technological experience, in other words an 'experiential ecology'.

Building on an existing, ontological argument that meaning is an a priori property of being, a proposition for materiality's intrinsic historicity is developed. It is argued that material things have meaning, anterior to interpretation, and that consequently meaning is connected to objects' pasts. It is then described how a principal implication of this understanding in the context of making with contemporary technologies is the adoption of an 'archaeological' approach to studying and producing artefacts which engages with such pre-existing meanings. It is suggested that a possible consequence of this archaeological engagement, for practitioners, is that they view their making activities as situated within ecologies of existing agencies and interactions of the material world into which practice intervenes. Building on Dewey's articulation of the connection of aesthetics to the circumstances of art's production aesthetic experience within such ecologies integrates the activity of making to the material histories of artefacts.

To inform making-practices thus conceived, a framework of five separate facets of materiality is developed: performative, distributed, spatio-temporal, fragile, and future-oriented. This framework is applied through a case study describing the making-process of a new artwork entitled 'Neurotic Armageddon Indicator'. The results of this application are examined to assess their contribution to the earlier introduced experiential ecology.

This practice-based research makes the following contributions: (i) a design framework that defines five facets of materiality and suggested applications and benefits, (ii) a series of experimental artworks that articulate and develop that framework and (iii) an articulation of experiential ecologies that offers ways for designers and artists to contextualise their production as part of a vibrant material world.

This thesis is dedicated to Gabriella Arrigoni with thanks for her patient understanding and constant supportiveness.

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Collaborators

Jamie Allen was the author of *Refractive Index*. My role was to assist Jamie (with Davide Gauthier) by writing computer code and working to realise the installation on site.

Alessandro Altavilla was the original author of *The Quiet Walk*. Alessandro and I jointly discussed the role of visualisation in the interaction and from this point I was considered as a co-author. I was chiefly responsible for technically implementing the iPhone app, particularly in its second revision and developed all the server side code.

Guy Schofield is the co-author of Burj Babil. Conceptual development of this work was jointly undertaken by us during the technical work. I wrote the points translation and glitching code, while Guy produced the computer model itself.

Help

I acknowledge the kind explanations of the following people. Where more specific help was given in the form of actual code or electronics, this is referenced at the appropriate point in the text which follows. I thank Tom Bartindale, John Bowers, Ko-le Chen, Phil Heslop, Dan Jackson, Karim Ladha, Sebastian Mellor, Guy Schofield and John Shearer.

Publications

The below publications were produced during the course of study.

Journals

Dec 2013, Data Materialism in Art Making. Tom Schofield, Far and Wide, *Leonardo Electronic Almanac*, Vol 19 No. 5, Editors: Ozden Sahin and Catherine M. Weir
July 2013, Null By Morse, Historical Optical Communication to Smartphones, Tom Schofield, *Leonardo*, Vol 46. No. 4. pp 344-352. 2013. Full paper.
Jan 2013, Machine Voices,Tom Schofield, *Artnodes*, n. 12. 2013. Short paper.

Conferences

July 2013, *Null By Morse, Historical Optical Communication to Smartphones*, Tom Schofield, Siggraph, 2013. Full paper.
June 2013, *Trigger Shift: Participatory Design of an Augmented Theatrical Performance with Young People*, Tom Schofield, John Vines, Tom Higham, Ed Carter, Mehmet Akten and Amy Golding, Creativity and Cognition, 2013. Full paper.
June 2013, *Indexicality and Visualization: Exploring Analogies with Art, Cinema and Photography*, Tom Schofield, Marian Dörk and Martyn Dade Robertson, Creativity and Cognition, 2013. Full paper.
June 2013, *Repeating the Past: Lessons for Critical Data Visualisation from the History of Computer Art*, Tom Schofield, ISEA2013. Short paper.
Sep 2012, *Macroscope and WikiVis: Two examples of data visualization inspired by material research practices*, Martyn Dade-Robertson and Tom Schofield, Digital Research 2012. Short paper.
Sep 2012, *Material Macroscope: Merging digital and physical research spaces through interaction with research objects*, Luis Hernan, Martyn Dade-Robertson and Tom Schofield, Digital Research 2012. Short paper.
Jun 2012, *Machine Autobiographies for Art Making*, Tom Schofield, Trans-disciplinary Imaging Conference, 2012. Full Paper.
Mar 2012, *Neurotic Armageddon Indicator: a Data Sculpture*, Tom Schofield, Artsit, Milan 2013. Poster.
Jan 2011, *Data Materialism in Art Making*, Tom Schofield, The Electronic Superhighway, Symposium, Tate Liverpool. Full paper.
April 2010, *Sticking Point*, Tom Schofield, Proceedings of Smart Graphics, 2010. Short paper and exhibition artwork.

Exhibitions

May 2014*, Me_asure*, (with John Bowers), FACT, Liverpool.
July 2013, *Neurotic Armageddon Indicator: a Data Sculpture*, Electronic Visualization and the Arts, London.
June 2013, *Null By Morse, Performing Optical Communication with Smartphones*, XCOAX.
June 2013, *Optimism Skywards*, Dear Angel, Globe Gallery, Newcastle upon Tyne, UK.
Oct 2012, *Null by Morse, Mark Inscriber*, Data Is Beautiful, Hungarian University of Fine Art, Budapest, Hungary.

Aug 2012, *Burj Babil*, Abandon Normal Devices Festival (A.N.D.), Cornerhouse, Manchester, UK.
Jun 2012, *Trigger Shift* Durham Brass Festival, UK.
Dec 2012, *Burj Babil*, Siggraph Asia, Hong Kong.

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Chapter 1. Introduction: Hello (Material) World

"Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it. But we are delivered over to it in the worst possible way when we regard it as something neutral" (Heidegger, 1954)

"I use technology in order to hate it more properly" (Paik, 2006)

1.1 Background and Related Work

This research is proposed at a time when the physical materiality of contemporary computing technologies is evident to researchers and publics alike. The popularisation of 3D printing, the 'Internet of Things'[1] and the ubiquitousness of computing devices all contribute to a growing popular vision of integrated physical and digital worlds. It is easy to forget that only a decade or two ago research describing the immateriality of digital content (Negroponte, 1996; Mitchell, 2000) seemed seminal to the point of ubiquitousness (Blanchette, 2011, pp. 1-8). The information stored in, and distributed by digital technologies, continues, though, to be seen as 'immaterial' and this view is as pernicious as it is pervasive (Kirschenbaum, 2008). It has been described how an understanding of digital as 'abstract zeroes and ones' (i.e. as immaterial) is afforded only by an a-technical understanding of the nature of computing systems (Blanchette, 2011, p. 2) which artificially separates computer systems from the data which they store and

[1] "…the integration of several technologies and communications solutions. Identification and tracking technologies, wired and wireless sensor and actuator networks, enhanced communication protocols (shared with the Next Generation Internet), and distributed intelligence for smart objects" (Atzori, Iera, & Morabito, 2010)

compute. Blanchette describes how this putative separation has permitted some researchers to make unfounded claims firstly about the nature of computer data (as lossless, free, infinitely fast), the design of systems (which should be primarily concerned with efficient abstraction), and the implications for culture (for instance as human memory achieves perfection by being augmented by infinite data storage) (2011, p. 4).

A number of scholars, however, have contributed to a dissolution of the 'myth' of immateriality in the context of designing and critiquing technological artefacts and systems. Their work will be reviewed more thoroughly in Chapters Two and Three but to summarise. Some have approached the material history of technology through specific artefacts asking how they can be used to critique contemporary technologies through both theory and practice (Ernst, 2003; Ernst, 2011; Flusser, 1990; Huhtamo, 2004; Huhtamo & Parikka, 2011; Zielinski, 2006). Others have attempted to identify how material concerns can be integrated into a design process through an engagement with formal qualities of materials (such as texture, colour, or form) (Jung & Stolterman, 2011; Wiberg, 2013). Some have described how the history of craft practices might provide models for materially-engaged making (Jung & Stolterman, 2012; Robles & Wiberg, 2010; Zoran, 2013).

Although the above research represents a number of significant critical advantages for thinking about the development of technologies and their implications in culture, efforts to apply materiality, as a concept, directly to design and the making-process remain in their infancy and suffer from a significant limitation. This limitation is that there is too explicit a focus on the formal qualities of materiality (Jung & Stolterman, 2012; Wiberg, 2013; Robles & Wiberg, 2010; Zoran, 2013) which is often discussed as a basis for 'hermeneutic'[2] (Jung & Stolterman, 2011, p. 402) approaches. Such approaches "examine[…] how material artifacts are

[2] While Jung & Stolterman, 2011, p. 402 appear to employ the term "hermeneutic" to mean 'interpretative' a further criticism would reject this rather glib use of the term, pointing to the long and contested pedigree of this concept in philosophy.

experienced and implicated in personal and social life" (Jung & Stolterman, 2011, p. 402). Such research, while offering valuable pathways for designers to explore audience/user responses to artefacts, represents a reductive approach to the rich philosophical history of the concept of materiality. Crucially it negates agential and performative approaches (such as in Barad, 2003; Drucker, 2013) to materiality which emphasise the way that materials *act* in the world. The nature of that action, and in particular the blurring of *a priori* distinctions between physical causality and human intentionality has been theorised by a number of authors (Harman, 2010; Latour, 2005; Law, 1992). The attribution of agency to objects as well as a sense of separation of materiality from human interpretation has lead to some authors to distinguish conceptually between 'objects' and 'things'[3] (Brown, 2001; Heidegger, 1971; Ingold, 2012). *This distinction presents an opportunity to revisit making-practices with material approaches that are not primarily focused on qualities and interpretation.*

In other research, some authors, artists and designers have explored how technological artefacts and systems may be thought of as part of an "ecology", taken as the "…interrelationship of a system and its environment" (Oxford Dictionary of English, 2010). Some research sees ecologies in cognitive terms where artefacts support or structure human cognition, action or perception (Hutchins, 1995; Gaver, 1991), where others focus on the way they contribute to the social organisation of work, (Bentley, et al., 1992; Heath & Luff, 1991; Sharrock & Anderson, 1993). More recent offerings though broaden the scope of ecological approaches by grounding ecologies in either explicitly material terms (Bennet, 2010; Ingold, 2012) or by describing them from an ontological standpoint Barad, 2003. Contemporaneously, some authors emphasise the social and psychological implications of living with technology (Dourish & Bell, 2011; McCarthy & Wright, 2004) focusing on how technological design shapes the environments where we

[3] Heidegger, does makes this distinction in a complex, partial and nuanced way which is discussed in more detail in Chapter 2.

live, work and play. Implicit in this latter point is the notion that we are *ecologically involved* with technology through such environments. Although ecologies have been related to materiality in a number of ways (Bennet, 2010; Ingold, 2012; Barad, 2003), *what is so far absent, is a developed account of how theories of materially founded ecologies, can substantively inform processes of experimental design and making.*

1.2 Road Map and Contributions

The overall contribution of this thesis is to inform making-practice engaged with development *for and with* computing technologies through a formulation and analysis of materiality, and though this to offer an alternative approach to theorizing our ecological relationship with them. The design and making-practice described is 'for' and 'with' technologies in the sense that it uses contemporary technologies (with) and is intended to contribute in a critical and speculative sense (as in Gaver & Martin, 2000) to the development of future ones (for). This contribution will be achieved in the following way.

First a variety of theoretical sources and practical art and research projects will be reviewed with a focus on how the concept of 'materiality' as been employed and with what effect. The goal is not to develop a *definition* of materiality but rather a series of features of interest, aspects which can be examined further through both practical and theoretical research. They are aspects of the concept which are potentially rich for making-practice and/or theoretically provocative. Subsequently, a number of sources which evoke the notion of an 'ecology' to discuss the way that we live with technology will be examined. From the synthesis and analysis of these sources and from the findings of an integrated, experimental art and design practice, a number of facets or categories of materiality will be defined and then applied in the following chapters. In Chapter Five, the facets of materiality are taken as a design framework and discussed through a case study of the integrated research and production process of an artwork.

In the final chapter, materiality, as part of a making-process, will be discussed as part of an ecology. The implications of an ecological perspective for both makers and audiences/users will be examined.

The three contributions of this thesis will now be summarised.

The major contribution of this thesis is to offer a materially informed approach to making through a framework of five facets of materiality. These facets are arrived at by an interconnected practice and theory based research process. This framework offers novel insights to makers by offering methods of embodying research in the process of making itself, informed by material concerns. The core focus of this framework is to fundamentally reposition makers in their attitude towards technological materials while simultaneously suggesting practical opportunities for intervention. This approach is oriented to artefacts themselves and seeks to reconstruct or repurpose artefacts through tailored technological intervention. Such interventions incorporate techniques from hardware hacking, creative programming and DIY electronics.

The second contribution of this thesis is to provide examples and analysis of this framework's application. A process of making, practically and theoretically informed by the five facets identified is discussed at length. It is described, for instance, how Null by Morse literally re-programmes smartphones to embody and perform research into historical communication media, Neurotic Armageddon Indicator rebuilds the 'Doomsday Clock' to query theories of representation, and (Refractive Index (2012)) *explores the relationship between screen content and physicality by applying fundamental concepts from computer programming to the context of 'screenology' (as in* Huhtamo, 2004*).*

The final contribution is, in response to the lack of explicit application of material-ecological theorisation to experimental making-processes, to develop, retrospectively to the practical research undertaken, an analysis of the three-way

relationship between materiality, ecologies and making, and to suggest potential directions for future research.

1.3 Motivation

This research is presented to contribute to a community of designers and artists and particularly to inform their making-practices. However, to offer such a contribution is to make a value judgement about the nature of what actually constitutes a benefit to an individual artist/designer. “In design we can see the representation of arguments about how life ought to be lived” (Margolin, quoted in Agid, 2012, p. 28). In a field as variegated as art and design this may be considered to be contentious. Benefits to makers could be categorised in different ways: as practical or methodological, as personal or developmental, as offering insight to future research, as financial even. When a design framework is intended to inform practice, it reifies certain values which are, of course, partial. Gaver explains how design *manifestos*, “suggest certain approaches to design as both as desirable and productive of future practice” (Gaver, 2012, p. 938), but is at pains to describe how *frameworks* avoid such “normative” stances, (Gaver, 2012, p. 938). Normativity, however, is inescapably implicit in the view of a particular kind of future practice, i.e. that produced by an approach to design. Unless productivity *of any kind whatsoever* is the goal of a framework, a certain kind of product is implicitly valued and proposed as a new norm.

In light of Gaver’s (2012) point above it is acknowledged, at this early stage that this thesis proposes a particular view of art and design practice whose theoretical motivations are implicit in the thesis as a whole but are clarified here. Approaches founded in materiality are posited as of benefit to those engaged in art and design practices with an emphasis on *techne* as a form of knowledge production[4]. That is

[4] The relationship between episteme (often translated as “knowledge”) and techne (often translated as “craft”) in ancient Greek philosophy is complex and interwoven (Parry, 2008). A full discussion of this is not within the scope of this thesis but

to say, practitioners whose work is engaged, with building, crafting, constructing, or sculpting conceived of as a contribution to knowledge irreducible to words. It will be explained later how particular kinds of views of the separation between knowledge and practice have become embedded in some forms of design practice as well as in some kinds of academic research (Ingold, 2013, pp. 1-2). The position adopted by this thesis is in opposition to this separation and it will find its use for those for whom this position has value.

The basis of this thesis in, and usefulness to such practices provides a distinct alternative to some other attempts to provide theoretical direction for art practice, born partially as responses to the digital age, over the last decade. For example, Nicolas Bourriaud (2002) proposed a “relational aesthetics”, an approach to contemporary art production, curation and critique which emphasized art’s potential as a site for social exchange. The canonical example of such practice, cited extensively by Bourriaud, is the artist Rirkrit Tiravanija whose art events based on cooking and eating with audiences represent a continuation of 1960s Fluxus happenings (Bourriaud, 2002, p. 25). It is not the intention here to denigrate such art practices but to suggest that to take the view that “…artistic praxis appears these days to be a rich loam for social experiments…” (2002, p. 9) is to potentially see practice as a site on which to apply theories. This is essentially a ‘top down’ approach to artwork that implicitly sees objects as expressions or representations of ideas. Bourriaud’s (2002, p. 9) claim that we are living in the final stage of a Debordian ‘Society of the Spectacle’ (Debord, 1995 [1968]) misreads the significance of digital exchange, seeing it, again, as immaterial. Curators Beryl Graham and Sarah Cook have attempted to position media art in continuation with contemporary art, particularly of the kind espoused by Bourriaud. Their approach.

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suffice to say that both are conceived of as forms of “knowing in the widest sense” (Heidegger, 1954, p5)

“explores the characteristics distinctive to new media art, including its immateriality and its questioning of time and space, and relates them to such contemporary art forms as video art, conceptual art, socially engaged art, and performance art.” (Graham & Cook, 2010)

Bourriaud, Graham and Cook’s research is intended principally for critics and curators (Bourriaud, 2002, p. 7; Graham & Cook, 2010, p. 1). As such it is perhaps unfair to criticize it for a lack of benefit for makers. But by emphasizing relationships to conceptual and contemporary art, and by omitting serious analysis of the process of art production in the former, and of technologies used to produce media art in the latter, the authors miss an opportunity to investigate the role of technology as part of practice.

The contribution of this research is intended for an audience of artists and designers who wish to found and develop their practice as embodying research, as a way of contributing to the production of knowledge. The implications of this approach and its congruence with recent positions in design research will be discussed shortly. Before that though, I will briefly describe how my own attitude towards art and design practice as a knowledge making activity was developed through my exposure to other disciplines through collaboration and participation in a particular kind of research environment. This short section, though autobiographical, is included to underscore the relevance of an approach which integrates practice and theory, to creative practitioners by highlighting the transformational effect such ideas had on my own development as an artist and subsequently, designer.

My undergraduate education as an artist comprised of studio practice with tutorials and occasional theoretical seminars and lectures as is typical in the UK. Although some effort was made by the faculty to integrate practice and theory, they remained formally separated in the both the study timetable and even the locations in which they took place (lecture theatres and seminar rooms on the one hand,

studio environments on the other). Further, and this experience may be particular to the institutions in which I was taught, I noticed that there was a division of labour between lecturers; broadly, the practicing artists taught studio, those with Phds taught theory. Exacerbating an already disjointed system was the problem that there appeared to be no coordinated approach to what kind of theory should and should not be taught. Lectures were given on an ad hoc and occasional basis reflecting the research interests of particular academics. The result was that my practice as an artist was mostly uninformed by theory until my application to be an Arts and Humanities Research Council (AHRC) funded, Master of Fine Art student, obliged me to reconceive of my practice as research. Around the same time I became involved with a new Masters of Research course in Digital Media in 2008. I 'sat in' on classes and began to learn the basics of computer programming and electronics. It was through this environment that I became exposed to a real research environment for the first time. The lab in which this course was based had a wide variety of researchers across Interaction Design, Media Art, Machine Learning, and Human Computer Interaction. As the engagement with technology in my artwork grew, so did a desire to extend my practice into an engagement with others through collaboration. Through such collaboration, I became interested in the methodologies of collaborators with different backgrounds, particularly in their processes of ideation and prototyping. My art practice became more and more integrated with design and an engagement with developing with open source technologies caused me to see parallels in technological, conceptual and aesthetic development processes. For this reason, throughout this thesis, I avoid making strong distinctions between art and design. Although some current threads of experimental design practice, in particular Critical Design (Dunne & Raby, 2013), exhibit strong conceptual, aesthetic and formal similarities with my work, I do not explicitly position my work as Critical Design. In common with Bardzell & Bardzel (2013) I am troubled by the basis on which Dunne and Raby's description of Critical Design explicitly rejects a description of their products as artworks. (Bardzell & Bardzel, 2013, p. 3299) rightly point out that Dunne and Raby's claim that art is not part of the everyday is demonstrably not true. Bardzell and Bardzel

cite examples of “teenagers in high school bands and ballet classes, art house cinema, sacred art…” (2013, p. 3299) and I add that this is exactly the juncture at which the blurring of design, critical or otherwise, and art becomes interesting and provocative[5]. It is here, at the juncture of everyday life with technologies, art practice and design, that this practice-based research is positioned[6].

1.4 Methodology

Although the road map described earlier indicates a strict formal research procedure, this thesis describes the production of a series of artworks whose stages of ideation, production, display, and iteration were anything but clearly delineated and whose relationship to its formalisation in writing is complex and not easily expressed. To describe the process and findings of this research as clearly as possible some production timelines have been simplified and their relationship to literary research separated into more or less clear themes or implications. In this sense the thesis owes much to the definition of an annotated portfolio (Bowers, 2012)[7]. The discussion of temporality in the production of *Null by Morse* is one example of such a gathering of implications (see Chapter 4). The production process of this artwork was long, technically complicated, marred by imperfect knowledge of some electronics fundamentals, assisted by colleagues (as described), anecdotal, and driven by a personal interest in the electric telegraph. The intention is not to misrepresent the nature of my practical research which is inevitably and necessarily messy, opportunistic and occasional, and I have preserved the significance that particular practical and theoretical findings had for one another. Instead I have attempted to consolidate these findings in ways that will make the thesis’ contribution clearer and more useful to other practitioners. The

[5] Indeed this position is supported (art) historically, in particular by 1970s art practices such as happenings and the Fluxus movement which sought to “blur art and life” (Kaprow, 2003).

[6] A long term aspiration which is not addressed within the scope of this thesis, but which nonetheless motivates it, is to consider the implications of the processes and methods described here in the context of pedagogy for practitioners across the spectrum of art and design.

[7] This point is expanded later.

risk of this approach is of representing my research practice as one of a series of logical and inevitable conclusions as an abstract plan rather than a series of situated actions[8] (Suchman, 2007) and it is this reading which I warn against here in the introduction. The framework which is later proposed is not to be taken as proscriptive, but rather, productive and as representing a support to a particular kind of practice, driven by particular values as described. Despite this lengthy series of acknowledgements and concessions, a number of clear research methods can be identified.

1.4.1 Literature Review

A careful study of relevant literature was undertaken and integrated with practice-based research. Literature was reviewed firstly which had correspondence with on-going projects. Work was then was taxonomised and clear aims for the review were developed as described in Chapters Two and Three. This provoked further reading. The literature review has been formally separated from discussion of the practice-based research undertaken for a number of reasons. First, there was a desire to investigate existing research on its own terms, reserving close comparison to the practice-based research undertaken for later integration with the discussion of that practice. There was also a recognition that while this thesis supports an understanding of artefacts articulating knowledge (as discussed in the following section), there are other modes of producing knowledge which have value in themselves and which may complement the former. A two-stage approach was consequently adopted where a relatively broad range of work is reviewed in Chapter 2 and Chapter 3, before a more comparative and processual discussion is offered through Chapter 4 and Chapter 5.

1.4.2 Research Through Design

This practice-based research is in many aspects consistent with a “research through design” (Frayling, 1993/4) approach and some key aspects of this methodology will now be briefly explored.

[8] Suchman’s work is discussed in more detail in Chapters 2 and 3

The development of this thesis has been a gradual one which occurred through the practical projects undertaken as well as being informed by findings from the literature review. This is stated to emphasize the fact that the practical research should in no way be taken as a kind of exemplum intended to illustrate particular theories but rather as a way of articulating and producing knowledge. Neither are findings post-rationalized by fitting post-hoc categories on to existing artworks, a practice which "[detaches an artwork] from the matrix of its production" (Carter, 2004, p. xi) and reduces them to "mere illustrations" (Gaver, 2012, p. 944). Rather the contributions presented here have been a result of *thinking though practice* as described here by Ingold: "To practise this method is not to describe the world or represent it, but to open up our perception to what is going on there so that we, in turn, can respond to it" (Ingold, 2013, p. 7). These artworks "embody the myriad choices made by their designers with a definiteness and level of detail that would be difficult or impossible to attain in a written (or diagrammatic) account." (Gaver, 2012, p. 944) and as such should be considered an integral, indeed dominant, part of this research. Such an approach, as mentioned, suggests a close correspondence with a "research through design" (Frayling, 1993/4) approach: The relationship between concept and practice in this thesis is consistent with recent literature that discusses various possible relationships between theory and design, such as (Bowers, 2012; Gaver W. , 2012). Such approaches to design are focused on "exploring and speculating, particularising and diversifying, and […] manifest[ing] the results in the form of *new, conceptually rich artefacts*" (Gaver, 2012, p. 937) [emphasis added]. The works of art and design in this thesis are discussed to explore their relationship with an emerging design framework. In this sense, earlier works particularly, could also be described as the subject of an 'annotated portfolio' (Bowers, 2012; Gaver, 2012). An annotated portfolio is;

"…a way of organising what can be learned from design in terms of annotations which formulate and highlight features of interest in a portfolio, while reciprocally gaining their sense and significance from their connection to the artefacts themselves." (Bowers, 2012, p. 76)

There is, in summary, a mutually constitutive relationship between the theoretical argument and making-practices described here which is, I suggest, 'written in' to the artworks themselves. For example, it will be later described how an artwork, *Mark Inscriber*, does not simply 'respond to' or 'represent' material histories of counting but rather *acts* as part of that history. It contributes (in this case) to an ongoing research process into the materiality of counting practices. Research through art and design is research "where the thinking is, so to speak, *embodied in the artefact*" (Frayling, 1993/4, p. 5) [emphasis in original]. The written thesis which accompanies the documentation of practical work is proposed as a compliment to the knowledge embodied in the artefacts produced. It is intended to explore them at different stages of the process. It is recognized that this written thesis represents an opportunity to enhance the value to the academic community of the research undertaken by conforming to academic standards and that this is not to the detriment of the points made in the preceding paragraphs.

1.4.3 Media Archaeology

In later sections it will be described how a clear implication of early practice-based research undertaken suggested a strong practical and theoretical focus on the history of technological objects. Such an approach is consistent with a description of Media Archaeology which investigates, "alternate histories of suppressed, neglected, and forgotten media that do not point teleologically to the present media-cultural condition…" (Huhtamo & Parikka, 2011). A Media Archaeological approach acknowledges the embodiment of knowledge in the artefacts of the past and seeks to study it through analysis and also through practice. The methodological implications of Media Archaeology will be explored more fully in Chapter 2 but at this juncture the points to be emphasized most completely are the integration of technical, forensic[9] (Kirschenbaum, 2008), investigation and cultural analysis. Media Archaeology, while not strictly a single method in itself represents

[9] Matthew Kirschenbaum's notion of 'forensic' materiality is discussed in more detail in 2.1.4.

an orientation towards a collection of particular methods of practice based research emphasizing hacking, retro-fitting and repurposing old technologies.

1.4.4 Prototyping

Prototypes are “a core means of exploring and expressing designs for interactive computer artifacts...” (Houde & Hill, 1997) and the works described in this thesis have all been developed through an iterative prototyping cycle. Given the predominant focus on the making-process throughout this thesis, and the emphasis given to experimentation and exploration of materials, as well as the previous reference to “research through design” (Frayling, 1993/4), it seems appropriate to view works produced as, to a significant degree, prototypical. Houde and Hill’s question, “what do prototypes prototype?” (1997) though, is predicated on a view of prototypes as part of an industrial development cycle whose eventual product will be an artefact for sale. Their approach is of most value once a fairly developed sense has been defined of what the object to be designed itself *is*. They propose a three-way axis for prototyping {see Figure 1} with “Role”, “Implementation” and “Look and Feel”, given as the dimensions. This model is referenced here by way of contrast to indicate that where a more conventional prototype is calibrated to ask questions about a design (perhaps of the kind suggested by this model), the prototyping process described in this thesis *begins a stage earlier*. In this thesis the “what” of “what do prototypes prototype?” (Houde & Hill, 1997) is the relationship between materiality and the making-process itself. In this sense it could be considered as a kind of ‘meta-prototyping’ a study of what material concerns *actually underlie* the prototyping sensibility.

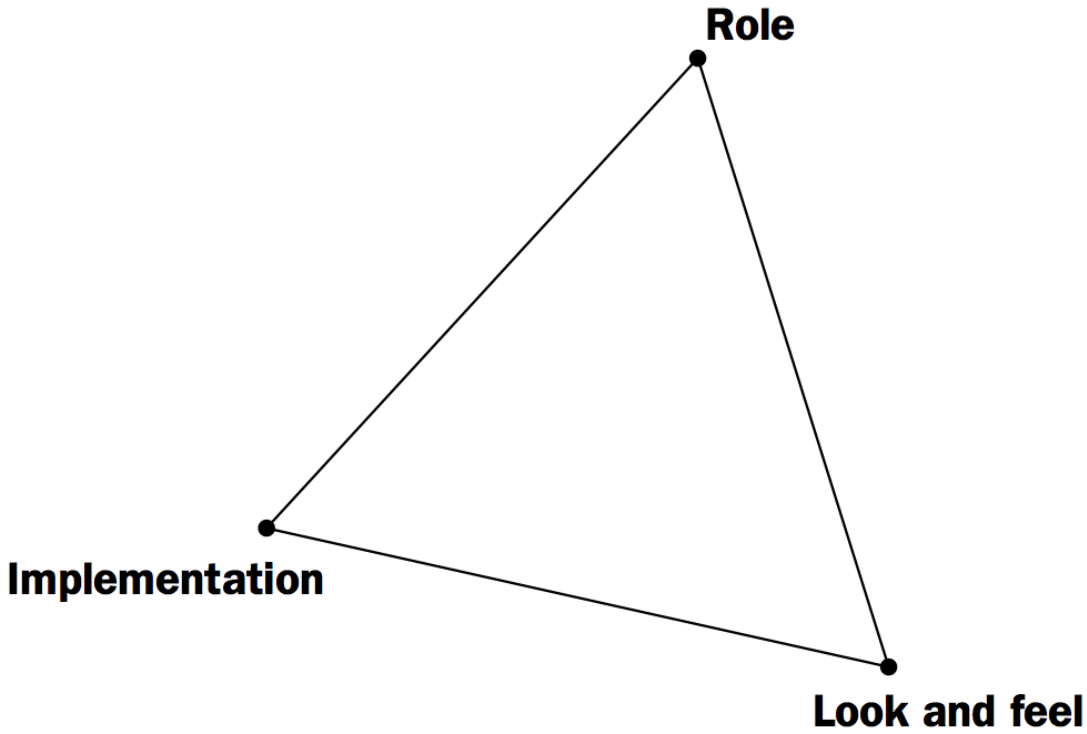

Figure 1: A Model of What Prototypes Prototype, Houde & Hill, 1997

The specific kinds of design and making activities conducted will, of course, be described in detail throughout this thesis but, to prefigure this, these can be abstracted to the following.

Computer programming has been a core activity throughout the research conducted. Projects described have been developed in C, C++, CSS, HTML, Java, JavaScript, PHP, and Python. Each project without exception has required new technical competencies and from a short, hobbyist background in the Java-based language Processing, a range of skills have been acquired. This point is made to emphasise that a dominant, daily practice of the experimental making-practice described in this thesis has been a struggle with a sharp learning curve with the technical demands of the projects described. Many long hours consulting forums, writing programmes in pseudo-code before re-iterating designs, asking advice from colleagues, and above all practicing and experimenting, have been spent. These practices were motivated by a sense that to critically engage with contemporary technology demands a 'below the hood' understanding of how it works. To re-work, re-purpose, mash-up and take apart the aspects which underlie the functionality of our quotidian technological world requires that we understand, to the extent that this is possible, how it works. Early stages of projects invariably involved (and still involve) *an integrated technical and conceptual understanding*. For instance, the research process of *Null By Morse* (see Chapter 4) required an implementation of a Morse Code receiver to be made. This process was closely involved with a historical study of the development of communications protocols. These research threads were mutually supportive as the historical study brought an increased understanding of the technical strengths and weaknesses of the protocol and technical work provoked further research questions[10].

[10] In this instance these questions concerned the implementation of the protocol in different media such as light, radio, and sound. More details are found in Chapter 4 .

A working knowledge of *basic electronics* was also developed through the research process. In exactly the same way that studying communications protocols was intrinsic to an earlier research project, the experience of designing, and having printed circuit boards manufactured, and interfacing with networking hardware was integral to the development of *Neurotic Armageddon Indicator*. In this case, learning about the functionality of the chip which drives the LED display was conceived of as an historical material engagement, integral to the research process. This is described in detail in Chapter 5.

1.5 Works Described

Throughout this thesis the making process of a set of media artworks is described. The sections below provide technical descriptions of six works produced. Of these, four are described in detail during the thesis: *Null by Morse*, *Mark Inscriber*, *Neurotic Armageddon Indicator* and *Refractive Index*. The development of the final two: *1280*1024* and *The Quiet Walk* contributed to earlier stages of the development of the framework of materiality proposed in this thesis but to a lesser degree. This thesis attempts to vividly describe the process of making with the materiality of contemporary computing technologies with a particular focus on the development and guiding influence of material facets. It was essential to preserve as much detail of this making as possible in order to avoid a reductive and impoverished account of these complex and materially specific processes. A decision was therefore taken in favour of depth rather than breadth. The development of the facets of materiality is described in Chapter 4 through a discussion of *Null by Morse* and *Mark Inscriber*. These works were begun early in the research period and were vital in developing and understanding this contribution. *1280*1024* and *The Quiet Walk* were produced roughly contemporaneously with *Null by Morse* and *Mark Inscriber* and were responsible to a lesser degree for some of the findings made. *Neurotic Armageddon Indicator* is described in detail throughout Chapter 5. This work was produced in later stages of the research and 5.1 describes how findings from the production of *Null by Morse* and *Mark Inscriber* were applied as guiding principles. Chapter 6 examines *Refractive Index* retrospectively to explore some of the ecological implications

raised by a focus on making with materiality. This work was produced over a long period of development and was iterated several times for different sites of display and exhibition. Because of this long time scale, a discussion of different points during the production of *Refractive Index* could have been included in both Chapters 4 and 5. It forms the basis of discussion in Chapter 6 because its production provided a number of locations (in terms of the cities and architectural contexts where it was shown and in the technical infrastructure supporting it) which were particularly resonant with the characterization of ecology proposed.

1.5.1 Null By Morse

A series of Morse messages is transmitted automatically by a military signalling lamp. The messages are drawn from the history of Morse and telegraphy. A custom app for iPhone and Android uses the phone's camera to identify the changing light levels of the lamp and the associated timings. The app then decodes the Morse and displays the message on the screen on top of the camera image.

Null By Morse (NBM) consists of two main parts: (i) an automatically controlled military signaling lamp, and (ii) a smartphone installed on a plinth {Figure 2}. The phone's camera points toward the lamp. A Quick Response (QR) code printed on the plinth provides a link for Android phone users to download a version of the app that is running on the installation phone. The lamp has been retrofitted. Its original incandescent bulb has been replaced by an LED bulb designed for car sidelights, which was chosen to allow for faster transmission. The bulb's flashing is controlled with an Arduino microcontroller ((Arduino, 2014)). A simple circuit uses a transistor to switch current on and off to the bulb. On the installation phone, an app that I developed (using Openframeworks (2013) wrappers for iOS and Android operating systems) uses the phone's camera to take measurements of pixel brightness. The area in which the brightness level is taken is defined by the user, who taps on the camera image over the lamp. The software uses the differing brightness levels to infer whether the lamp is on or off. The timing interval defines a dot, dash, inter-character or inter-word space. The app displays the messages it has received on

the screen. In some exhibited versions of the work, users can also download the app and use it in the gallery space on their own Android phones. All code for this project is freely available on a Github source code repository. See {Appendix 2} for code.

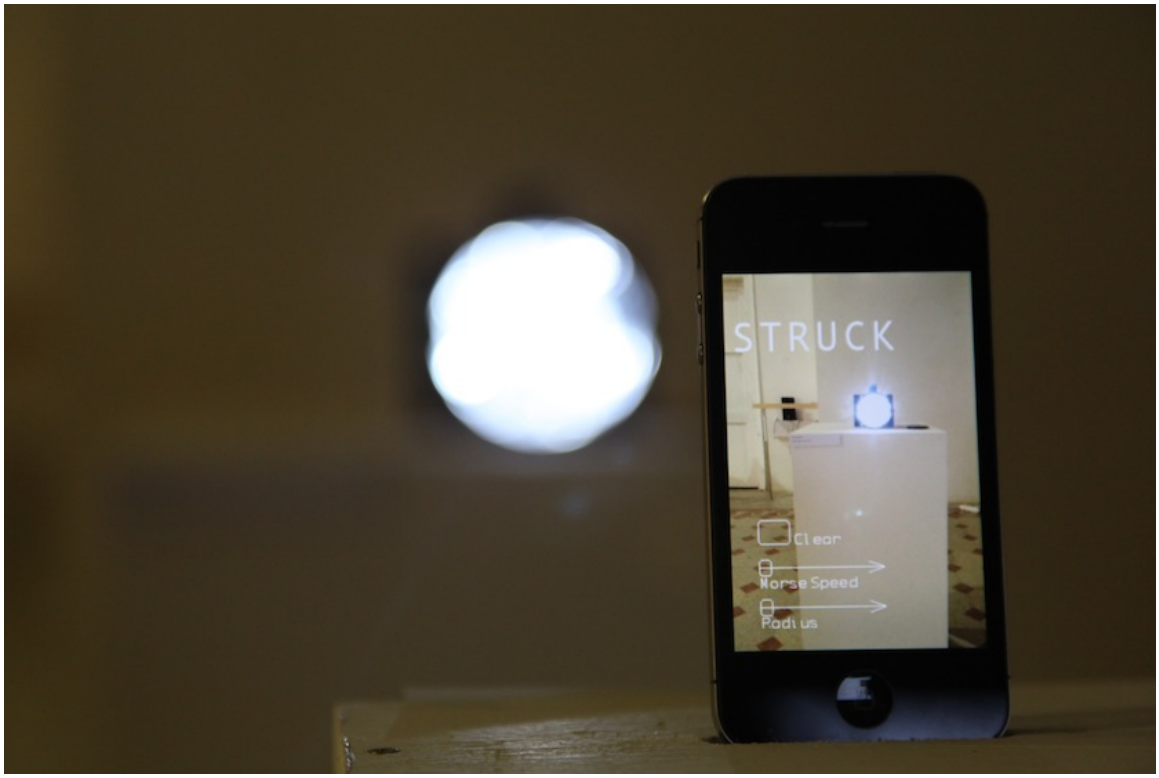

Figure 2: Null By Morse, Installation View

1.5.2 Mark Inscriber

A horizontal linear bearing supports a small metal carriage. On the carriage a mechanism causes a small blade to shoot forward and mark the wall. The lateral movement of the carriage is controlled by a motor-driven chain. The blade cuts a short vertical mark in the wall and the carriage advances a short distance. This process is repeated until the length of the bearing has been covered. The carriage then returns to exactly the same starting point and the process is repeated. Each iteration causes the marks to be cut more deeply into the wall.

The cutting blade mechanism consists of a sharpened piece of steel which was[11] welded to a 12v solenoid. An Arduino (2014) microcontroller causes a transistor to switch current to the solenoid. The solenoid is actually overloaded with 48v and three amps to maximise the cutting force. The movement of the carriage is controlled by a stepper motor which, in turn, is also controlled by the Arduino.

1.5.3 Neurotic Armageddon Indicator

Neurotic Armageddon Indicator (NAI) is an installation artwork which visualizes the 'Doomsday Clock', a symbolic clock maintained by an academic journal, *The Bulletin of Atomic Scientists* (henceforth *The Bulletin*) ((Bulletin of the Atomic Scientists, 2013)). The Doomsday Clock represents the proximity to Armageddon expressed as minutes to midnight where midnight signals the advent of nuclear holocaust. NAI takes the form of a small, 1980s-style wall clock (or on a stand as a desktop clock {Figure 3}) with a black plastic shell and red LED, 7 digit numeral displays {see Figure 24}.

The artwork is in two pieces. One is a small computer programme running on a server which 'scrapes' the content of the bulletin's home page as often as possible[12]. The other is the clock itself.

[11] I wish to acknowledge the help of Steve Rowarth for his help with the welding and also Karim Lahda who improved the circuit.
[12] The meaning of 'as often as possible' is discussed in 5.2.5

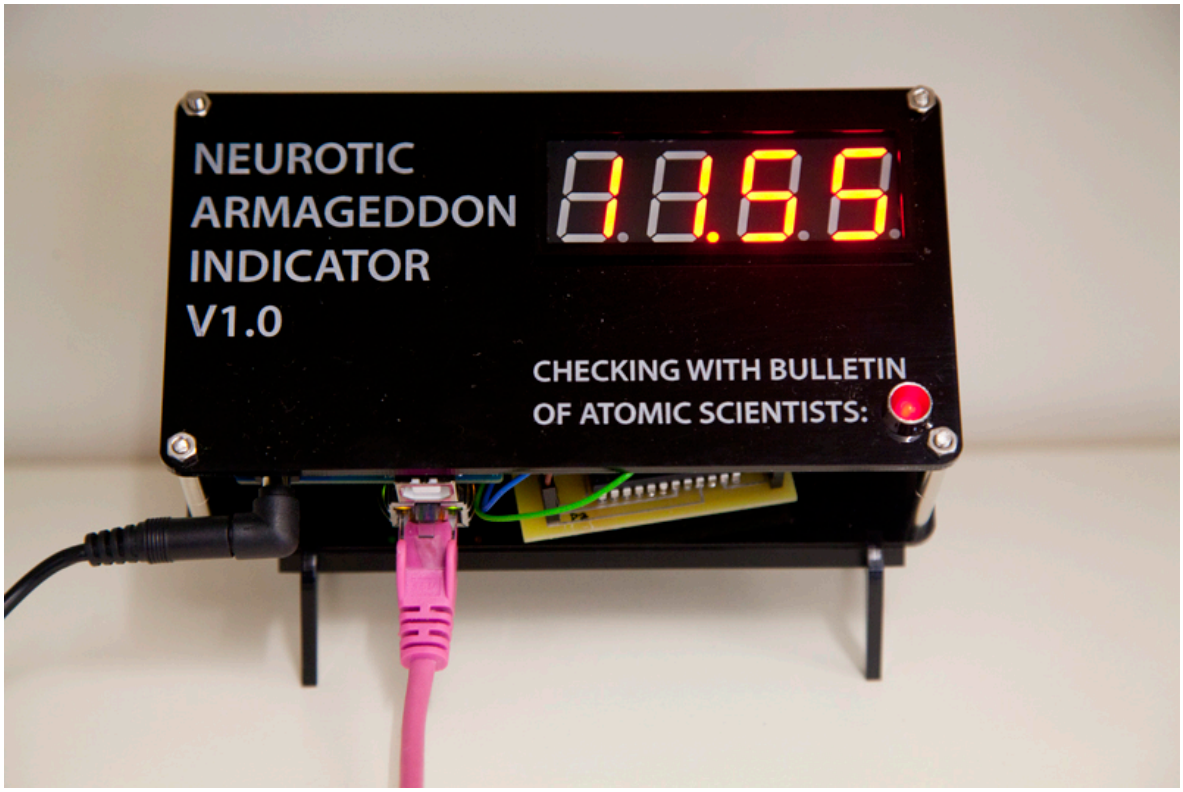

Figure 3: A Neurotic Armageddon Indicator (shown in desktop configuration)

The software checks the current status of the clock and then sends the results over the internet to the second part of the work, a small wall clock which displays the time of the Doomsday Clock on a red LED clock display. This process repeats as fast possible so that the device shows in near-real-time the status of the doomsday clock. This constant process of checking is the 'neurosis' of the title of the piece.

The server-side of *NAI* is written in Python using 'Beautiful Soup' ((Richardson, 2013)) web-scraping libraries and the Python Socket module for communication to the Arduino. The clock device uses an Arduino Ethernet shield to control the clock display and LED indicator. I designed a PCB for the clock and the Eagle PCB design files are freely available with code and other designs on a Github source code repository {see Appendix 2}.

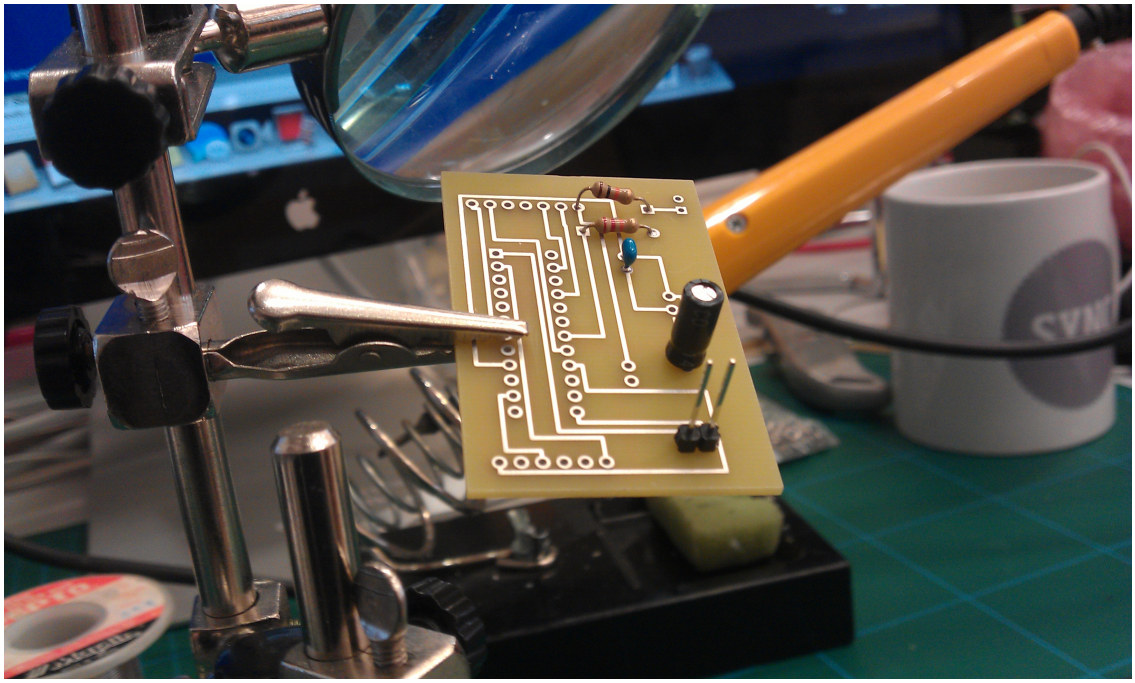

Figure 4: Building an Armageddon Indicator

*1.5.4 1280*1024*

*1280*1024* is a screen-based artwork which treats each individual pixel of a display screen as an individual screen in its own right. The title is derived from the resolution of the screen used. Other versions of the piece had different resolutions and were named accordingly (e.g. *1024*768*). The piece is driven by a data source which varied in different versions of the piece. In an initial version, a 'data dump' of Wikipedia (acquired from (Wikimedia, 2013)) provided the data. In a later version, a web spider, which I developed in Python, crawled particular IP ranges of the internet and scraped webpages indiscriminately. The visualization is written in C[13] and C++ using Openframeworks ((2013)) libraries.

[13] I acknowledge the assistance of Daniel Jackson who helped me understand the memory management demands of the project and supplied some native C code.

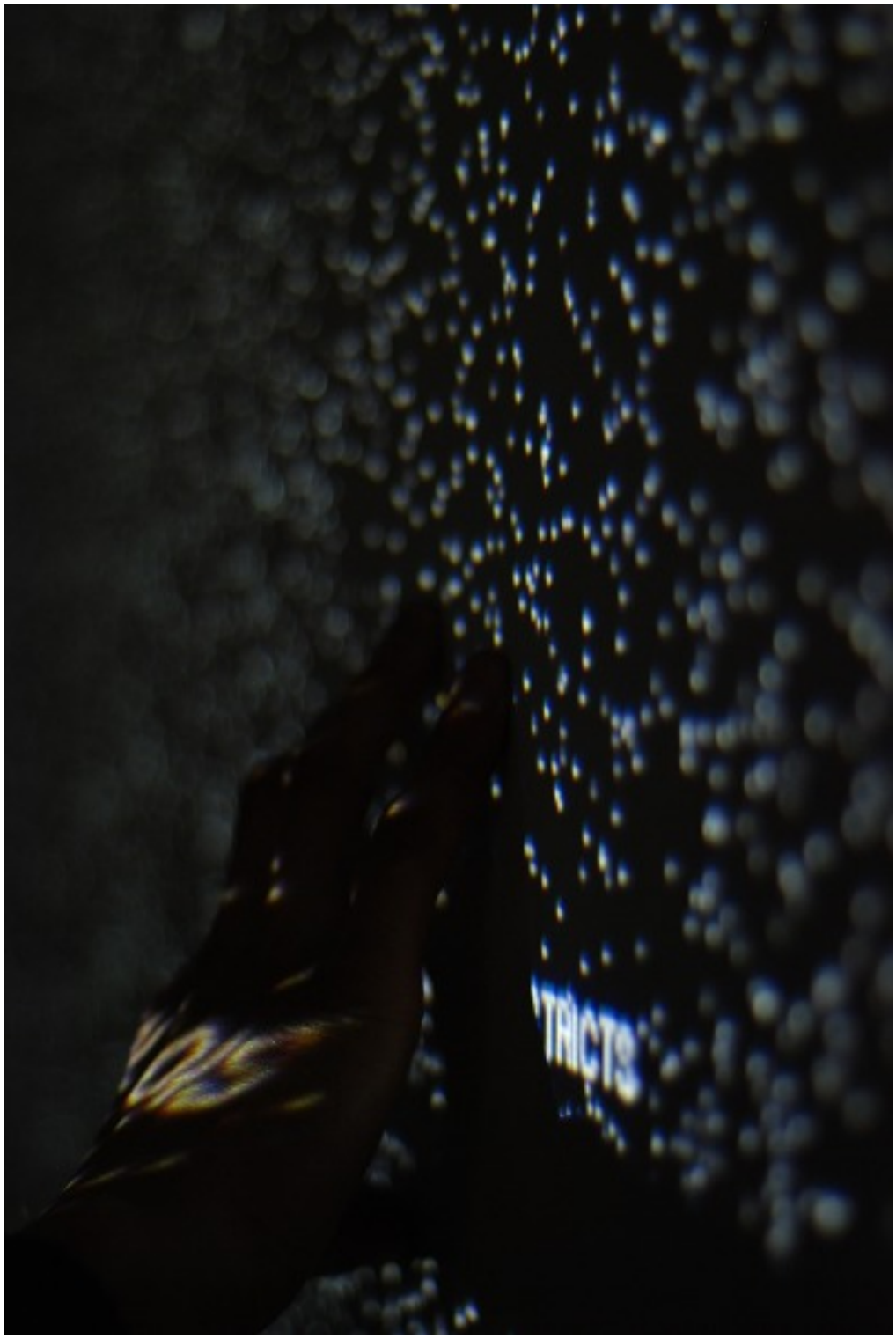

Figure 5: Installation Image of 1280*1024

Individual pixels are assigned a data item. In the case of the Wikipedia version, this item is a randomly selected article. In the version based on the web spider, the item is a page of html. The data is transmitted in Morse code by the pixel flashing black or white. The screen begins with no data and gradually one pixel at a time is added until all 1310720 (1280*1024) pixels are flashing.

1.5.5 Refractive Index

Refractive Index ((Allen, 2011)) is a multi-site artwork based temporarily on permanent, large-scale (approximately 12 square meter) displays, owned by the British Broadcasting Corporation (BBC) and based in British town centres. The piece is authored by Jamie Allen and I was employed (with Davide Gauthier) to write software code for the project. Authorship of the project belongs with Allen. *Refractive Index* was developed in C++ using Openframeworks (2013) libraries and code is available publically on a source code repository {see Appendix 2}.

Refractive Index uses the large urban displays as 'light projectors'. Surrounding streetlights, in some locations, are extinguished with the collaboration of local councils. The screens' 'gain' or intensity is turned to the maximum and a series of different coloured flashes and shapes are displayed in succession. Meanwhile the integrated CCTV camera in the screen captures images of the surrounding architecture. Algorithms, written by Gauthier, Allen, and myself, examine the resulting video footage for variations in light reflection and absorption. New images {Figure 6 } representing the results are finally played back on the screen, completing the cycle. Allen describes the work as:

"Investigations into the reflective and refractive power of public media displays. Imagery and software marks the physical effect that public media displays have on city spaces. An art-research project that uses large scale displays as a kind of active camera obscura; inverting the usual use of the screen and showing us what our screens 'see' when they peer into the night sky." (Allen, 2011)

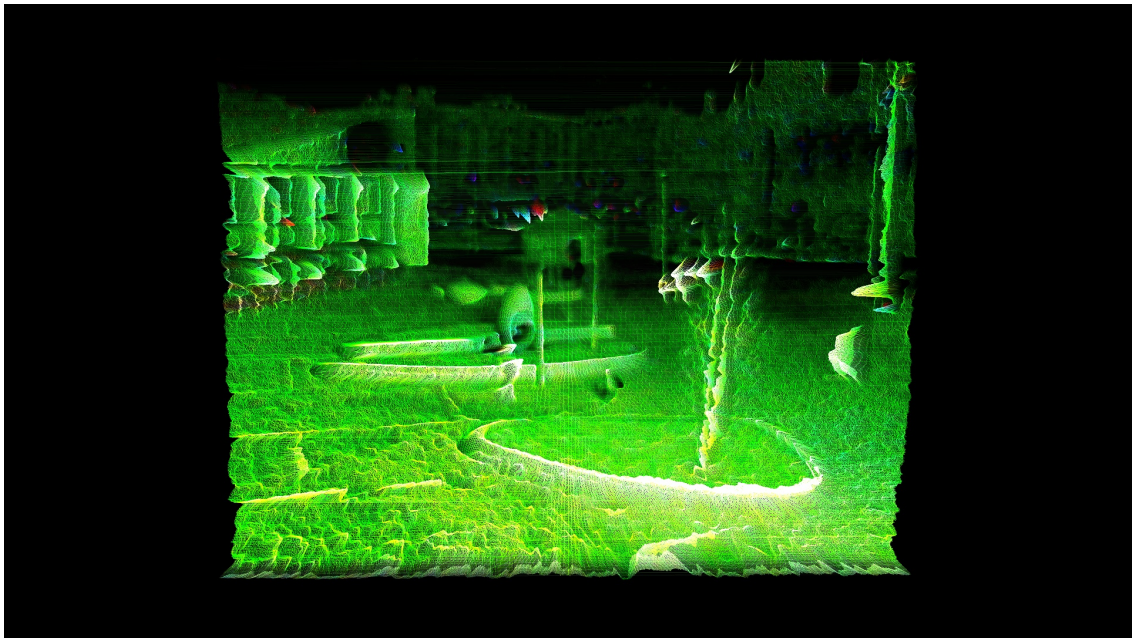

Figure 6: An Image Generated by Refractive Index, Manchester Site

1.5.6 The Quiet Walk

The Quiet Walk is a collaboration with sound artist Alessandro Altavilla. Altavilla developed the original concept and I joined the project as a collaborator to conceptually and practically develop a shared visualization element. I was also active in the development of the original iPhone app.

"The Quiet Walk is an interactive mobile artwork that allows users to make a walking exploration of urban space, driven by the sonic information captured on a smartphone. Instead of using a geographical reference in order to navigate around the city, the mobile suggests to avoid particular noisy areas of city, giving directions to reach quiet zones. The data collected generates a constantly changing map of the city according to its sounds." (Altavilla, The Quiet Walk, 2011-13)

Figure 7: The Quiet Walk Interface In Action (photo copyright Alessandro Altavilla 2012)

“The Quiet Walk is based on a purpose-built app for the iPhone which analyses the sounds of the city in real time and suggests for the user to make a deviation if the level of noisiness is too high. As the mobile transmits its GPS coordinates in real time to the project server, a system of routes and trajectories is drawn, creating an acoustical trace of the user’s walk.” ((Altavilla & Tanaka, 2012))

The second version of the *Quiet Walk* app which incorporated visualization elements was built by myself [14] using Openframeworks libraries ((2013)). There are a series of server side scripts, written by myself, which collate GPS and acoustical data from the apps and produce two online visualizations. The first of these marks GPS locations at which people have stopped and listened. It

[14] Though Altavilla contributed some resources (such as some screen overlay designs) and design feedback. Also the php posting code was provided by a third party.

translates the decibel levels recorded by the app into Italian, musical notation, for example '*ff*' (fortissimo) for very loud. These are written to a custom map marker and added to a Google map {see Figure 8}.

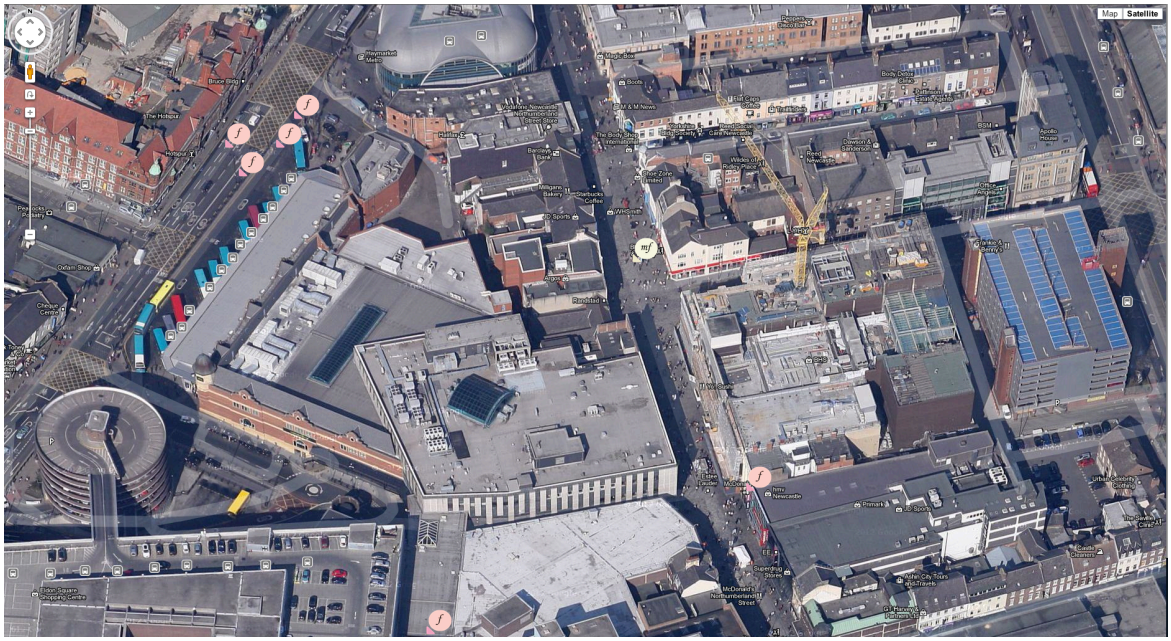

Figure 8: One of the Two Visualizations in the Quiet Walk. Markers here show "f" (forte) for "loud" and "mf" (mezzo forte) "quite loud"

The second visualization adds each new data point (of GPS and acoustic data) to a 'heat map', a graded map which interpolates values between known data points. The more data is added to the map, the more detailed it becomes. The algorithm used for this was Shepard's Method (Shepard, 1968), for which implementations in Java (Processing), C++, and PHP were produced by myself during the research process (see Appendix 2 : ofxHeatMap). These were released as open source libraries. {Figure 9} shows an example heat map, created in Taranto, Italy, early in testing. Users of the app could link to the two visualizations from the app itself. The intention was that users would be able to view the walks taken by others in their vicinity. The project is freely available on a source code repository {see Appendix 2}

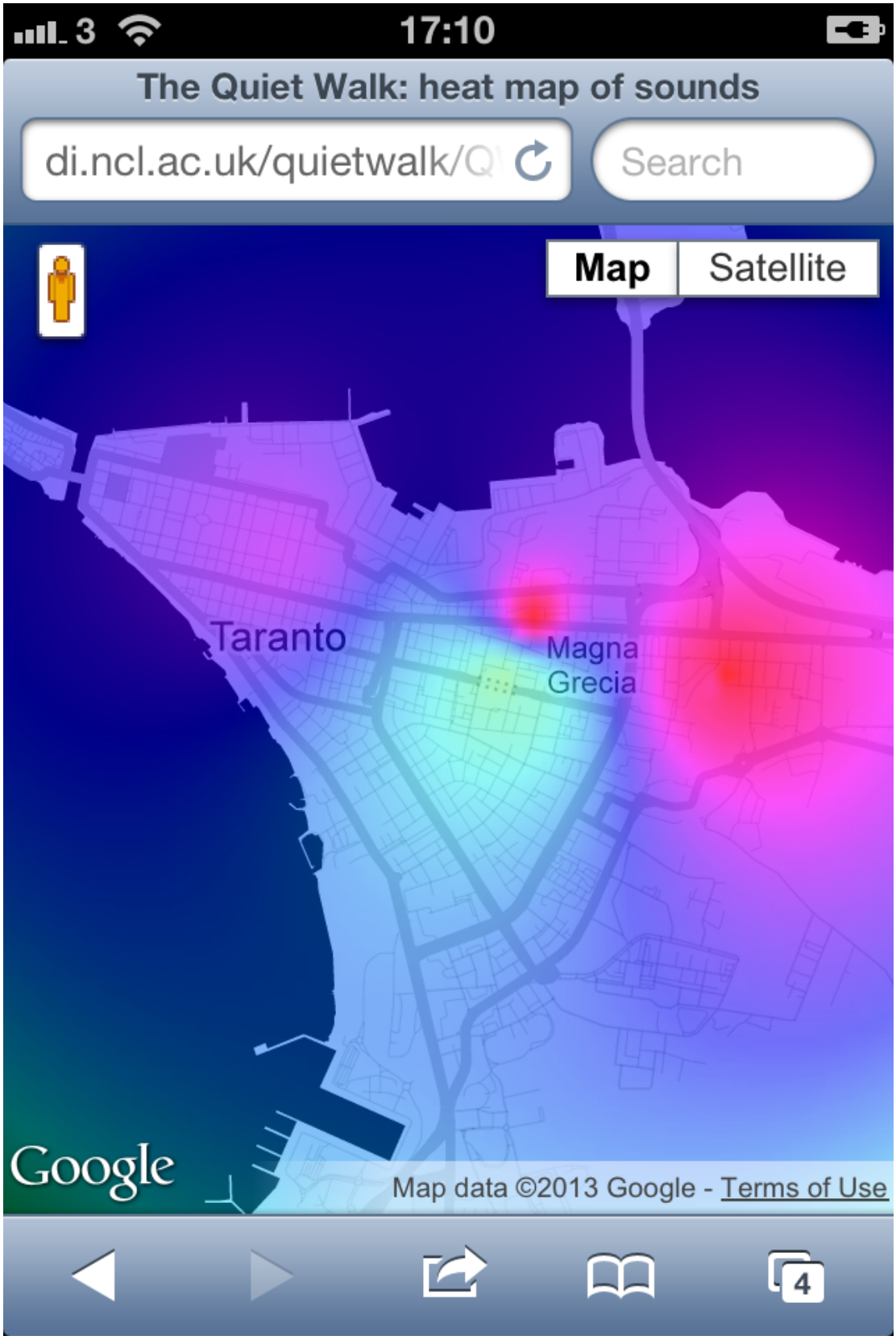

Figure 9: iPhone Screen Grab of the Second of Two Visualizations in the Quiet Walk taking during testing in Taranto, Italy.

Chapter 2. Materiality: a Definition in Action

This chapter provides a background review to inform the later development of a series of facets of materiality. These in turn will form a framework with which to approach the making of works of art and design as described in 1.4.2. First the principal aims and objectives of the review will be identified and a rationale provided for the method used. After the review, a short summary of findings will form a precursor to Chapter 4 in which the facets of materiality will be fully developed. At this point it is reiterated that while this review is presented here before full discussion of the practice-based research, this is not to be taken as indicative of the research timeline. As was emphasised in Chapter 1, literature research and practical investigation were reciprocally influential and they have been separated only for the sake of presenting a coherent account to the reader.

The rationale for an investigation into materiality has already been introduced but will be clarified at this point. It has been described how ‘immateriality’ has been claimed to be an important defining feature of the digital age (Negroponte, 1996; Mitchell, 2000). Even Friedrich Kittler, in many senses a staunch materialist, has not proved immune from making unfortunate (and contested e.g. by Kirschenbaum, 2008, p. 6) claims about digital technologies affording limitless speed and infinite interoperability (1987, p. 101). Such a view of digital technologies as immaterial gained considerable currency through the successive decade(s) and is only recently being substantively challenged. A number of provocative books such as (Bennet, 2010; Huhtamo & Parikka, 2011; Ingold, 2013) have, in different ways suggested how a conceptual and practical focus on materiality can bringer a richer conception to the understanding of technological systems in action, to the study of art history, and to understanding making-practice respectively. While these accounts are rich in example and strong in their theoretical underpinnings they do not offer much *practical direction* to the maker as to how to conceive of materiality

as something which helps them create knowledge through practice (though Ingold's work has this aim (2013, p. 14)). A key finding which motivates this literature review is that, *so far, there is a discrepancy in the quality of research from those actually describing the process of designing and making things when compared to accounts which highlight benefits of materiality without, so to speak, getting their hands dirty*. A principal problem that will be identified through this chapter is that much research which claims to discuss materiality *in practice*, particularly in some kinds of Interaction Design, inadvertently produces a 'thin' version of the concept flawed by an inappropriate use of metaphor (e.g. in Ishii, 2008) and an exaggerated focus on form and interpretation (e.g. in Jung & Stolterman, 2012) to the detriment of philosophical or conceptual investigation which could inform and enrich design work.

This claim motivated a further question for this review. Given a philosophically enriched conception of materiality and its implications for making-practice, what questions or considerations need be addressed for the way makers situate themselves in relation to the materials with which they work? In early paragraphs it will be argued that with the consideration of particular philosophical stances on materiality, pertaining to the origin of meaning, concerns arise for the attitude of makers. These provoke not only further philosophical questions (about the definition of meaning) but ethical questions about the way that the material world is valued.

2.1 Aims and Objectives

This review chapter has three principal aims, separated into sub-sections.

Section 2.1.1 aims to identify philosophical and ethical dimensions to materiality as it pertains to makers. Specifically it works with a particular ontological conception of meaning and with some related perspectives on ethics and materiality. It asks, in the light of a number of concepts identified, what possible impacts might exist on the attitudes of makers towards their work.

Section 2.1.2 identifies a number of instances where materiality has been invoked to theoretically support arguments for specific approaches to the design of particular interactions (e.g. in Ishii, 2008) and the design of particular kinds of computer systems (e.g. in Weiser, 1991). This section critiques some of this work for its under-developed philosophical grounding. It is argued that a philosophically "thin" definition of materiality undermines some of the background justifications, given by designers for particular approaches.

Section 2.1.3 recognizes that a key problem with research discussed in Section 2.1.2, was a failure to bring materiality, action and ecologies into a coherent picture. It develops a definition of agency, building on previous research, which will be taken forward into the thesis as a whole.

Building on the findings of the previous sections, Section 2.1.4 aims to provide a more comprehensive survey of the concept of materiality and, with the benefit of practical experience, identify relevant existing concepts and research strands which might integrate with a proposed framework for materially-informed making. Having done so, it notes the concordance of *methodologies* from the, admittedly heterogeneous, field of Media Archaeology with concepts identified here.

2.1.1 Meaning and Attitude

As was indicated, the focus of this section is on how a particular philosophical approach to the origin of meaning can substantively affect the way that practitioners conceive of their engagement with the material world. Specifically, it will be argued that if meaning is viewed as an *a priori* property of being, as something existing anterior to interpretation (as in Meillassoux, 2010), the making of artefacts should consequently be re-construed as a development or repurposing of a range of such pre-existing meanings. It will then be acknowledged that this philosophical position carries associated ethical implications derived from our ontological connection to the material world and these will be described.

Materiality and ontology (the study of the nature of being) are deeply, historically connected in Western philosophy and it is beyond the scope of this thesis to provide even a partial overview of this history. Specifically though, Heidegger asserts that to consider the nature of being, is actually to consider the *meaning* of being;

"All ontology[…], remains fundamentally blind and perverts its most proper intent if it has not previously clarified the meaning of Being sufficiently and grasped this clarification as its fundamental task." (Heidegger, 1996 (1927), p. 15)

At a casual reading, to consider the meaning of being appears almost tautological: being appears to be its own meaning and nothing can be said about it. However the status of meaning as something which actually inheres to the world as opposed to something applied to it, *a posteriori* (i.e. in empirical analysis). Or derived from it in interpretation, is fundamental to the question of why materiality is a significant concern for makers. This claim will now be articulated in some detail making use of the work Quentin Meillassoux (2010).

Materiality is employed by Quentin Meillassoux as part of a philosophical argument about meaning. He takes materiality as a grounding from which to problematize strains of philosophy which are solely based on what is knowable by human beings, a position he holds as associated with most of the Western philosophical canon since Emmanuel Kant (Kant, 1958 [1787]; Meillassoux, 2010, p. 3). Such a philosophical tradition, according to Meillassoux, does not admit meaningful discussion about the nature, existence and interaction of objects outside of what he calls 'the correlation' (Meillassoux, 2010), this 'correlation' being that between objects, 'out there' in the world, and the 'inside world'[15] of human consciousness.

[15] I use the terms "inside" and "outside" to clarify this relationship as simply as possible. Meillassoux (2010, p9) uses the term "interiority" to discuss this division in more detail.

“By 'correlation' we mean the idea according to which we only ever have access to the correlation between thinking and being, and never to either term considered apart from the other.” (Meillassoux, 2010, p. 13)

Meillassoux, however, wishes to at least speculate about the nature of things outside of this relationship in what he calls the ‘great outdoors’ (Meillassoux, 2010, p. 17) of philosophy. That is to say that he makes an ambitious attempt to speculate about things *in themselves*.

A key consideration which will be developed throughout this thesis is how making-practices are affected by the idea that one can meaningfully think about the being of things without necessarily contextualizing them solely in terms of human subjectivity. That is to say, to speculate on the kinds of meaning which inhere to them as things. Meillassoux, as it will be shown, suggests some philosophical justification for this approach. The motivation to follow him in this regard is partly a practical consideration and partly a matter of attitude as a maker. Practically it provides a motivation for looking for specific ways in which meaning inheres in the world (more explanation on this point is given below). As a speculative attitude Meillassoux’s philosophical drive is of interest because it suggests that, at least in some senses, meaning is not created by works of art or design, rather it is something which is potentially, partially at least, found by them. This is a view, radically at odds with what remains a pervasive and insidious view of art and design practice; that objects of art and design are *representations* of ideas[16] and will now be discussed.

Meillassoux demonstrates his approach to being and philosophical foundations of meaning with the example of an ‘ancestral statement’. This is a piece of scientific knowledge regarding facts antecedent to human life such as “the age of the

[16] This view has been challenged through the concept of performativity, notably by (Butler, 1988; Thrift,1996; and Suchman, 2007) and will be discussed extensively later in this thesis.

universe, the formation of stars, or the accretion of the earth." (Meillassoux, 2010, p. 21). He asks whether, in making claims about such events, we are trying to establish an *independent truth* or merely demonstrating that the effect for us is the same as the effect for others;

"One does not validate a measure just to demonstrate that this measure is valid for all scientists; one validates it in order to determine what is measured." (Meillassoux, 2010, p. 17)

Meillassoux describes here a goal of approaching objects' 'primary qualities', the aspects of themselves 'in-themselves', which do not depend on an observer, which are to all purposes independent. The essence of his argument is that *meaning* comes from the material world itself, as pertaining to its being.

"This is what we shall express in terms of the ancestral statement's *irremediable* realism: either this statement has a realist sense, and only a realist sense, or it has no sense at all." (Meillassoux, 2010, p. 33) (emphasis added)

In other words, our philosophical interest in meaning, achievable or not, is in establishing *meaning as a property of being*, not in establishing a correspondence in our understanding. Ontology for Meillassoux therefore implies a breaking down of barriers in our knowing relationship with the world around us. The idea that we might have access to objects as they are in themselves rather than through some mediated secondhand is attractive for makers whether philosophically justified or not. It points to a potentially more authentic[17] relationship with materials.

Materiality in Meillassoux's writing acts as a counterpoint to the idea that meaning is necessarily, wholly, man-made. It provides a *point of reference* outside human subjectivity without which, he claims, it is simply not meaningful to describe the

[17] Authenticity is discussed in more detail in 6.4.

world. As part of a making-practice this contradicts the notion that meaning is something that is *a posteriori* to materials as they are used to *represent ideas*. Making is an engagement *with* meaning, not just a creation *of* it.

This exposition of Meillassoux's work is included first because of its immediate speculative orientation, which is identified as commensurable with the processes of ideation and prototyping described in this thesis, and secondly because it provides a philosophical grounding for later concepts which form part of the proposed framework of material facets. This will be explicated in more detail but for now, suffice to say, this is fundamental to a view of the world where makers exist in a dynamic and varied ecology *which formulates our understanding of the social. I suggest that this characterisation of meaning in materiality remains broadly unexplored in frameworks for making and consequently that this is a significant aspect of the contribution offered by the facets of materiality which will be proposed.*

Although the inclusion of this influence from Meillassoux *into making-practice* is posited as an original contribution, there is some precedent to be found in Heidegger's later writings. Heidegger also held the view that the attitude of a maker would be affected by his or her understanding of a thing having its own existential meaning. His ontological approach to the notion of 'the thing' (as in Heidegger, The Thing, 1971) involves an explicit discussion of the relationship between a thing (in this case a jug) and its maker. He distinguishes between the jug as a "represented object" and its "thingly character" (Heidegger, 1971, p. 405) and describes how the making-process has the character of bringing out the jug "*qua thing*" (Heidegger, 1971, p. 408):

"It is, to be sure, no longer considered only as object of a mere representation, but in return it is an object which a process of making has set up before and against us." (Heidegger, 1971, p. 406)

As for (Meillassoux 2010, p. 17), the implication for makers is that materiality is encountered as an engagement with meaning, not in terms of a construction of representations. As Paul Dourish, describing Heidegger's ontological approach, suggests, "[m]eaning inheres in the world as we find it" (2004, p. 108). The continuing process of making is to build on such meanings through processes such as combination, re-working and juxtaposition. Examples of such processes are provided in Chapters 4 and 5.

To understand materiality as discussed by Heidegger, a certain amount of context is required. Materiality in Heidegger is part of a particular kind of ontological relationship *for* a particular kind of being of which humans are the known example: *Dasein* (there-being). His tool analysis (Heidegger, 1996 (1927), p. 67) employs materiality to demonstrate that the being of the world is always, already in a relationship with *Dasein*. This relationship is a privileged one and is part of the primal state of the world. His formulation of two modes of being found in objects, "Vorhandenheit" and "Zuhandenheit"[18] uses materiality as a place to discuss how being is resolved through action[19]. Heidegger's ontology is founded in the assertion that being is in essence a series of "modes" (Heidegger, Being and Time, 1996 (1927), p. 7) which are inherent to that kind of being. Being is posited as a question of 'how' rather than a question of 'what'. The implications of this approach, which have been explored in the context of interaction with technology, (e.g. Dourish, 2004, pp. 107-108; Winograd, 1995), are to consider being-in-the-world as a kind of *action* in which we are always already involved. This involvement demonstrates that materiality, properly construed is already engaged with a sense of one's part in an ecological whole. That action is also conceived of in specifically ethical terms (1996 (1927), pp. 169-213), one's ontological connection with the world motivates,

[18] Handiness, readiness-to-hand, or Zuhandenheit is the way that we are usually involved with the world as part of our attitude of care towards the world. We encounter objects in a neutral, useful modality. Un-handiness, presentness-to-hand, or vorhandenheit is a break in zuhandenheit, the canonical example is the hammer which breaks and causes us to examine it closely in its construction.

for Heidegger, particular moral attitudes to it. *We are morally implicated in the world because of our ontological connection to it as part of particular kinds of mode of action*.

Heidegger's work then, has ethical implications, derived from his philosophical conclusions. However, ethical dimensions of materiality are also explored by Webb Keane to question our background assumptions about the relationship between materials and meaning (Keane, 2005; 2013) draws from an entirely different tradition: semiotics. Keane suggests that a perception of materiality as somehow immoral has influenced Western culture to separate material and meaning. He begins by describing how in the protestant tradition, for instance, overt interest in the material world is perceived as immoral.

"…the misapprehension of material things is not [perceived as] merely a mistake-it has grave consequences. It leads us to invert our values, imputing life to the lifeless and thereby losing ourselves. The proper understanding of material signs has moral consequences." (Keane, 2005, p. 184)

For makers, who are constantly involved with materials in their professional lives, such an attitude is problematic. Counterpoints can, of course, be found at home and abroad. Traditional Japanese arts and crafts, for instance, suffer no such moral dilemmas (Tanizaki, 2001). Keane describes how this moral stance has had a pernicious influence on cultural analysis. For Keane, background concerns about the 'immorality' of materials have caused an artificial theoretical rift between things and the meanings which they are assumed to represent:

"…social and cultural analysts still find it difficult to treat objects as no more than illustrations of something else, as, say, communicating meanings or identities, it is because we remain heirs of a tradition that treats signs as if they were merely the garb of meaning…" (Keane, 2005, p. 184)

A sign therefore, for Keane, in the form of a piece of statuary for instance, is not a *representation* of an idea such as femininity or martial valour. Rather that statue is involved in *constituting* those meanings and associating them with others through both the history and future of that object. To compare this approach to (Heidegger, 1996 [1927]; Meillassoux, 2010), Keane is not presenting an ontological argument about the way meaning actually inheres in objects. Rather he makes an account of the production of meaning but locates it, not just in human perception, but in the complex material interactions that things are involved in. Things become *associated* in the sense of "united in action or purpose" (Oxford Dictionary of English, 2010) rather than of "Connected in thought, mentally related" (Oxford Dictionary of English, 2010). Their situation in a dynamic world means that they are involved with one another and their meaning is affected through these material interactions. Human subjectivity is certainly part of the picture, but it is not the whole story.

This perspective incorporating the past interactions of objects with one another, also offers, through its historicity, a way of considering making-practice as part of a *continuity*. If materials are approached as inherently historical, that historicity suggests precedent kinds of engagement with them, for instance through older making traditions which can be assimilated into practice. Perhaps most importantly for this thesis however, Keane suggests that the embodiment of meaning in materiality locates it in a dynamic and combinatory set of relations. The interactions of objects mean that:

"…the semiotic character of material things means that outcome is not, in principle, settled. It is not simply that their meanings are underdetermined, but also that their semiotic orientation is, in part, toward unrealised futures." (Keane, 2005, p. 193)

To clarify, Keane maintains that not only does our interpretation of, or relationship with, things remain unsettled but that their capacity to *embody* signification means that their meaning is wrapped up in future possibility. Added to accounts of

meaning as intrinsic to objects in the world (Heidegger, 1996 [1927]; Meillassoux, 2010), Keane's work suggests ways of thinking about the future production of meaning through engagement with materiality. To summarize, the research described here holds that meaning and materiality are closely imbricated. This opposes a view (which it will be shortly argued is implicit in much art and design work) wherein objects are seen as representations of ideas. This finding is identified as significant as it provides a justification for considering materiality as central to the design process*. Approaches which attempt to impose meaning onto artefacts without due attention to the intrinsic meaning of materiality risk implicitly denigrating the physical world to a 'second tier' status as a proxy for ideas. Such approaches potentially ignore both the history of art and design practice as a knowledge making activity and richly productive methodologies suggested by a historical engagement with technologies. This latter will be discussed later in this chapter.*

There are also, as we have seen, ethical aspects to our engagement with materiality both as part of a world with which we are already connected (Heidegger, 1954; 1971; 1996 (1927)) and as makers who are proudly involved with our craft as in (Tanizaki, 2001).

Lastly, the "unsettled character" (Keane, 2005, p. 193) of material things means that our engagement with them as makers is always towards 'unrealised futures'. *This point is taken as foundational in proposing that consideration of the inescapable future orientation of materiality would fundamentally affect the making-process*.

2.1.2 Making Art and Technology

While the previous section examined some foundational concepts for materiality in and its relationship to makers, this section examines how materiality has hitherto been employed to inform design practice. Research discussed in this section has the function of explicitly discussing and informing the creation of works of art and

technology. It is situated to provide direction for current or future design work and in this respect shares a goal with this thesis.

A principal aim of this section is to describe how some previous applications of the concept of materiality in design practice rest on philosophically under-developed conceptions of the term and it will be claimed that this has restricted potential benefits to design. It will also be explained that many of the underlying problems with the view of materiality expressed by some of the research which follows stem from a lack of integration between the concepts of materiality and ecology. A key area in which this separation occurs is identified within the concept of affordance.

Affordance, a concept that has become vital to Interaction Design, was originally defined as a "specific combination of the properties of its substance and its surfaces taken with reference to an animal" (Gibson, 1977, p. 67). In essence it is a kind of potentiality between the particular qualities of an object and the physical or mental capacities of an animal (human or otherwise) to interact with it.

"When the constant properties of constant objects are perceived (the shape, size, color […] I have coined this word as a substitute for values, a term which carries an old burden of philosophical meaning. I mean simply what things furnish, for good or ill." (Gibson, 1966, p. 285)

In the following paragraphs two contrary positions towards affordance will be described, treating affordance as an inherent property of the world, or a product of perception, respectively, before a third approach will be introduced as a favourable alternative. In this last, it will be described how Suchman's articulation of "situated action" (Suchman, 2007) provides some integration of the concept of affordance with an ecological approach, prefiguring discussion of the latter in Chapter 6. Given the relationship between affordance and materiality, this point will strengthen the overall position of this thesis in establishing the importance of incorporating material concerns in making-practice.

There is disagreement among some scholars, as to the exact nature of affordance and particularly its status as either inherent to objects, or existing solely as a mental state of animals (including humans), so called “perceived affordance” (Jones, 2003; Norman, 1999). Perhaps the most vocal exponent of affordance in its relation to Interaction Design, Donald Norman’s account proposes it as a an answer to the question, “When you first see something you have never seen before, how do you know what to do?” (Norman, 1999, p. 39). Norman’s rhetorical question, however, is revealing of a problem with both of the above understandings of the concept. To seriously consider Norman’s question, we would have to treat experience as a series of essentially isolated units. To claim that we had “never seen something before”, we would have to superimpose a categorization on the world which clearly separates individual experiences. Whether we treat affordance as inherent to an object or to perception, we implicitly adopt a position which holds that the properties of an object are *detached from action*. It is exactly this claim that is refuted by Lucy Suchman. Suchman’s (2002; 2007) work is a lengthy exposition of the idea that knowledge and action are inseparable from circumstance. In the context of a critique of cognitive science, Suchman points out that “[…f]or cognitive science the background of action is not the world as such, but knowledge about the world.” And it is exactly this kind of perspective which would allow Norman to ask “When you first see something you have never seen before, how do you know what to do?” (Norman, 1999, p. 39) The clear implication from that question, is that there is a schematising set of a *priori* rules to which, on some level, we refer. Instead, by Suchman’s account, action must be taken in the particular dynamic context in which it occurs. This necessarily includes a relationship with materiality.

“…the contingency of action on a complex world of objects, artifacts, and other actors, located in space and time, is no longer treated as an extraneous problem with which the individual actor must contend but rather is seen as the essential resource that makes knowledge possible and gives action its sense. […] A basic research goal for studies of situated action, therefore, is to explicate the

relationship between structures of action and the resources and constraints afforded by material and social circumstances." (Suchman, 2007, p. 177)

In the following paragraphs, it will be suggested that the application of the concept of affordance, without due consideration to materiality itself or its contextualising ecology causes problems for design.

Materiality has been explicitly invoked by authors in the domain of Tangible User Interfaces (henceforth TUI), a field of computer interface design, who seek to use the affordances of physical objects to create more pleasurable or efficient interactions. The seminal paper in this field was that of (Ishii and Ullmer, 1997) in which they developed a vision of "Tangible Bits", physical mediators that would "… take advantage of natural physical affordances to achieve a heightened legibility and seamlessness of interaction between people and information." (Ishii & Ullmer, 1997, p. 2). Considering affordance is intended to make designs easier to use, reduce cognitive load, and encourage interaction by leveraging a combination of the physical properties of objects and their (inherent or perceived) relationships with human physicality. Affordance therefore is posited as a way of *using* materiality to design for usability. It is given a function of *overcoming* a divide (between human physicality and information spaces for instance). This view of affordance as something which is principally of use value is a factor which differentiates the position of this thesis from (Norman 1999; Ishii and Ullmer, 1997). In the position adopted by this thesis, affordance is considered as an intrinsically philosophically interesting feature, in its relation to making-practice and the consequences of this focus will be discussed in 2.1.3.

This use of materiality in the form of affordance described in the research above is, however, a thin form. It is asserted here, that the stated aim "to bridge the gaps between both cyberspace and the physical environment" (Ishii & Ullmer, 1997, p. 1) is at best poorly explained and at worst disingenuous. While it is arguable that

phicons[20], for instance, bridge gaps between human physicality and information spaces (Ishii & Ullmer, 1997, p. 1) it is much harder to justify that Ishii and Ulmer's vision engages us in our environments in anything other than token ways. They offer "tangible bits" as an instantiation of Weiser's (1991; Weiser & Brown, 1996) vision of ubiquitous computing, a way of integrating computing with the environment. It is strongly asserted by this thesis, however that it is *not* an integration of computing with the environment. It is a *replacement* of the environment with computational devices.

"by relying on strategies for mapping via analogues and metaphors, tangible computing inadvertently invests in maintaining the separation in order that they might cross the divide. Moreover, metaphors and analogues, by definition, operate a level up from the basic materials themselves." (Robles & Wiberg, 2010, p. 137)

The use of phicons in TUI research, is a substitution of one kind of materiality for a distinctly different one and relies on metaphor and association (as described above) to infer similarities between the two). It is not a way of *engaging* with the former. As indicated, the vision of affordance offered here ignores the *situated character* of the real-world[21] interactions, which are effectively *mimicked* by phicons.

There has quite recently been a renewed interest in the explicit application of materiality to designing interactions with digital artefacts (such as in Jung & Stolterman, 2011; Jung & Stolterman, 2012; Wiberg, 2013). A key feature of this research is that it treats materiality as something whose principal utility to design is

[20] Phicons are physical objects, augmented to serve as interface media, for instance by using camera tracking technologies

[21] Clearly interactions with phicons also exist in the "real-world". Here I intend, the already existing interactions which tangible user interaction mimics. Take, for example a phicon which serves the function of a volume control. Twisting the phicon reduces or increases some variable in software. This interaction is based on a "real-world" interaction of twisting a potentiometer.

in helping designers to think about the way their products are *interpreted* by users. Materiality in this research is instrumentalized for this purpose, rather than being a feature of interest, for research, in its own right. It will be described in the following paragraphs how a focus on interpretation has replaced a more nuanced analysis of the relationship between the materiality of objects and the way they behave in interaction. This analytical oversight, causes problems for the understanding of agency as it pertains to design. This assertion will be fully expounded in the subsequent section.

“Form and materiality are rather abstract concepts to be purposefully interpreted rather than quantifiable properties to be objectively measured. This means that research on form and materiality requires hermeneutic approaches to clarify what are specifically meant by those terms in a certain context of inquiry and why certain perspectives of interpretation are selected out of other existing views before applying them to a general research framework or design principles.” (Jung & Stolterman, 2012, p. 646)

In other words, the qualities of objects are culturally constructed and context specific, rather than in any sense pertaining to the objects themselves. To study those qualities, suggest these authors, requires a focus on that context rather than on the object as such. Form according to Jung & Stolterman;

“…is based on an artifact-centered and interpretive approach that examines how material artifacts are experienced and implicated in personal and social life, stressing that the use, display, and ownership of individual artifacts cannot be understood in isolation from context and environment.” (Jung & Stolterman, 2011, p. 401)

Materiality for Jung, Stolterman, and Wiberg is approached as an *expression* of factors external to the object. Materiality, as has been noted, is instrumentalized to

help researchers think about the *use* of objects, the *values* that people attribute to them or the way that objects *express* cultural phenomena such as fashion.

The emphasis by these authors (Jung & Stolterman, 2012; Wiberg, 2013) on qualities and form is also sometimes related to traditional craft practices of reflection upon or through materials but brought to bear on "digital objects". This practice has been referred to as the, "…'sketching in hardware approach' [which] highlights the importance of explorations through an intimate relationship with the materials at hand." (Wiberg, 2013). Although this aim is identified as consistent with the aims of this thesis, there seem to be few real examples of this 'intimate relationship' at work in the research.

In summary, a problem shared by both the vision of 'tangible bits' (Ishii & Ullmer, 1997) and qualities-based, interpretative design approaches to materiality (Jung & Stolterman, 2012; Jung & Stolterman, 2011; Wiberg, 2013; Robles & Wiberg, 2010) despite a putative reliance on materiality, actually see materiality as something that is *mutable* through human interpretation. Ishii and Ullmer's (1997) research implicitly views physical designs as metaphorical replacements for the real-world. Such a view ignores the situated nature of affordance (Suchman, 2007). Meanwhile, other Interaction Design research described here fails to explore the relationship between materiality and interpretation, effectively conflating the terms.

It is asserted at this early stage that the approaches to materiality described thus far are reductive, implicitly consigning objects to a role as signifiers; representations of something else, be they physical interactions (in Ishii & Ullmer, 1997), or cultural associations in (Jung & Stolterman, 2012; Jung & Stolterman, 2011; Wiberg, 2013; Robles & Wiberg, 2010). To overcome this quandary, and to form a more nuanced background to our later development of the concept of materiality, it is proposed that some initial account for the interconnection of materiality and action must be provided and that this must necessarily, following Suchman's comments, integrate an ecological aspect. Such an account will be

begun in the following section with an exploration of the relationship between materiality and agency.

2.1.3 Agency and Materials

So far a key finding of this section has been that a more or less exclusive focus on interpretation in some kinds of design practice implicitly denigrates the role of materiality in shaping our relationship to technology. It is proposed that underlying this focus is a particular notion of agency as located wholly with human beings. To seriously critique this notion an initial exposition of the concept of agency as it will be applied throughout this thesis must be offered. In the following paragraphs, it will be shown how an exploration of the relationship between materiality and agency inevitably engages both concepts with an ecological understanding. The concept of agency is proposed as foundational to ecologies because of its significance to the most basic assumptions of what an ecology *is*: "the production of action and what counts as action (and of actors and what counts as actors)" (Thrift, 1996, p. 2) that is to say who, or what conjointly compose an ecology and how they relate to one another.

A foundational claim for this thesis is that a nuanced philosophical and practical approach to materiality is lacking from art and design making-practice despite the efforts of some researchers (particularly Ingold, 2012; 2013*) to integrate them*. it will be suggested that at the heart of this lack is a failure to adopt some productive, *existing approaches*, particularly from Actor Network Theory (ANT) (such as Latour 1988;1993; 2005), to understanding agency *into* design practice, in a significant and methodical way. Some first steps will be attempted here from the discussion of this existing ANT research, re-applied to making-practice.

To begin a discussion of the manifestation of agency we will begin with Bruno Latour. Latour discusses how materiality is agential to problematize social theories which rely on human intentionality for impetus, to the exclusion of the material world (Latour, 2005). By doing so he provides a productive, theoretical path

through which to integrate our earlier established notions, of the historicity of material meaning, into an ecology containing a variety of different kinds of actors. Latour achieves this by deemphasising the *motivation* of actors and turns instead to the way that they "modify states of affairs" (Latour, 2005, p. 71). That is to say that he looks at *what* things do and *how* they do it, without making assumptions about *why* they do it.

"If action is limited a priori to what 'intentional', 'meaningful' humans do, it is hard to see how a hammer, a basket, a door closer, a cat, a rug, a mug, a list, or a tag could act. They might exist in the domain of 'material' 'causal' relations, but not in the 'reflexive' 'symbolic' domain of social relations. By contrast, if we stick to our decision to start from the controversies about actors and agencies, then any thing that does modify a state of affairs by making a difference is an actor…" (Latour, 2005, p. 71)

While avoiding putting objects and humans in parity, Latour rejects *a priori* distinctions between "causal", "intentional" or "meaningful" actions. That is to say that he focuses on the way that people and things embody and enact relationships "symmetrically" (Latour, 2005, p. 76).

"To be symmetric, for us, simply means not to impose a priori some spurious asymmetry among human intentional action and a material world of causal relations." (Latour, 2005, p. 76)

Instead of accounting for what lies behind action, he begins from the position of looking at the kind of 'differences'[22] produced by things in networks. Things, like people "might authorize, allow, afford, encourage, permit, suggest, influence, block, render possible, forbid…" (Latour, 2005, p. 72). Crucially (Callon, 1991, p. 134; Law, 1992, p. 380) agree that the focus on such differences produced, motivates a

[22] A fuller exploration of such 'differences' will be undertaken shortly.

stance that agency is as much a product of the network as of the actor. Things are able to produce differences because of their embeddedness in a network. Their conclusion is that what counts as an actor, *is actually the network and vice versa*. This point is crucial; are we to understand that the capacity of actors to produce difference is *purely* their position in a network? Surely not, since to argue thus would be to suggest that objects are entirely interchangeable. To suggest that the role of objects is defined purely by interaction generates a significant problem: what factors influence or define that interaction itself? The reading of ANT adopted by this thesis acknowledges that *agency is a production of both materiality and the relational position of things within networks*. It is added that it is at this juncture that the previous discussion of ontological meaning, once again, finds its relevance. If things are not to be taken as having generic roles, that is to say as being interchangeable, within a network, the only possible approach to accounting for their specific role within a network, *must* be derived from their ontological meaning. To propose otherwise would *always* locate their agency *wholly* outside them. To support this proposition we must however acknowledge a separation of definitions. It has been claimed that what counts as an actor is actually the network and vice versa (Callon, 1991, p. 134; Law, 1992, p. 380). We have also seen that the reciprocity of this relationship is only meaningful if it is shaped by the ontological meanings of the actors which constitute that network, together in relation. If we consider the actor to be defined by its network we must acknowledge that materiality itself is never wholly reducible to the agency expressed as an actor. That is to say that materials are *not only actors*; there must remain a core of ontological meaning, held in reserve[23]. As Whitehead (1919) has it, "Objects are the elements in nature which can 'be again.'"

To further expound this argument by example, let us examine how John Law brings this into an explicit discussion of technology noting that previous accounts

[23] This view is commensurable with Graham Harman's formulation that the object always "withdraws" in causation. (Harman, The Road to Objects, 2011)

which attempt to locate dominant agency in either the domain of the machine or in the social context in which it is active, are inevitably reductive:

“[these] reductionist versions tell that either machines or human relations are determinate in the last instance: that one drives the other. However, though these reductionisms are different, they have two things in common. First, they divide the human and the technical into two separate heaps. And second, they assume that one drives the other.” (Law, 1992, p. 382)

Law’s work can also be compared and contrasted related to previous work which dealt with the role of technology inside social contexts such as (Pinch & Bijker, 1987; Winner, 1980). Such contexts are relevant because they represent particular kinds of ecological situation. Langdon Winner’s seminal article “Do Artefacts have Politics” (Winner, 1980) begins by staking a claim that artefacts *themselves* have politics while acknowledging that:

“...to go beyond [the] obvious fact [that technological systems and infrastructure change the exercise of power] and to argue that certain technologies in themselves have political properties seems, at first glance, completely mistaken. We all know that people have politics, not things.” (Winner, 1980, p. 122)

To support his claim to the contrary, Winner presents a number of examples where technical systems either strongly encourage or actually require particular social configurations, thus locating, at first glance at least, a degree of agency with those technologies themselves. In this sense his view is consistent with that of Michel Callon who argues that “technical objects […] more or less explicitly define and distribute roles to humans and non-humans.” (Callon, 1991). Technologies, by Winner’s account encourage, and (in the stronger version of this theories) *produce* social arrangements (Winner, 1980, p. 130). For example, in the context of architectural technologies;

“one can point to Baron Haussmann's broad Parisian thoroughfares, engineered at Louis Napoleon's direction to prevent any recurrence of street fighting of the kind that took place during the revolution of 1848. Or one can visit any number of grotesque concrete buildings and huge plazas constructed on American university campuses during the late 1960s and early 1970s to defuse student demonstrations.” (Winner, 1980, p. 124)

Their ability to produce such arrangements relies though on their prior embeddedness in an existing social milieu. Haussmann’s boulevards were successful because the would-be revolutionaries did not have the resources to build barricades wide enough to block them. This point is duly acknowledged, but what is missing from Winner’s account is a developed picture of the role of the material of the technology in the production of agency. That is to say, there is little discussion about what it is about that material which causes it to behave the way it does, and consequently to encourage or produce (Winner, 1980, p. 130) the arrangements it does. This is exactly the point expressed by the previous arguments developed, about the role of ontological meaning within networks. To a point Winner acknowledges this himself.

“To understand which technologies and which contexts are important to us, and why, is an enterprise that must involve both the study of specific technical systems and their history as well as a thorough grasp of the concepts and controversies of political theory.” (Winner, 1980, p. 135)

To properly integrate the relationship between material, context and agency, we must return to Callon, Latour, and Law and specifically the concepts of translation and authorship. An *a priori* assumption of Winner’s account is that politics and social organisation on one side, and technological systems on another, *are fundamentally different things*. We have already seen how (Latour, 2005, p. 71) rejects this view and similarly Law insists that “society, organizations, agents, and machines are all effects generated in patterned networks of diverse (not simply

human) materials." (1992, p. 380). Latour, Callon, and Law would reject the distinction given above between the "specific technical systems and their history as well as [..] the concepts and controversies of political theory." (Winner, 1980, p. 135). We have already developed an argument about the status of the actor in its relationship to the network and established that agency relies on this relationship. Whether we acknowledge the gap (between technology and social arrangements) identified in Winner's proposal, or not, we must now turn our attention to the *quality* of agencies at work in our ecologies, that is to say to how, exactly, that agency is expressed. By doing so we will lend credence to Callon, Latour, and Law's collapse of Winner's distinction.

Earlier it was noted that Latour expressed agency as the production of "difference" (Latour, 2005, p. 72). This process or production is referred to in ANT as "translation" (Law, 1992, pp. 385-9). Law notes that within networks, some actors appear so embedded as to be, effectively immovable, giving entrenched political regimes as an example (Law, 1992, p. 379). Their position comes to appear 'natural' and their internal composition of a heterogeneous range of individual actors is reduced to a "black box" (Callon, 1991, p. 152), a unit apparently functioning *as one*, a status referred to as "punctualised" (Callon, 1991, p. 153). It is only with considerable force that such black boxes are opened and their workings revealed and potentially recomposed or scattered. Callon associates this depunctualising force with "authorship" (1991, pp. 135-6). For him, an author is an actor able to successfully position itself within a network to overcome resistance to change. It is exactly this definition that is held as productive for practice-based research. In this thesis, agency is that which is produced between materiality and an ecology and is reducible to neither. It is the capacity of things to overstep their boundaries (conceived of as their routine interaction with others[24]) and exercise

[24] A description of such boundaries as 'naturalised' can be found in later discussions.

translation in their ecology. Agency, in short, is measurable by the degree to which an actor is responsible for depunctualising other, strongly embedded actors.

A key finding of this review is that *the concept of a making-practice which consciously engages with the agential aspects of materiality is absent from design literature. Previous research has emphasised interpretative approaches to materiality missing benefits to making-practices*. This finding will be foundational for Chapter Five.

2.1.4 Critiquing Technologies; Avenues and Methods

In Section 2.1.2 some design research was criticized for applying a conceptualization of materiality which lacked a serious philosophical grounding for its approach, and which failed to articulate the interconnection between materiality and ecologies. The intention of this final section is to broaden the scope of the review by examining a wider range of research identified as a having potential for a productive relationship with making-practice. To further ground the later development of a number of facets of materiality into a framework for practice, this section will begin by examining some relevant strains of research which have already identified some particular features of materiality and assess to what degree these might be commensurable with a future design framework. Finally, some other research, in Media Archaeology, will be examined to ascertain whether its *methodologies* can be conceptually integrated with the developing approaches to materiality described thus far.

Matthew Kirschenbaum (2008) has produced an influential (for instance on Berry, 2011; Drucker, 2013) taxonomy of 'forensic', in the sense of ‘evidential’ aspects of materiality (which he describes as physical traces) and formal ones (such as the layout of a document)[25] which inform his detailed study of hard disk technology as

[25] Forensic materiality is found in '*the material substrates of computing — its drives, tracks, disks, and fundamental physical supports*” (Drucker, 2013). Formal materiality, meanwhile, is the instantiation of rules (Kirschenbaum, 2008): A CSS

a site of writing. His approach is compelling not only for its integration of technical detail with conceptual factors but because he has actually applied it in practice. His research archival practice (Kirschenbaum, 2013) is strongly founded in his conceptual formulation of materiality. His in-depth technical understanding of the specificities of particular kinds of storage media (such as magnetic floppy disks and VHS tapes) has informed his strategies for presentation and restoration of a number of archives of electronic literature wherein the materiality of the storage media is intimately connected to the writing process.

"[vintage computing] machines served a dual role: on the one hand objects of preservation in and of themselves, artifacts that we sought to sustain and curate; but on the other hand, the vintage systems served as functional instruments, invaluable assets to aid us in retrieving data from obsolescent media and understanding the material affordances of early computer systems."
(Kirschenbaum M, 2013)

Kirschenbaum describes the operation of hard disks as part of a process of *writing* emphasizing the similarity between human and machine forms of inscription. In Kirschenbaum's research, erasure and storage are conceived of as contributing to a wider process of meaning creation. In fact they are conceived of as part of rhetoric. Kirschenbaum describes materiality as a kind of evidential articulation of argument whose particular "rhetoric[al]" (Kirschenbaum, 2008, p. 15) mode is bound to its material foundations. Electronic literature, according to Kirschenbaum is expressive in ways which are inseparable from its material form.

As concepts, forensic and formal materiality have further potential for making-practice. Forensic materiality highlights the value in working with computer systems below the interface level, engaging with their mechanisms (as he puts it). This

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class which styles a webpage, for example, manifests formal materiality: It applies a set of formal decisions to that document and produces a stylistic effect.

implies a recognition that this infrastructural level shapes and structures those interfaces. Formal materiality affords a way of thinking about the way that constraints are introduced into that infrastructure through the application of rules. Those constraints may be as simple as styling on a webpage, or as fundamental as access restrictions to a computer network which determine one's interaction and experience with it. Both of these aspects present opportunities for intervention in design and making. Forensic aspects suggest literal places to work, areas of computer systems that can be remade differently with consequences for users. Formal aspects can be adjusted, rules re-written to produce different experiences. These points will be dealt with more fully in later chapters. Kirschenbaum's categories are exceptional in this review section in that, rather than forming the basis of facets of materiality themselves, their use is identified as methodological across the thesis as a whole. In many respects, Kirschenbaum's work is consistent with a Media Archaeological approach in his focus on the materiality of vintage technologies. The relevance of such approaches will be dealt with more thoroughly at the end of this section.

Johanna Drucker adds, to Kirschenbaum's (2008) formal and forensic categories, "distributed" and "performative" materialities (Drucker, 2013). In the following paragraphs, it will be shown that these two categories are inter-related, indeed co-dependent and that they have profound consequences for our relationship with contemporary computing technologies. Further, it will be demonstrated that while Drucker's categories provide a solid starting point, there are a number of concepts identified by other researchers which have a considerable bearing on these former and these correspondences will enrich both concepts.

The concept of distributed materiality "disturbs assumptions of singularity or stability" (Drucker, 2013) about technological artefacts and focuses on their interdependent and modular character. By highlighting this feature, Drucker aligns her research with (Blanchette, 2011), who describes the complex interdependencies of contemporary, networked technologies as a paradigmatic

form of contemporary technological materiality. Similarly, Nigel Thrift and Mathew Fuller provide analyses of the way that software structures contemporary culture on an *regulatory* level through such interconnected and modular systems. For instance[26], the enactment of finance through stock market algorithms, or the enablement (or disablement) of communications, are brought about only through the concerted action of a distributed network of computing devices, servers, PCs, electronic door locks, or Radio-Frequency Identification (RFID) tags. A co-dependency exists between the modularity of contemporary computing and the power of contemporary software: The relation of these, through both coordinating control software, and technical standards for interoperability, for Thrift, is best described as "a series of writing acts […] in which language is both message and medium" (Thrift, 2005, p. 242). It is in this sense that Thrift and Drucker describe the action of software as "performative" (Thrift, 2003). The performative[27] capacity of software identifies it as a both event and object. That is to say that it has material form (in computer memory and processors) but is also embodied in action as a series of interconnected processes. The complex relationship between written language (in computer code), the act of code compilation, and the processes which follow are the subject of Casey Alt's (Alt, 2011) discussion of object oriented programming (OOP) and the definition of computers as a medium (rather than a tool). Alt describes how the complex internal relationships of object-oriented software form, themselves, a kind of ecology:

"…within this multidimensional space of perpetually unfolding, interacting, affective objects, the program feels more like an embodied community and less like a linear script." (Alt, 2011, p. 296)

Spatiality was, of course, intimately involved in the development of early OOP languages such as Alan Kay's Small Talk. Kay's description of the early history of

[26] My examples.
[27] A fuller exposition of performativity will be given in Chapters four and five.

Small Talk is littered with references to spatial relationships in the form of architecture, boxes, cards and so forth (Kay, 1993).

The interaction of such software with the outside world can be seen as an integration of distributed and performative materialities. Modularity is present, not only in independent, networked devices but in the composition of software itself as an ecology of interacting programming objects[28]. The writing of software which brings about such interaction is performative in the sense that it, quite literally, 'writes action'. That is the acts of writing and computation are inexorably connected through the compilation process of software and through the subsequent interaction of integrated software objects and modular computing hardware.

A feature of the distributed and performative aspects of technology is that, for users, it is often difficult to actually see it in operation. Contemporary consumer technology, in particular, is designed to abstract users' experience from the technical infrastructure on which it relies[29]. Put differently, software is effectively invisible until its effects are made known. Thrift calls this state of invisibility "a kind of absorption, an expectation of what will turn up in the everyday world" (Thrift, 2005, p. 241). Technology continues to operate in the background but meanwhile shapes our understanding of our environment and how we interact with it.

Following (Foucault, 2009 [1966], p. 165), and in common with (Fuller 2008, p. 4), Thrift, notes the "conditions of possibility"[30] (the structural effects that technology has on regulating communication, relations, power) brought about by software and the way that such conditions become quickly naturalized and difficult to apprehend. Fuller suggests that a contributing factor to this 'naturalization' process is a view of

[28] In the sense of an OOP object.
[29] This point is developed further in the next chapter.
[30] The phrase "conditions of possibility" is attributed here to Foucault as integral to his exposition of the "episteme". It should be noted however that this term has a longer history, also being associated with Kant. (Russell, 1996, 637-51)

software systems as ‘immaterial’ which he finds to be “ultimately trivializing and debilitating” (Fuller, 2008, p. 4). He notes that although invisible, software materiality causes,

“…events [which] can occur at the level of models of user subjectivity or forms of computational power, that exceed those of pre-existing social formatting or demand new figures of knowledge.” (Fuller, 2008, p. 4)

This ‘invisible’ aspect of materiality will be theoretically developed in 4.3.3 to develop a number of distinct kinds of invisibility. The implication of these for both making-practice and ecological aspects of materiality will be discussed.

Like Kirschenbaum’s forensic materiality, distributed materiality also suggests technical starting points for makers. In this instance however, those are an investigation into the way that computer systems operate in combination. This distributed aspect is exploited by some artworks which technically intervene at the level of the network. Examples include Julian Oliver’s *Transparency Grenade* {Figure 10} which captures wireless network traffic and streams it to a remote server, (Oliver, 2012) and Jonah Brucker-Cohen’s *Wifi-Hog* (Brucker-Cohen, 2003) which disrupts public access WiFi networks by jamming the signal for other users (Brucker-Cohen, Gaye, & Goodman, 2004). These two artworks engage subversively with the infrastructure which allows distributed devices to co-exist. They are founded in a knowledge of that infrastructure in both its technical and performative aspects. Both works are engaged with a political debate about the security of wireless networks and the new modes of behavior that have evolved around them. The specifics of their politics however, is not the chief motivation for their inclusion as examples. Rather, it is that these works, following Kirschenbaum’s description, articulate a “rhetorical” (Kirschenbaum, Ovenden, & Redwine, 2010, p. 62), material argument. They exploit the technical infrastructure to ‘phrase’ their political points, through specific materials. Just as a rhetorical speech, relies on particular persuasive modes, or employs motifs to structure a

Figure 10: The Transparency Grenade, image and copyright Julian Oliver 2012

discourse for listeners, the interventions produced by Oliver and Brucker-Cohen use the technical resources at their disposal to reconfigure technical systems to embody a critique.

Having discussed various strands of research, tentatively grouped under the categories of performative and distributed materiality a final aspect is identified as what will be referred to as ‘fragile’ materiality. Some researchers have discussed aspects in which the materiality of contemporary technologies renders it fragile or vulnerable. Hitherto the main implication of this research has been in informing preservation and maintenance but it will be suggested in the following paragraphs that this aspect of materiality also has implications for making-practice.

(Manoff, 2006 and Berry, 2011) invoke parallels with the materiality of older media to describe the vulnerabilities of electronic objects:

“…critics have acknowledged that electronic objects are as dependent upon material instantiation as printed books. We access electronic texts and data with machines made of metal, plastic, and polymers.' (Manoff, 2006, p. 321)

Manoff and Berry use this comparison to explore implications for the maintenance and upkeep of digital objects asking: “Who will pay to maintain the digital resources? […] Will the user forums, and user contributions, continue to be monitored and moderated if we can’t afford a staff member to do so?” (Berry D. , 2011, p.11). Manoff points out meanwhile that the vulnerability of digital media is not only due to their dependence on financial support and human maintenance, it is also ‘built in’ to the physical materials from which they are made: “As physical artefacts, digital media are prone to degradation over time. This kind of disintegration is sometimes called bit rot or data rot.” (Manoff, 2006, p.318). These are only two examples of what will be described throughout this thesis as ‘fragile materiality’. Their significance for making-practice though is considerable. The exploration of perishable, temporary or fragile aspects of non-digital materials has

occupied many notable artists and designers including Gustave Metzger (Flailing Trees, 2013), and Felix Gonzales-Torres ("Untitled" (Portrait of Ross in L.A.), 1991), and thus some precedent for the creative potential of fragility exists. *Flailing Trees* (Metzger, 2013) upturned fifteen willow trees in a block of concrete, exposing their dying root systems and denying them the chance to photosynthesize. Torres' (1991) work meanwhile, allowed visitors to remove pieces of candy from the exhibition space. Representing the body of his dead partner, the candy effectively time-limited the exhibition, and brought the theme of loss and transience directly into the gallery space. Some artists have specifically taken 'digital loss' as both theme and form in their work. Zach Gage's *Lose Lose* {Figure 11} visualizes a computer's entire file system (including system files and applications) as aliens in a 'shoot-em-up' game (Gage, 2009). Successful kills result in the file being permanently deleted. The game playfully, and dangerously, explores digital fragility by making 'bit-rot' an intentional action.

What these works have in common is to use the fragility or vulnerability of the material world as an opportunity for the engagement of audiences (with environmental destruction, the effects of AIDS, and computer security respectively). These works demonstrate, if nothing else, that fragility is an aspect of materiality which is *affective*. However, audience (or user in other contexts) engagement is not the principal concern of this thesis. Instead, it is now suggested that to consider fragility in the context of making-practice is to acknowledge a particular kind of view of technology as inherently fallible. In Chapter 4 and Chapter 5 this notion will be explored more fully but at this early point it will be limited to some brief remarks. There is an interrelationship between fragility and the distributed nature of technological materiality described in previous paragraphs. In fact the former is, to a large degree, a product of the later. The increasing codependence of one technology on another brings about the potential for domino-effect failure, and with increasing technological complexity, this is increasingly difficult to predict. In Chapter 4 some historical examples of this phenomenon will

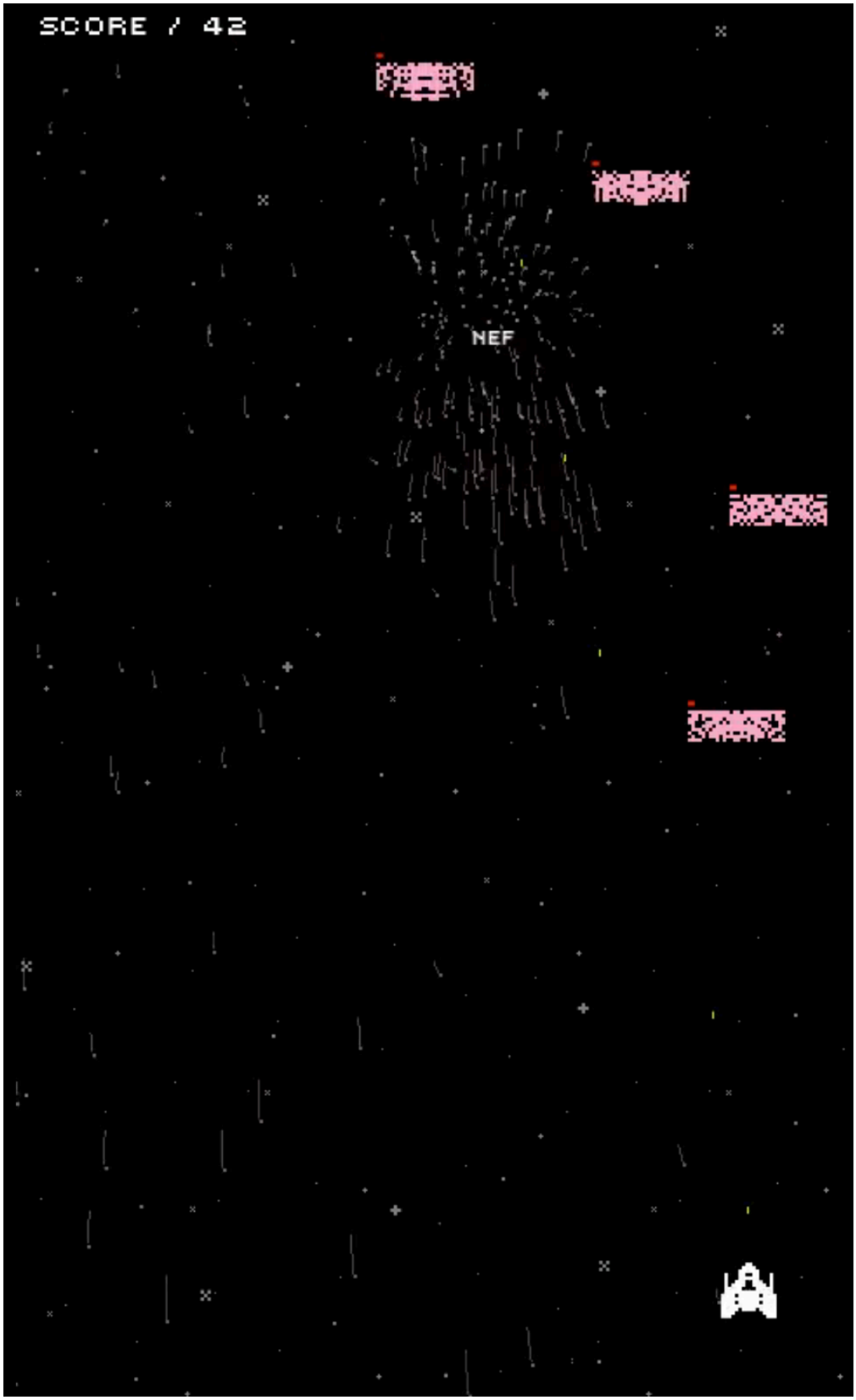

Figure 11: Lose Lose, screen grab. Copyright Zach Gage 2009

be described concurrent with a description of how this provided particular conceptual and technical opportunities during the process of creating an art work.

To this point, this section has examined research, which has been explicitly involved with the theorization of materiality as a concept. Various strands have been assimilated and some commonality established. Now a different focus will be introduced: Research described in the following paragraphs can all be described as falling under the label: ‘Media Archaeology’, although there is no canonical definition of the term, and various, diverse theoretical directions exist within its rather broad church (Huhtamo & Parikka, 2011, pp. 1-5). What is attractive about the field for practitioners is its focus on the artefacts produced by our technological past. In Chapter 4, further justification for an ‘archaeological’, or historical approach will be provided but in this section, some existing research will be examined for its methodological focus.

Friedrich Kittler examines historical and contemporary technologies (notably Gramophone, film, and the typewriter (Kittler, von Mücke, & Similon, 1987), fibre optics (Kittler, 2010), and computer graphics (Kittler F. , 2001)) to establish, in technical detail, connections between technological innovation and systemic, formal influences on human culture. He asserts that materiality manifests a cultural and historical agency, deterministically shaping the human sensorium and, by extension, our cultural imaginary. To provide an account for “the domain of technological manipulation of the real” (Winthrop-Young, 2006, p. 87), Kittler points out that “we knew nothing about our senses until media provided models and metaphors” (Kittler, 2010, p. 34), and that “what we take for our sense perception has to be fabricated first” (Kittler, von Mücke, & Similon, 1987, p. 103). As a society and as individuals, our ways of seeing and listening, for example, are shaped by technologies such as film or the gramophone, which also provide structures (rather than simply analogies) through which to talk about them. Kittler provides the example of the phenomenon of one’s life flashing before one’s eyes in the moments before death (Kittler, 2010, p. 26). Without the visual forms (in terms of

cinematographic convention, position of the viewer and other formal aspects) of cinema, he argues, this phenomenon simply would not exist. Kittler claims that our studies of history have become too focused on human beings. History is not a list of, “directors, stars, studios and celebrities, which in the end remains organised around a series of titles” (Kittler, 2010, p. 26). In other words, to fundamentally understand historical phenomena, we must provide a theoretical material foundation to the technologies which give them genesis.

Kittler uses materiality to account for the way that our bodies are related to technology (such as the ear to the gramophone) and to provide a counterpoint to historical approaches which emphasize human agency as the sole or even main impetus in history and culture. The main relevance of Kittler’s work to this thesis is in encouraging a *historical* or *archaeological* study of particular technological materialities. Kittler’s analysis is always grounded in specific technologies which provide new avenues of thought. A commonality exists between Kittler’s writing and the aims of this thesis in that it, methodologically, *it begins empirically* with a study of technology in action before making its claims. In Chapter 4 and Chapter 5 it will be described how the practice-based research of this thesis adopts aspects of this approach, combined with experimental making-practice.

Kittler’s position is considerably more extreme than that given by (Winner, 1980) or (Pinch & Bijker, 1987) both of whom take a more balanced view of the determining forces at play in the social arrangement of people and technology. Pinch & Bijker’s main contribution is, perhaps, to note that “the developmental process of a technological artifact is […] an alternation of variation and selection” (Pinch & Bijker, 1987, p. 28). Pinch and Bijker discuss the development of artefacts (their chief example is the bicycle) as situated in a social context which produces a selection from developing technological alternatives. The ‘safety bicycle’[31], for

[31] The ‘safety’ is what we might think of as a modern bicycle with a diamond-shaped frame and pneumatic tires.

instance gained dominance because of its successful adoption into the racing market, bringing it to popular attention. In essence the agency of this design is located completely contextually. In the terms adopted by this thesis it is successful because it is situated in a network, arranged favourably to its success. What is dramatically missing from Pinch & Bijker's account and, to a lesser degree from (Winner, 1980), is much developed discussion of what precisely it was about that design that contributed to that advantageous situatedness. The role of the mechanics who actually built the bicycle and their skills, the advances in steel and welding techniques, in short the materiality of the bicycle itself is reduced to a short note about the engineers' disapproval of the pneumatic tire (Pinch & Bijker, 1987, p. 422). These vital processes of building are precisely what eludes an analysis based on "selection and variation" (Pinch & Bijker, 1987, p. 411).

Wolfgang Ernst uses a technical exploration of storage media (such as recording media; discs, tapes or vinyl) to propose new approaches to media history (Parikka, 2011, p. 53). In line with (Huhtamo & Parikka, 2011; Parikka, 2011) he argues that media histories have hitherto focused too sharply on 'narrative' approaches. That is to say they have sought to describe the *effects* of media on culture through studying both its content (such as the plotlines or imagery of films) and the theories of other historians. Ernst's approach, though applied by himself to historical study, is identified as having some methodological implications for this thesis. Particularly, his combined technological and conceptual analysis of storage media (which has some resonance with (Alt, 2011; Blanchette, 2011; and Kirschenbaum, 2008), provides further proof not only that such a combination is possible and productive, but that it offers a radically different order of conclusions than research conducted without such a close technological reading. Some of such conclusions from Ernst's research will be described in the following paragraph.

Ernst outlines a notion of "media archaeo***graphy***' (Ernst, 2011) [emphasis added]. The '-graphy' refers to histories of technology authored by machines themselves in the form of wax cylinders, magnetic tape and patina. In every medium of recorded

audio, he argues, a different *kind* of writing survives. Ernst's proposition is to consider this technological writing not as historical *sources*, but as other historical *accounts* with particular modes of expression, temporality or spatiality. This approach fundamentally refocuses media studies on the specificities of technology in terms of its technical functionality. From there it can go on to discuss its place in culture, its effect on users and its relationship to other technologies. The emphasis though is in the way that technology *acts itself* rather than in the way that it functions as a *medium* for content. In this sense there are parallels with McLuhan's (1994) work whose descriptions of "hot" and "cold" media emphasized the capacity of specific technologies to embody particular modes of communication. Where Ernst's research departs from McLuhan, though, is with an increased emphasis on the kinds of *meaning* produced by technological systems in their own right[32]. Ernst explores the particular configurations of space and time produced by storage media in terms which approach the architectural. It is here that real significance of Ernst's work for makers, is located. By undertaking close descriptions of media in their spatio-temporal aspects he implicitly encourages makers to treat those as working *spaces* to be explored:

"…the historical mode of describing temporal processes has been confronted with alternative modelings of time, When it comes to describing media in time, this aporia becomes crucial, since one can no longer simply subject media processes to a literary narrative without fundamentally misreading and misrepresenting their Eigenzeit[33]. Historical media narratives take place in imaginary time. Storage technologies, on the other hand, take place in the symbolic temporal order..." (Ernst, 2011, p. 242)

An "Eigenzeit" for Ernst, is a recognition that computational processes are subject to an unthinkable complexity in the relationship between time, space and

[32] A point commensurable with Meillassoux's 2010 work already discussed.
[33] Eigenzeit translates approximately to "own" or "characteristic" time. (Oxford Dictionaries, 2013).

materiality. Alt's (2011) work noted that the dynamic intra-action, action between different parts of the same programme, means that OOP creates, what he calls, "communities" of parts. Ernst's work implies that to map such a community requires different tools for the historian, it cannot be expressed as existing on a linear, or even branching sequence of time and necessitates new forms of description and intervention.

The development of new conceptions of time and space can be shown historically to have a reciprocally influencing relationship to creative practice as well as scientific research (which of course have at times been integrated)[34]. It is suggested (without necessarily implying a direct relationship) that many aspects of Ernst's "Eigenzeit" are implicit in the sound artwork of Shintaro Miyazaki[35]. Miyazaki sonifies sorting algorithms and computer electromagnetic emissions (Miyazaki, 2012) by taking such spaces as both a subject (the pieces are about the physical and algorithmic spaces of computers) and a material (they are made *in* and *with* those spaces). Miyazaki's treatment is distinctly spatial; *Algorhythmic Sorting* Miyazkai, ongoing substitutes and reorders sounds in a space which is both sonic and based on computational processes. *Computer Music* (2012) explicitly deals with the physical extent of a laptop computer and the shifting activity, through time, of particular components within that space.

2.2 Summary: Materiality

This chapter investigated a broad range of theories and philosophical approaches to materiality. A key finding of the review is that there is a richer, more historical, more critically informed account of materiality and its implications to be found in research which theorises materiality in the context of technology *after* the making-process is effectively over. There is consequently an opportunity to develop theories of materiality that integrate more tightly with making-processes. It is asserted that some research in design (Ishii, 2008; Ishii & Ullmer, 1997; Ishii,

[34] For instance in Bakhtin (1981).
[35] Miyazaki's work is of particular interest because of his treatment of the times and spaces produced by contemporary computational hardware.

Lakatos, Bonanni, & Labrune, 2012; Jung & Stolterman, 2012; Jung & Stolterman, 2011; Robles & Wiberg, 2010; Wiberg, 2013), has hitherto focused on a narrow definition of materiality, based principally on qualities, form (i.e. the aspects of materiality which inform perception), metaphor and interpretation, which, while useful as described, represents only part of the potential benefits of research into the concept as applied to making. Crucially such approaches do not satisfactorily account for the agency of technological artefacts and systems. A proposition for such an account was offered in section 2.1.3, founded in the discussion of ontology in 2.1.1. It was argued first that ontological meaning is an a priori part of materiality and being. An integration of that view with ANT was then offered and agency was established as the capacity of actors to 'exceed their limits' based on a combination of their situatedness within a network and the interactions of ontological meaning which constitute that network.

The first contribution of this thesis, which has begun in this chapter, is to explore how a multifaceted approach to materiality can inform and benefit making-practices. A synthesis and development of key concepts from works described and original analysis of them is now offered.

Drucker (2013) offers the term "performative materiality" to align her theories of materiality with previous work (Austin, 1962; Butler, 1988; Searle, 1976) which focus on the capacity of utterances to act in the world. Her method though inadvertently reduces such action to an effect of language (a tendency criticised by Barad, 2003, p. 802). It is proposed that a more powerful conception of the term would, drawing on (Blanchette, 2011; Fuller, 2008; Kirschenbaum M. , 2008; Thrift, 2005), account for the way meaning and action are processually created, how technical systems and human creativity combine to produce them. Drucker's formulation of this term is insufficiently founded in specific technological examples and the adoption of Media Archaeological approaches such as in (Ernst, 2011; Huhtamo, 2004; Kittler, von Mücke, & Similon, 1987) are proposed as a remedy.

Better realised is Drucker's notion of "distributed materiality" (Drucker, 2013) and examples have been offered of how some artists (Brucker-Cohen, 2003; Oliver, 2012) have already produced work which intervenes on this level or "register" (Thrift, 2005) of materiality. Distributed materiality emphasises the modular, layered (Blanchette, 2011, pp. 8-12) and inter-connected nature of contemporary computing technology and the way that it combines to structure or regulate our "conditions of possibility" (Foucault, 2009 [1966], p. 165; Fuller, 2008, p. 2). It has been noted that there is an interrelationship between the kinds of materiality indicated by the previous research and Thrift's concept of "writing acts" (Thrift, 2005). Thrift's 'writing' is proposed here as a way of integrating performative and distributed materialities as software interacts with modular and networked technologies.

Materiality affords a way of thinking of the *fragililty* of technology. The term 'fragility' is employed to emphasise the nature of technology as "perishable" or "easily destroyed" (Oxford Dictionary of English, 2010). Drawing inspiration from (Berry, 2011; Manoff, 2006) some contemporary artistic work (Gage, 2009) was aligned with examples of older creative practice. These latter, explored the fragility of other kinds of material (Gonzalez-Torres, 1991; Hirst, 2009; Metzger, 2013). It was consequently demonstrated that fragility, as a source of creative inspiration has precedent. More importantly it was suggested that fragility is a corollary effect of the distributed character of materiality and consequently, the understanding of one, involves an appreciation of the other.

Ernst's (2011) work on the "eigenzeit" or distinctive temporalities of recording media, together with Kirschenbaum's account of writing with hard disks as a "rhetorical" process (2008, p. 15) share a notion that technology creates new *spatio-temporal arrangements*, and both researchers serve as exemplary models of integrated conceptual and technical research. An early proposal is advanced that the idiosyncratic spatio-temporal arrangements of particular technologies, in

the context of practice, can be thought of as *working spaces* to be explored, re-shaped and creatively intervened with.

Finally *future-oriented materiality* is offered, as a way of encapsulating and developing a number of disparate threads identified in this review. (Heidegger 1971; 1996 [1927]; Keane 2005; 2013; Meillassoux, 2010; and Miller 2005) all offer distinct ways of considering the production and origin of meaning. The embodiment of meaning in the world means that meaning is never 'settled' leading to a variety of potential futures (Keane, 2005, p. 193). To engage in making, with such a perspective on materiality, is to see one's work as an intervention into the production of future meanings, not as a *creation* of meaning *ex nihilo*. In Chapter 4 and Chapter 5 the effect of this understanding on making-practice will be explored through an account of the production of a number of works of art and design.

These five facets are presented here at an initial stage. Chapter 4 will develop them further describing how they are also a product of practice-based research. Having presented some initial descriptions of the five facets of materiality identified, in the next section a different focus will be adopted. In the introduction, it was suggested that a benefit of materiality, as the basis for a making-process, is that it suggests a number of ways that one's work integrates into the contexts in which it is exhibited, deployed or otherwise put into circulation. The next chapter will develop some theoretical background for this ecological approach.

Chapter 3. In What Sense, Ecologies?

This chapter provides background review to inform the later development of a notion of an ‘experiential ecology’. The previous chapter dealt, at length, with a series of conceptual and methodological factors pertaining to the integration of concepts of materiality with making-practice. A key finding, particularly from the discussions of agency, affordance and the distributed nature of contemporary technologies, was that a conceptually developed understanding of materiality *inevitably* engages with an ecological approach. Briefly, it was argued that (a) understanding agency involves an integration of concepts of ontological meaning and situatedness within a network (b) affordance is a meaningful concept only when taken as a product of animal, environment and action (irreducible to rule-based abstractions) (following Suchman, 2007), and (c) contemporary computing creates what are in effect ecologies of interacting objects of software (in the sense of OOP) and modular technologies (building on Alt, 2011; Fuller, 2005; 2008; and Thrift, 1996; 2005). Thus, there are three initial provocations for further literature review into the way that the concept of the ecology has been formulated previously. These will be discussed here before being revisited in the final chapter.

In the following sections it will be observed first how (Gaver 1991) notes the “continuity of information” in groups of “nested affordances” which are part of an ecology of action-cognition. Next, (Sharrock and Anderson 1993) stretch the concept of affordance outwards from its earlier application to individual interactions and in terms of individual properties of affordance, into an ecological dimension involving interconnected and co-dependent individuals, tied together in activities. While (McCarthy & Wright, 2004) following (Dewey, 2005 [1934]), provide an experiential dimension to ecologies, (Bennet, 2010) attempts a more holistic account of the way that humans and objects co-exist in ecologies by describing them as ‘publics’.

3.1 Aims and Objectives

Given the findings from Chapter 2 described above, the overall aim of this review chapter is to provide an overview of the concept of an 'ecology', as it has been applied to technology, to describe the defining features of various kinds of ecologies and how they differ, and to identify relationships between theories of ‘ecologies’ and materiality. This analysis is intended to inform the later development of what will be called ‘experiential ecologies’ by asking, for instance, how ecologies are formed, how a making-process can be affected by an ecological understanding and what, if any, are the aesthetic implications of ecological contexts for making. More specifically the objectives are:

In 3.1.1 to re-visit some ontological approaches to materiality and establish their rapport with theories of ecology.

In 3.1.2 to examine previous accounts of ecologies in studies of technology and to consider their potential applicability to, or contrast with, experimental making-practice as described in this thesis.

In 3.1.3, by discussing the relationship of cybernetic theories to early 1970s art practice, to consider the role of modeling in ecological theories.

In 3.1.4 to begin a discussion of the relationships between ecologies and experience and specifically to attempt an integration with aspects of materiality.

In 3.1.5 to consider some ways in which ecologies are formed and delimited.

3.1.1 Making Ecologies

Chapter Two began to argue that particular philosophical approaches to the origin of meaning, tied to materiality, had the potential to provoke a particular attitude from makers. Briefly, it was suggested that viewing meaning as something inherent to materiality motivates a methodological involvement with the pasts of artefacts, such as that found in some approaches from Media Archaeology (e.g. Ernst,

2011), and also brings about a view of them as involved in the production of future meaning (following Keane, 2005; 2013). It was further argued that there is an ethical dimension attached to this view of materiality and that this latter, is founded on an understanding of ourselves as ontologically connected to the ecology in which we create things. It is the definition and implications of this connection which will be expanded here. This chapter will discuss a variety of approaches to the concept of ecology but it will be seen how some common threads emerge. A point of concentration for analysis, taken as central in this section, will be the degree to which the material world and human cognition are perceived as separate or integrated. In short, it is proposed that a central question to be resolved for any definition of an ecology is the nature of subjectivity/objectivity within it and the relationship of both with the world around us. Disagreements over this fundamental issue, it will be shown, permeate many discussions of ecology over the past forty years in literature and practice.

Before examining the notion of ecology as specifically applied to technological systems and their relationship to human users, the following paragraphs will describe how Heidegger conceived of the relationship between people and the material world, and building on the discussion in Section 2.1.1, consider their implications for making-practice. Heidegger's perspective will provide a philosophical grounding for the particular, materially implicated, view of ecologies which will be developed throughout this thesis. Heidegger (1996 [1927]) offers a significant disruption to a Cartesian view of subjectivity /objectivity in which the internal mind is essentially distinct from world around us. His account of the relationship between humans and the world begins by claiming the privileged ontological position of a human, or human-like actor: Dasein.

It was described in the previous chapter that materiality in Heidegger is part of a particular kind of ontological relationship *for* a particular kind of being. In Heidegger, however, there is also a complex and troublesome mix between a dependence on human intervention and an absolute insistence that it is also

inherent to beings. For instance ‘handiness’ (*Zuhandenheit*), the quality of being encountered as *for a purpose* (Heidegger, 1996 [1927], p. 60), despite dependence on *Dasein* is described as “the ontological categorial definition of beings as they are **‘***in themselves***.’***”* (Heidegger, 1996 [1927], p. 67) [emphasis added]. For Heidegger, this apparent contradiction is resolved by developing an account, or rather accounts, of the *way* things are in a world in which Dasein is involved with careful attentiveness. This ‘care’ is part of the ‘primordial’ nature of Dasein as part of a connected whole.

“Our absorption in taking care of things in the work world nearest to us has the function of discovering; depending upon the way we are absorbed, innerworldly beings that are brought along together with their constitutive references are discoverable in varying degrees of explicitness and with a varying attentive penetration. The kind of being of these beings is ‘handiness’ (Zuhandenheit). But it must not be understood as a mere characteristic of interpretation, as if such ‘aspects’ were discursively forced upon ‘beings’ which we initially encounter, as if an initially objectively present world-stuff were ‘subjectively coloured’ in this way.*”* (Heidegger, 1996 [1927], p. 67)

Our ecological relationship with our surroundings, in a Heideggerean mode is resolved only through an active relationship with the world. This action for Heidegger is part of an on-going attentive relationship with the world. Our ontological relationship with our surroundings is actually defined and maintained by the kind of engagement with them that we enter in to. This account of action as ontologically defining provokes a view of ecologies in which we are always already engaged with the world and as such our relationship with it cannot be reduced to the ‘them and us’ of Cartesian subjectivity:

“Such a view of ‘engaged agency’ leads Heidegger to jettison the Cartesian way of thinking of human beings, as isolated and disengaged subjects who represent objects to themselves, and to settle instead for the world-disclosing function of

practices which always assumes a background of implicit familiarity, competence and concern of involvement." (Thrift, 1996, p. 10)

More recently Heidegger's position finds a compliment from (Suchman, 2002; 2007). Where Heidegger was making claims for the ontological status of the world however, Suchman is interested in the way people make sense of it in activity. What is common to them both though, and what justifies their discussion together here, is that in both there is a constitutive relationship between activity and the world that is not divisible to physicality versus conscious thought. Suchman's research is relevant here, although her focus is on social interaction, because her account of the social is integrated with an understanding of our relationship to the material world. Her account of sense-making, from which an example passage is given below is founded on a notion that activity, thought, and the world are not meaningful concepts if taken independently.

"The sense of the situation I am after, […], is a radically performative and interactional one, such that action's situation is in significant respects constituted through, or stands in a reflexive relationship with, on-going activity. It is through the latter that the sense and relevance – just what the situation comprises – is produced, re-enacted, contested, and/or transformed." (Suchman, 2007, p. 125)

Both Heidegger and Suchman, in different ways, treat our relationship with the world as one in which we are already engaged. For Heidegger, this engagement is part of an ontological relationship. For Suchman the establishment of 'social facts' "…how it is that the mutual intelligibility and objectivity of the social world is achieved" (Suchman, 2007, p. 76), rests on a study of how social experience is played out in concrete experience in particular circumstances located in the physical world. Suchman (above) suggests that situations are also, in part, constituted in performance. That is to say that sense making is only possible because of an on-going, iterative, contribution by (in Suchman's case) people in action, to what the world is. The previous chapter saw that 'performativity' can also

be regarded as a facet of the concept of materiality and this connection between materiality, performativity and ecologies, will continue to be developed throughout the thesis.

In the previous chapter it was noted that our ontological involvement with materials provokes, for Heidegger a sense of moral responsibility for this involvement, and this view here has been expanded to look at how our involvement is also, inherently ecological. While the previous chapter considered this from the perspective of our relationship to materials, it is now acknowledged that such a mode of "engaged agency" (Thrift, 1996, p. 10) provokes a view of oneself as already 'carefully' involved with the ecologies in which one makes. This in turn brings about a consideration of the way our making-practice is, in fact, a mode of activity through which we express our ecological involvement. *This last point is presented as a finding of this section of literature review*.

3.1.2 Affordances and Social Ecologies

The concept of 'affordance' has already been examined briefly in the way that it has provided designers with a way of thinking about materiality when they design interactions. It was asserted at that point that the concept of affordance is, in fact, meaningless without a due consideration of its ecological nature and that a failure to fully appreciate this undermines the claims of some design activity[36]. Affordance, it was proposed can be thought of as a combination of animal, environment and action and this definition establishes its relevance to the concept of an ecology. In fact, previous research has, in different ways, attempted to integrate these concepts and some of this will be examined in the following paragraphs.

Gaver notes, following (Gibson 1979), that the interplay of perception, action, and the environment is fundamentally an ecology.

[36] Reference the discussion of materiality and metaphor in some TUI literature in 2.1.2 in which it was claimed that by metaphorically *referencing* the affordances of interactions misses the rich and situated character of that interaction.

“The notion of affordances is in many ways the epitome of the ecological approach, encapsulating ideas about ecological physics, perceptual information, and the links between perception and action.” (Gaver, 1991, p. 79)

Gaver goes on to develop a nuanced analysis of how this operates in perception/interaction by noting how affordances can be mutually supportive and exploratory. Affordances, according to Gaver, combine in objects to form local ecologies, what he calls, “nested affordances” (Gaver, 1991, p. 82) of their own which provide interactional opportunities to users, that is to say, things to explore:

“In general, the affordances of complex objects are often grouped by the continuity of information about activities they reveal. Affordances are not passively perceived, but explored.” (Gaver, 1991, p. 82)

Gaver gives the example of the “nested affordances” of a door (Gaver, 1991, pp. 81-82). The separation of the door from the wall affords movement which in turn supports the affordance of the handle which suggests pulling or pushing. This model is ecological in the sense that it presents a user located in domain of multiple possibilities of interaction. The user is always already engaged in an exploration of such possibilities. In the context of the door, they can push or pull it, use the handle or ignore it but each of those choices is a kind of ecological *exploration*. The aim of Gaver’s research into affordances is not dissimilar from that of (Norman, 1999), already discussed. What separates them is that by integrating action and environment through the discussion of exploratory possibilities, Gaver does not present us with the false dichotomy described by (Norman 1999) between affordances as perceptual or inherent to the world, but integrates the two by acknowledging exploratory action as the bridge.

Sharrock and Anderson (1993) develop an unorthodox notion of affordance, and apply it to the way that knowledge is distributed around workspaces. Their affordances are ‘unorthodox’ inasmuch as they seek to develop a “delineation of

the *social construction* of affordance" (Sharrock & Anderson, 1993, p. 144), [emphasis in original] to understand the organisation and distribution of cognition within such environments (Sharrock & Anderson, 1993, p. 144). To do so, they point out that cognition relies on particular "structuring affordances" (Sharrock & Anderson, 1993, p. 147). As an example they describe how an office layout embodies part of a social, cognitive ecology (Sharrock & Anderson, 1993, p. 144) in the distribution of knowledge around a team, as physical clues such as the table or desk one sits at implies ones engagement in particular tasks which form part of a chain or workflow:

"We always perceive, see, hear something. One sees a chair; hears a voice; touches a surface. But, in that it is intentional, perception involves us, the perceiving agents, in a relationship with our environment as an environment of perceived objects. Hence Gibsonian theory is ecological. We like to think of this relationship as one of 'structuration'. We do not just see, hear, feel things. We see, hear and feel them in a context, against a background of other things and actions." (Sharrock & Anderson, 1993, p. 146)

Sharrock and Anderson's use of affordance describes the way that physical objects, combined with social relationships, structure cognitive processes by mediating interaction between team members. This extended or distributed interaction is construed as a knowledge creating scenario. Because these actions extend through objects into ones relationship with others in a workplace, and *vice versa*, knowledge-in-action is mutually constitutive:

"The connection between knowledge and action is defined in constitutive terms. Patterns of knowledge and patterns of action define each other. Hence knowledge is seen as social through and through." (Sharrock & Anderson, 1993, p. 149)

In their examples from the workplace Sharrock and Anderson describe the production of knowledge through the interaction of team members. Their

understanding of how to accomplish tasks, is imbricated with an appreciation of how work flows through a physical and social environment. Sharrock and Anderson ask, “what it is about the social worlds in which we all live which enable us to see organisational objects in the ways which we do?” (Sharrock & Anderson, 1993, p. 158), pointing out that to see world as social and organised, provokes a question over how inter-subjectivity is embedded in our environments. The first implication of Sharrock and Anderson’s work for the notion of the particular sense of ‘ecology’ as it will be developed here is in their account for the way that knowledge production is embedded in the world and resolved in action.

The wider field of distributed cognition also evokes notions of the ecology. In (Hutchins 1995) the concept of a ‘cognitive ecology’ is used to describe interactions between a team of sailors, their instruments and the boat itself in “an ecology of thinking in which human cognition interacts with an environment rich in organizing resources” (Hutchins, 1995, p. xiv). Hutchins’ ecology though while seeking to integrate inner cognitive worlds and external worlds of tools and actions is founded on the basis that these are separate. When he suggests that, “Every argument showing why a particular tool is easy to use is also an argument showing why both internal and external tools are part of the very same cognitive ecology.” (Hutchins, 1995, p. 114), there is an implicit ontological claim being made wherein two opposing kinds of *thing* (internal and external tools) are described and juxtaposed.

The second main implication, for the developing notion of an ecology from this work, is the recognition that an environment of things ‘structure’ or ‘organise’ knowledge. This indicates an important recognition of a particular kind of role for materiality within ecologies in the context of making-practice. Earlier, agency was defined in terms of the ability of actors to cause structural changes to a network. This was described as an ability of things to ‘overstep their limits’. The concept of a ‘nested’ or ‘structural’ affordance is another way of accounting for the kinds of roles that materiality can embody in this scenario. If materials are taken as being able to

redefine a working environment in their own unique ways then they have a role in the kind of knowledge that may be produced within that environment.

This thesis aims to develop an understanding of ecological involvement which will inform and support making-practice. Although the paragraphs above have begun to describe some of the rich scholarly history of the concept of ecology, *it asserted that there remains significant scope for contribution to be made in the area of technologically-engaged creative-practice.* Supporting this claim is the fact that there are methodological commitments, and elements of professional organisation which differ radically from the work described in this thesis, and the research referenced above.

Although the structuring involvement with social arrangements or knowledge creation assigned to materiality, as described by (Sharrock & Anderson, 1993), is significant, it adopts (perhaps appropriately given the field of research in which it is located) an anthropocentric approach which is not entirely commensurable with the aims of this thesis. The focus on the materiality of contemporary technologies in the context of making, here, provokes further reflection of the kinds of roles enacted by technology in ecologies. Given the particular nature of the practice described in this thesis (as creative and trans-disciplinary) there is an imperative to think more broadly about the relationship of materiality and ecology: A key understanding, as described in the introduction to this chapter, is that previous research into ecologies described in this section, belonged to *a particular historical period of the study of human computer interactions* (the 1980s to mid 1990s) and was mostly generated around the field of Computer Supported Cooperative Work and associated conferences and journals. This is significant because of particular *methodological arrangements* which accompanied such work. Early ethnographic studies (such as Heath & Luff, 1991; Sommerville & Bentley, 1992), in common with (Sharrock & Anderson, 1993), attempted to provide accounts for the social organisation of work as enacted within an environment. The rich, detailed, observations made by such studies certainly produced plausible accounts of the

way that social arrangements functioned in the workplace[37] and are not inconsistent with a definition of those arrangements and the environment in which they are enacted as ecological. However the work produced during the period identified, referenced here, was intended to describe ecologies with an entirely *different kind of practice* in mind and this motivates new methodological approaches. The ethnomethodological work cited above was produced in environments where there was a division of labour between the empirical social scientist researcher, who was asked, eventually, to extract design recommendations, and the systems designer who implemented them. There was consequently a temporal, organisational separation between study, design and implementation, arranged on a mostly linear transition from one to the next, albeit with iteration over various stages.

The transition, described above, from observation to implementation was not at all unproblematic as has been noted (e.g. by Plowman, Rogers, & Ramage, 1995; Pycock & Bowers, 1996), and this has been a source of some criticism of ethnographic techniques. It is also perhaps, a contributing factor to the development of more hybrid methodologies, adopting ethnographic approaches but combining them with various forms of critique such as (Dourish & Bell, 2011, pp. 61-90). In addition to the difficulties involved in the transition from observation to design there are further motivations for contributing new understandings of the ecology into thinking about the process of making art and design. This thesis describes a methodology where observation (of technical systems and interaction, rather than the social organisation of work), and experimental making-practice are not formally separated. The ecological focus suggested by such a practice is founded in the working space itself and may precede any interaction with audiences or users. An important distinction being made is that rather than

[37]Crabtree, Rodden, Tolmie, & Button's (2009) reminder that ethnomethodology is applicable not only to "work" situations is noted.

ecologies around the use of technologies, post design, this thesis examines ecologies of technology where making-practice and investigation are integrated.

Until this point understanding affordance has been used as a way of explicating user experience, not as a facet through which to study our creative interaction with ecologies. However, some attempt to reconcile these different aims can be found in John Bowers' (2002) description of "performance ecologies" in live improvised, electro-acoustic music. Bowers describes how the arrangement of various instruments both supports his own performance and gives perceptual cues to other musicians.

"Guitar to the left and physically manipulable. Computer to the right and running composition machines. Synthesiser centrally placed offering knob control over noodling patches amongst other things. The point here is that by moving from one side of the table to the other I can do different things and be seen to be doing different things – different in gesture type, device type and sonic consequence. Not only does this organisation of my playing environment make things more effective for me, it gives clues to the legibility of my gestures, both for co-performers and audience." (Bowers, 2002, p. 52)

Bowers' performance ecologies are ecologies of not only musicians but of instruments as well. The particular layout, as well as the technical connections between one instrument and another form organisational affordances that allow different kinds of structure to his actions. These are bound, to the presence of objects and their arrangement in space, relative to one another, to him and to his co-performers. There is, in this respect, some commonality with Sharrock and Anderson's (1993) work but relocated to creative practice. By invoking the visibility of gestures, Bowers implies another kind of ecological analogy with the natural world which is also emphasised as potentially helpful to making-practice: An ecology of communicating animals in a dynamic interaction with the material world around them as well as with each other. Such an analogy serves as a reminder

that ecologies are, and should be vibrant, communicative places where choices are made and expressed.

3.1.3 Environmental Ecologies

Other authors have invoked notions of the ecology to describe a variety of modes of interaction between people and their technological environment. It will be observed that a recurrent issue for debate in this area is the relationship between model/theory and the world which it describes. This issue is pertinent here, since creative practice will later be proposed as one way of avoiding this duality. Fuller (2005, pp. 3-6) summarises a number of distinct strands of 'ecology' which, for him, form a useful intersection. First, "information ecologies" is employed to discuss the movement of information through an organisation through (human) management and computer infrastructure. We might include Sharrock and Anderson's (1993) work in this category. A second strand is a kind of 'environmental ecology' inspired by the contemporary green movement is relevant first because it provides some example of problems encountered in the close application of an ecological model to the world itself and second because of its involvement with creative practice. As such a brief overview of the field will be offered.

"Such environmentalism also often suggests that there has passed, or that there will be reached, a state of equilibrium: that there is a resilient and harmonic balance to be achieved with some ingenious and beneficent mix of media." (Fuller, 2005, p. 4)

An example of such an environmentally inspired ecology is found in (Nardi and O'Day, 1999) and builds partly on the writings of John von Neuman (as described by Thrift, 2005, p. 244). This environmentally inspired ecology is beholden to the field of cybernetics (for instance in Bateson, 1970; Weiner, 1948; Wilden, 1972) which was also influential in early computer art. The idea of the cybernetic system

– a self-regulating machine whose goal is homeostasis based on feedback[38], was applied enthusiastically as a model for nature. The adoption of a techno-environmental model (the cybernetic system) was, indeed, explicitly referenced in the 1968, Institute of Contemporary Arts show *Cybernetic Serendipity* and *Software* (Shaw, 1968), Jack Burnham's contribution at the Jewish Museum, New York (Burnham, 1970) and Roy Ascott's 'cybernetic vision' (Ascott, 2003, p. 126).

Some stronger versions of the cybernetic model (such as in Weiner, 1948), adopt significantly different positions than that adopted by this thesis with regard to the nature of intra-ecological communication. Commentators (eg Curtis, 2011; Suchman, 2007), have observed that some influential research, both informing cybernetics (such as Shannon, 2001 [1948]), and influenced by it more recently (particularly in AI research such as Brooks, 1999), adopt a Cartesian dualism by treating communication, for example, as a phenomenon which can be described in the abstract, without a true, contextualizing situation. The notion that natural systems can be reduced to signal processing of the sort described by (Shannon, 2001 [1948]) is, to some degree, implicit in the metaphor of the cybernetic circuit. Such accounts are criticized by (Suchman 2007, p. 251) as fundamentally misunderstanding the nature of communication which she describes as a series of actions, contingent on both in-the-moment decisions, and as being a kind of *performative* action, similar to that described in Chapter 2.

However, some contributors to the field of cybernetics approach the performance of communication and feedback differently and raise points which have potential relevance for this thesis. Bateson (1970) discusses the relationship between formal abstractions (models) and the world itself, with an awareness of the problematic relationship between the two. His definition of 'difference', for instance, was

[38] Cybernetics employed the notion of a 'circuit' (in the sense of an electronic circuit) as a model for understanding the interactions of organisms within a system. Feedback, the capacity of organisms to respond to stimuli, is a key requirement of a successful "circuit".

intended to lessen this by noting how abstract the very notion of the difference between the physical world and representation is. In the following quote he discusses this through an analogy of the territory and the map respectively.

“The territory never sets in at all. The territory is *Ding an sich* and you can’t do anything with it. Always the process of representation will filter it out so that the mental world is only maps of maps of maps, ad infinitum. All ‘phenomena’ are literally ‘appearances.’” (Bateson, 1970, p. 509)

Bateson continues by proposing various ways that the mind extends into its environment, proposing something not unlike the distributed cognition of (Hutchins, 1995) and though there remains a distinction between the world outside, and the mind within, that distinction is conceived of as a matter of degree. Interestingly, like (Heidegger, 1954; 1971;1996 [1927]), Bateson conceives of ethical implications for this imbrication with one’s environment, suggesting that: “A certain humility becomes appropriate, tempered by the dignity or joy of being part of something much bigger…” (Bateson, 1970, p. 525) suggesting further justification for incorporating ethical concerns into the growing picture, developed through this thesis, of an ecological-informed approach to making.

This example of cybernetics applied to artistic practice is significant because it represents an ongoing desire to conceive of art and design work in ecological terms. Cybernetics offered an analogy by which to position art work in a new kind of mutual correspondence with the world. The mistake made in applying cybernetic ideals to natural systems is that some versions of those conflated a logical, rule-based abstraction with reality itself. They in fact, occluded materiality and by doing so failed to adequately describe real ecologies. A viable description of an ecology must avoid this tendency. Donna Haraway’s vision of the cyborg is a critical fictional device proposed to problematize exactly this relationship between the technological and organic highlighting a number or ways that this relationship can and has become gendered and politicized (Haraway, 1991).

It has been shown in this section that there has historically been a motivation to see technical systems (as well as artworks) and their interactions with people in ecological terms. This establishment of precedent for an ecological conception of our interaction with technology is not a justification in itself. However, the cybernetics research described above and in the previous section *does* indicate a desire to understand our relationship with technology as a phenomenon which has significance outside immediate proximal interaction, in other words, in extended networks of material interactions. In later sections it will be seen how a failure to understand such extended significances has historically proved problematic for both the technical functionality of technological systems and for the experience of using them and living with them. This latter focus on the lived experience of technology has been the focus of some influential contemporary research. Some of this will consequently be examined in the following section.

3.1.4 Experience and Care

As has been suggested, the application of the notion of ecology into technology indicates a desire to conceive of experience as dependent on an interconnected network. Experience, in short, has been conceived of as ecologically implicated. Some contemporary research has, in fact, explicitly referenced experience as a defining design consideration, and some of this will now be discussed.

McCarthy and Wright (2004) provide a common reference point for what has been called the ‘experiential turn’ or ‘third wave’ Human Computer Interaction (HCI). Third-wave HCI is “characterised by non-work settings and topics such as lived-experience, intimacy, pleasure and embodiment.” (Bowers, 2012). Although not explicitly invoking ecologies as such, their work nonetheless has a number of distinctively ecological aspects. McCarthy and Wright propose that after the first and second waves of HCI research (emphasising the active thinking qualities of users, and their social settings, respectively), HCI research should focus more on the *qualities of experience* which they break down into threads as emotional, compositional, spatio-temporal, and sensual. They build on Dewey’s (2005 [1934])

work to articulate experience as constituted relationally between thinking subjects and objects in action (McCarthy & Wright, p. 54):

"…any experience is simultaneously sensual, emotional, and intellectual-that is relational. It attempts to capture something of the relationship between subject and object and self and other." (McCarthy & Wright, 2004, p. 86)

By linking affective, sensual and intellectual modes, the authors try to demonstrate that experience is, first a mixture of bodily and cognitive facets and is, second, very much a phenomenon founded in the physical world. The authors also point out how, for (Dewey 2005 [1934]), experiences are in *aesthetic* continuity[39] with other past experiences and indeed with everyday life (McCarthy & Wright, 2004, p. 54). This continuity implicitly suggests a kind of extended ecology of objects and experience. Like Keane's (2005; 2013) work in the context of the functioning of signs, McCarthy and Wright's application of Dewey suggests historical and future-oriented ways that the experiences, the 'life-histories", of objects, are wound into experience.

While McCarthy and Wright focus on the implications for *user experience* of Dewey's view of experience, his work has ramifications beyond considering the way that objects make us think and feel. Dewey's work emphasises the fact that objects stand as evidence of past interactions with human beings. The appreciation of past interventions by craftspeople with objects is a key part of his formulation of aesthetic appreciation (2005 [1934], p. 50). However where this thesis departs from Dewey's work (and from McCarthy and Wright's adaption of it) is to explicitly consider the histories of objects as *inherently valuable*, within themselves, rather than as evidence of past human intervention. The arguments presented in 2.1.1 gave justification for a sense of ethical involvement with the material world irrespective of its connection with humankind. Dewey's work, adapted here, adds

[39] Aesthetic experience is discussed in more detail in 6.4

to that sense a notion of an *expanded definition of experience which disregards a priori distinctions between the experience of people and artefacts and instead focuses on a practical investigation of those experiences*. Experience then, as articulated in relation to the historically-oriented approach to making discussed through this thesis, is a concept for further exploration. The adoption of the term 'experience' for the past histories of objects is intended to emphasise their active role in interaction, their potential to manifest agency, and to highlight their irremediable realism (Meillassoux, 2010, p. 33), that is to say their irreducibility to interpretation.

There are several aspects of McCarthy and Wright's reading of Dewey that are identified as relevant to the development of a concept of ecology in this thesis. Already discussed are the application of his work to technology and the alignment of experience with our own histories to create meaning and continuity. A final point though builds on the discussion of the attitude of makers, begun in 2.1.1 and continued in 3.1.1. Where 3.1.1 drew on Heidegger's notions of subjectivity to discuss our ontological involvement with the world as an answer to overcoming Cartesian dualisms, a further relationship with Heidegger's work is suggested by McCarthy and Wright. These authors (following Bakhtin, 1993) emphasize the importance of 'concern', our capacity, through effort, to create meaningful experiences. This concern, it is proposed, can also be compared to the concept of "care" (*sorge*) in (Heidegger 1996 [1927], p. 193). Where McCarthy and Wright employ 'concern' to "bring structure and meaning" (McCarthy & Wright, 2004, p. 89) to experience, Heidegger defines care as a precondition of the *being* of *Dasein*, it is its "existential meaning" (1996 [1927], p. 193). Although beings can act in ways that are "careless" this is more than a question of superficial emotional attitude. Such carelessness for Heidegger is actually a betrayal of *Dasein's* fundamental ontological orientation. It suggests an inauthenticity of being itself. In ecological terms, it suggests another kind of link between people and their environments. Care, which in Heidegger is achieved through a kind of independent attitude (Heidegger, 1996 [1927], pp. 165-180), is a way of more fully locating oneself as

part of the world. ‘Careful’ ecologies, would suggest a relationship between ecologies and making. If care or mindfulness are a way of creating a meaningful or authentic experience (following McCarthy and Wright and Heidegger respectively) then a careful making-practice is one which is more properly ecological. This point will be explored further in the final chapter.

3.1.5 Publics

The *formation* of an ecology has been examined by some authors (Bennet, 2010; Warner, 2002) as a specifically political phenomenon to which the concept of the *public* is integral. These accounts are pertinent because they further integrate the description of agencies proposed in the previous section into the notion of ecologies applied here by examining their formation and by providing a way to consider how their limits are defined.

Jane Bennett (2010, pp. 100-104) interprets aspects of Dewey’s philosophy to add to her own account of ecologies the notion that the interplay of agencies at work in ecologies actually exercise a kind of *material politics* through their various groupings, differentiations or arrangements. It is in this sense that she finds accord with Dewey’s notion of a public (Dewey, 1991 [1927]). Whereas Dewey, of course, was concerned with human politics, Bennett takes inspiration from his account of the formation of publics through a shared ‘problem’. She notes that there is much in his description of this phenomenon that can actually be applied to ecologies of materials, not restricted to humans. Such publics, for Bennett, consist of:

“…confederation[s] of bodies, bodies pulled together not so much by choice (a public is not exactly a voluntary association) as by a shared experience of harm that, over time, coalesces into a ‘problem.’” (Bennet, 2010, p. 100)

While for Dewey such ‘problems’ are generated and experienced by humans, for Bennett this notion is generalizable. For her, a public is a way of viewing an ecology that provides ways of understanding its emergence and of accounting for its limits, of deciding what is in, and what is out. Some initial directions for this

question have already been seen in (Pinch & Bijker, 1987), and (Winner, 1980) all of whom produced accounts where the materiality of technology was conceived of as affording, encouraging or demanding particular social arrangements. What is relevant about Bennett's publics is that they follow Law in refuting the idea that "either machines or human relations are determinate in the last instance: that one drives the other" (Law, 1992, p. 382). Instead of focusing on social arrangement as the *de facto* unifying factor of publics, she adopts an ANT-like approach which draws on Dewey's notion of "conjoint action" (Dewey, 1991 [1927], pp. 15-16). Conjoint action is the combinatory and distributed effect of actors which *transcends immediate*[40] *interaction*. At the heart of Dewey's definition of public is the distinction between private exchanges and public effects, those latter being defined as having the character to involve others indirectly[41]. In essence the conjoint action of the extended implications of interaction is what shapes publics.

Bennett, however, rightly points out that Dewey's notion of "conjoint action" does not preclude a reading wherein non-human actors combine to influence, the formation, structure and limits of ecologies calling such networks of agencies "political ecologies" (2010, p. 102). She notes (2010, p. 100) (as Dewey[42] does (Dewey, 1991 [1927], p. 23)), that asking *why* things come to be associated should be abandoned in favour of asking *how,* a position easily commensurable with (Latour, 2005, p. 71). This question of *how* things are associated, and once they are, how they act together in "conjoint action" is political in the sense that:

[40] In the sense of proximal in time and space.
[41] In one example Dewey describes how a blood feud begins between two individuals and progressively involves more and more people. (Dewey, The Public and its Problems, 1991 [1927] pp16-17).
[42] The formation of publics is caused by a tension between and private exchanges and their public resonances, which eventually cause a need for regulation (Dewey, The Public and its Problems, 1991 (1927) pp15-16).

“conjoint actions generate ‘multitudinous consequences,’ and each of these consequences "crosses the others" to generate its own problems, and thus its own publics or ‘group of persons especially affected.’ (Bennet, 2010, p. 101)

The political aspect of such an ecology is that members of an ecology are connected together through the conjoint consequences of their actions. The combination of conjoint action is what delimits that ecology. In this sense an ecology is very much like an extended ‘sphere of influence’ and are constantly reforming, not unlike Latour et al.’s (following Gabriel Tarde, rather than Liebniz) theory of the monad (Latour, Jensen, Venturini, Grauwin, & Boullier, 2012). Bennett gives Dewey’s work a material application by arguing that since the coalescence of ecologies occurs through contingent circumstance rather than rational design, this is a tacit acknowledgement that non-human agency can also be responsible for the formation of publics.

“Dewey presents the members of a public as having been inducted in to rather than volunteering for it: each body finds itself thrown together with other harmed and squirming bodies […] What is more, in naming a problem (rather than an act of will) as the driving force behind the formation of a public, Dewey (almost) acknowledges that a political action need not originate in human bodies at all.” (Bennet, 2010, pp. 102-103)

In summary, Bennett’s ‘political ecologies’ have two significances for the development of an ecological theory. Firstly she gives some suggestions for understanding how ecologies form. Secondly she provides some justification as to why an ecology comprising both people and things, can be thought of as a public[43]. The formation of ecologies which occurs as a response to a ‘problem’ provides a way of understanding how an ecology is delimited. In terms of making-practice it also provides a practitioner with a way of deciding how to begin, which, it is

[43] A discussion of the implications of this finding are reserved until 6.4.

suggested here, has close similarity with the way that many artists and designers thinking about the design space of their work. For instance, it will be described, in Chapter 5, how, in developing an art project, *Neurotic Armageddon Indicator* thematic, theoretical and technical research was integrated into approaching a number of material aspects of the subject of the work, the 'Doomsday Clock'. The making of this work was informed by a notion that the various technical, historical and theoretical components of the clock were part of a limited, local ecology through which it produced a kind of performance[44]. To see an ecology as a public, is, as Bennett indicates, to see it as an ecology of consequence in which intervention suggests responsibility. Taken together with McCarthy and Wright's "concern" ((2004, p. 89)) and Heidegger's "care" (1996 [1927], pp. 165-180), it is once again reiterated that a making-practice seen as part of an ecology should reflect ethical concerns. This point will be developed fully in the final chapter.

3.2 Summary: Experiential Ecologies Prefigured

This chapter has examined some existing research into ecologies paying particular regard to their relationship with, indeed dependence on, theories of materiality. First, it was seen that a key understanding for the development of ecological theories is that Cartesian separations between mind and body, between subject and object, are not easily compatible with the fundamental notion of an ecology. It was suggested that making-practice offers a particular way of participating in ecologies, and indeed a way of avoiding this dualism. It was also discussed how some research from a certain period of CSCW and HCI research (the 1980s and early to mid 1990s) was particularly concerned with similar questions and sought to answer them from a social perspective by considering the way that social arrangements are expressed through, and founded in, environments (Heath & Luff, 1991; Pycock & Bowers, 1996; Suchman, 2007). A significant finding of this chapter is that this research was intended to describe and inform, particular working arrangements, which are in many senses different from the kind of

[44] The concept of "performativity" will be explored thoroughly in the next chapter.

individual practice described in this thesis. *There is therefore both a demonstrable precedent and a clear opportunity for an ecological account around creative, technologically-oriented, making-practice, which integrates research and making-practice.*

The final three sections all, in different ways, explored the dynamics of ecologies, considering the way that they might be modelled (or not) (Bateson, 1970), the way that they extend into past or current experience (Dewey, 2005 [1934]; McCarthy & Wright, 2004) (integrating with notions of distributed materiality), and the way that they form and are delineated (Dewey, 1991 [1927]; Bennet, 2010).

In the following chapter, practice-based research will be described for the first time. Theories of the ecology will be referred to principally as signposts for later discussion in Chapter 6. Instead a focus will be adopted on how the facets of materiality, already suggested, were as much the product of an experimental making-practice as of theoretical research.

Chapter 4. Historical Materiality: Finding Facets

In the preceding two chapters previous research into materiality and ecologies was reviewed and some relationships between them were described. It was also suggested that materiality is historical in a number of important respects. In this chapter the historical aspects of materiality will be explored through specific 'facets' of that concept. The facets of materiality which will be developed are; *performative materiality, distributed materiality, spatio-temporal materiality, fragile materiality and future-oriented materiality*. Some of these distinctions have been previously defined by the authors referenced in the previous sections. Some have not. In those cases where categories of materiality are borrowed from other authors (performative and distributed), it will be described where the definition presented in this thesis departs from theirs. These facets should be considered as porous. Indeed perhaps the word facet, evoking sharp edges and clear delineation is inappropriate for what are, in fact, overlapping areas of reference. Nonetheless, the word facet carries the implication of a glass-like lens through which we can focus on the topic at hand before replacing it with another, different lens.

The following chapter will explore the historicity of materiality through a close examination of two artworks: *Null By Morse* and *Mark Inscriber*. Taking each facet of materiality in turn, a theoretical discussion will be integrated with a description of the making-process of the two artworks. It will be discussed how this process informed the further development of material facets sometimes in response to and sometimes leading theoretical research. Concurrently, it will be explored how the *historicity* of materiality, particular to the various facets, is not only intrinsic to them, but is also potentially suggestive of approaches to making. This latter aspect will be developed later in this thesis as a contributing factor to 'experiential ecologies'.

4.1 History and Archaeology

The discussion of the historicity of materiality is intended to support later assertions about the value of considering the role of materiality in terms of making artefacts. The motivation for this chapter is to emphasise that materiality has had a strong

agential presence in the history of technological ecologies and by examining this, to *underscore its relevance to contemporary making*.

A historical, material approach provokes the question, 'how is an approach based on the historical aspect of materiality in ecologies different from other historical studies?' A precedent response to this question can be found in (Foucault 2002). The kind of historical research against which this thesis is contrasted is that which is focused on the development of a narrative sequence of events, founded in evidence but with a focus on the establishment of different interpretative versions of that narrative[45]. Of course, all historians use material evidence, but the difference here is that such material evidence is not valued as helping to construct a narrative whole, but as a source of understanding those objects themselves as intrinsically valuable. The problematisation of history as narrative is precisely what provoked Michel Foucault (2002) to turn attention to those narratives (discourses) in themselves, rather than in their function as a representation of something else. That is to say, Foucault treated discourses as *things* in their own right rather than as signs through which to access some notional historical reality. This shift caused Foucault to characterize his work (such as Foucault, 2002) as *archaeological* rather than historical *and this thesis strongly identifies with Foucault's project in that regard*.

A *material* approach is historical, not in the sense of providing *interpretation* or narrative but in the sense of looking at historical action as located in ecologies of particular materials. It emphasizes a focus on studying (or in the case of practice-based research, experimenting with) the kinds of agency embodied by materials in context. Analysis starts at those materials themselves asking what do they permit, or provoke as part of a network. This approach is not, however, incommensurable with an appreciation of human intentionality. For example, a soldier who fires a shot in the Second World War has a host of motivations for doing so. But, as has

[45] A notable example of this genre of historical research is (Shirer, W L, 1991).

been suggested, following (Latour, 2005, p. 71), this appreciation is balanced with a focus on *how* things act to produce network effects, rather than *why*. A material approach brings into the analysis a consideration of the other agencies at work in that ecology. The shot which kills the enemy soldier is only possible though because of a *combination* of the first soldier's courage or fear, the state of cleanliness of his rifle, the distance from the enemy and the weather conditions that day. What is lost in some approaches is a sense of the role of things in the constitution of events. The examples given here are based in physical causality, and indeed, these are perhaps the least controversially explained. What I will provoke though, through this chapter, is the sense that things contribute to events also through *performative* functions. "Matter, we will soon realize, is a highly politicized interpretation of causality." (Latour, 2005, p. 76)

The relationship of this approach to archaeology, as I have suggested, is perhaps more striking than its resemblance to history, and a clear, methodological identification has already been made with the field of Media Archaeology (as represented by Huhtamo & Parikka, 2011)[46]. Archaeology suggests a focus on material things as *things* rather than seeing them as "expressions" of abstract cultural values. Even archaeology though, as (Bjørnar Olsen 2003) notes, is not immune to an approach where "the hard physicality of the world […] sometimes is reduced to little more than discursive objects" (Olsen, 2003, p. 88). He laments how even for the "discipline of the spade" (archaeology) "attention turns to thought, meta-theories, politics and society, in short, to the 'noise of discourse'" (Olsen, 2003, p. 100) Although Olsen acknowledges that he has no real solutions of his own, he cites ANT as an inspiration (Olsen, 2003, p. 98) for an approach to archaeology which treats things as irreducible to discourse. Ingold, in common with Olsen, suggests that the separation of knowledge from the physical world is a phenomenon which runs deep in contemporary academia (Ingold, 2013, p. 4).

[46] It was noted in the introduction that this is a very heterogeneous area and these are authors are not proposed as representations of the whole, more of a particular grouping.

The following account of historical materiality told through the research process of making two artworks will attempt to demonstrate some flavor of this irreducibility to discourse.

4.2 Historicity: Background

A number of authors cited in the previous review of functions of the concept of materiality have discussed how their particular perspective on materiality is historical. These will be briefly summarised in order to demonstrate that an historical approach to making with an historical sense of materiality has precedent, particularly with respect to the Marxist notion of historical materialism. It will then be discussed where these ideas will be extended, developed and applied.

Keane (2005; 2013) describes how signs are historical through their embodiment in objects which have had, and indeed continue to have interactions with other, historically related objects, a process which he calls “bundling” (Keane, 2013, p. 188). A photograph not only embodies a number of significances, through its depiction, for example, of one’s long departed grandparent, but also how that significance is materially related to other objects. The photograph could be duplicated for instance and the copies distributed, creating new spatial relationships. The torn edges attest to years of fond handling causally connecting it with human physicality. The sense that the pasts of objects are intrinsic to the materiality is an idea that has a degree of historical lineage and much influence for it can be found in Marx.

Marx’s treatment of “historical materialism” (Marx, 1999 (1887), pp. 29-42) aims to elucidate the consequences of the separation of different kinds of value from commodities[47] (exchange value, and use value) and to relate this to paradigm shifts in the history of society. A full discussion of the broader context of Marx’s theories, for instance as relating to the connection between commodities and

[47] commodities being conceived as “an object outside us, a thing that by its properties satisfies human wants of some sort or another” (Marx, 1999 (1887), p. 7)

ownership or the division of classes, is outside of the scope of this discussion but his work is included because of its seminal relationship to understanding the relationship of artefacts and labour which is key to certain configurations of the relationship to makers and their materials. A key problem identified by (Marx 1999 [1887]) is the separation of labour and commodity which is fundamental to capitalism.

“If then we leave out of consideration the use-value of commodities, they have only one common property left, that of being products of labour. But even the product of labour itself has undergone a change in our hands. If we make abstraction from its use-value, we make abstraction at the same time from the material elements and shapes that make the product a use-value; we see in it no longer a table, a house, yarn, or any other useful thing. Its existence as a material thing is put out of sight. Neither can it any longer be regarded as the product of the labour of the joiner, the mason, the spinner, or of any other definite kind of productive labour.” (Marx, 1961, p. 8)

In Marx, the promotion of exchange value (the abstracted relative value of one thing for another) over use value subjugates the materiality of commodities as physically involved with those who use them. As the use of things is devalued, they begin to be seen purely as expressions of something else, i.e. as exchangeable forms of capital. Enrolled in this concept of exchange value is that commodities become expressions of “homogeneous human labour” (Marx, 1999 (1887), p. 9), which have lost the particular specific character of having been made by a particular person for a particular purpose. A short discussion of this ‘commodity fetishism’ will be offered later in this chapter, but first it is noted that this understanding of the history of the object, as a made thing, has a clear relationship with Dewey’s formulation of experience which was discussed in Chapter 3. The extent to which Dewey was actually influenced by Marxism is doubtful (Westbrook, 1991), but (Miettinen, 2009) points out a number of similarities, including the fact that praxis in Marx is conceived of a way of producing the self “by changing nature

and by producing the world of cultural objects". This is similar to (Dewey's (2005 [1934]) notion, already discussed, that careful activity is also a way of aesthetically integrating oneself into one's environment. For Dewey, materiality is a link between current aesthetic experience and past processes of production or origin (Dewey, 2005 [1934], p. 50), exactly the processes Marx criticised as being homogenised under capitalism. Our experience of made things, for Dewey, is infused with an historical understanding both of their processes of production and our own past experiences which are in continuity with the present. One of the things, for Dewey, which makes aesthetic experiences aesthetic therefore, is historicity, and therefore a Dewey-like reading of Marx would suggest that a generalisation of labour is a falsification of this aesthetic historicity.

Kittler (1987; 1992; 2010) has, perhaps most vocally, proposed that technological materiality acts as a sense making, cultural force (Partington, 2006, p. 56). He has claimed (as was noted in 2.1.4) that "what we take for our sense perception has to be fabricated first" (Kittler, von Mücke, & Similon, 1987, p. 103). It has been noted that Kittler's thesis is that the development of our cultural condition and, relatedly, the human sensorium is anchored in the genesis of particular technologies. In this sense materiality is necessarily historical in the sense of a narrative. The narrative of this history is one in which technological development is responsive to material contingencies rather than directed by human decision making. The availability of new raw materials or the discovery of new properties of existing resources for instance provoke technological innovation. According to Kittler, successive technologies have iteratively or iconoclastically impacted on humanity through their material specificities while concealing that process from plain sight. In the following example we see an example of such a specificity while also demonstrating a, perhaps *the*, motivation for a study of this historical materiality, the naturalizing effect of material influence on culture. Here certain writing technologies (the pen and certain kinds of handwriting, versus the typewriter) are discussed as producing a naturalizing effect, a capacity to present themselves as appearing divorced from their material origins.

“The ‘hermeneutically-conditioned readers’ of 1800 were able to forget the textual nature of text, and were able to conceive of it instead as an extension of nature, because the discourse network effectively operated to suppress its own materiality and origins.” (Winthrop-Young and Wutz xxiv) quoted in (Partington, 2006, p. 59)

In this historical period, textuality, the quality of being a text, had become synonymous with a particular romantic mode, emphasising personal expression. This mode found its form with “organic, natural” handwriting (Partington, 2006, pp. 58-59). Crucially this, like all of Kittler’s ‘discourse networks’, became naturalised to the extent where only a new technology, the typewriter, could expose the artificial[48] nature of this medium of handwriting. Each technology then, according to Kittler, has unique ways of disguising its own particular materiality and it is through examination of past ruptures in this naturalization that we can come to terms with the culturally-influential material agency expressed by those particular technologies. Material for Kittler creates, or at least influences, history itself by determining human action.

Where Kittler attempts to describe an insidious determining force to technological materiality, Sean Sayers (1990, pp. 148-9), notes that (Marx, 1999 (1887)) also proposes a determining capacity to materiality (in the form of instruments of production such as factories, in physical labour, and in raw materials) (1990, p. 144). Such a reading of Marx provides some theoretical precedent to Kittler’s views. Unlike Kittler though, and contrary to (Cohen, 2000), Sayers’ reading of Marx maintains that the determining capacity of materiality is in a mutually constitutive relation with social forces.

[48] I use artificial to invoke “artifice” in the sense of both “cunning, trickery” (Oxford Dictionary of English, 2010) and “craftsmanship, workmanship” (Oxford Dictionary of English, 2010).

“[Marx] maintains that social forms are not merely ‘conventional’ and not changeable just at will. Definite material conditions of production impose definite social forms, and it is through the development of material conditions that social relations change. Man, through labour, alters nature in accordance with his needs and is in the process, altered by it. There is an interaction here.” (Sayers, 1990, p. 148)

Where Kittler see the determination of culture by materials as a essentially a one-way phenomenon, Marx (in Sayers’ reading) notes that labour provides a way of understanding this relationship as reciprocal. This sense of reciprocity is particularly significant if we envisage making-practice as a kind of ecological-material engagement. Such a view will be expounded in Chapter 5.

I have begun with a summary including the examples above for two reasons: First to recall some of the ways others have proposed materiality to be historical, before I detail my own research through *Null by Morse* and *Mark Inscriber*. Second to make clear that this following investigation is not intended as an exercise in intellectual curiosity but rather as a method of developing critique for the present, however tortuous and inefficient. To the discussion of history in relation to *materiality I have two main contributions: One is a taxonomy of specific facets of materiality applied to historical technologies which are then related to contemporary ones.* These facets enable a more focused analysis of agency within the experiential ecologies formed with these technologies. I will explore the second contribution in the next chapter. Here *I will explore how materiality’s historicity can become part of design and making-practice with consideration of the facets of materiality developed here.*

4.3 Five Facets of Materiality

4.3.1 Spatio-Temporal

Several studies of technology and new media have focused on the capacity of new technology to produce new human perceptions or conceptions of time and space. (Gere, 2006; Kittler, 2010; Virilio, 2008) have all discussed the warping effect of

technology on human understanding of both speed and time. Other authors have related this relationship between technology and consciousness to a phenomenological strand of philosophy from Husserl through Heidegger and Alfred Schutz to Merleau-Ponty (as described by Dourish 2004, pp. 103-116).

In this thesis though, a different perspective is adopted. Rather than investigating the 'consciousness-shaping' effects of technology, here there will be a more acute focus *o*n the way that technology continually *embodies* new arrangements of time and space. To be clear by 'embody' I refer not to the human body (as in Merleau Ponty, 2002) but to any body, any physically present technology. The emphasis on new arrangements of time and space, as embodied in particular technological artefacts or systems is intended to inform the approach to such things as *spaces for work*. To approach them as such can be considered analogically as a kind of 'site analysis'[49] as in architectural practice, a site for qualitative exploration[50]. To be explicit, this focus, while empirical in the sense of being based on observation and experience, is not proposed with any claim to objectivity. The understanding of systems as sites for exploration necessarily positions them as involved with the explorer as sites of situated action (as in Suchman, 2007). In the sense that this work is concerned with exploring sites of interest and with establishing situations within them by reconfiguring, juxtaposing or rebuilding, there are some parallels with methods in Systems Art as described by (Burnham, 1968, pp. 49-50; Ascott, 2002, p. 106). In the paragraphs that follow, the processes by which I came to see technological materials as spatio-temporal spaces for work will be described.

[49] I employ the term 'site analysis' figuratively to suggest an "on the ground" multimodal exploration. An appraisal of logistical possibilities and a theoretical analysis of them. Some student examples which illustrate this idea are found here: (Architecture, First in, 2013).

[50] Another analogy for such a working process might be taken from the world of music: As an amateur jazz guitarist I improvise melodies based on particular tempos and around a variety of scales. Each particular scale has its own mood and effectively structures the solo. Within that scale though, the possibilities are literally infinite. Such a combination is a spatio-temporal "space for work".

The production of *NBM* mixed theoretical research and practical prototyping in an iterative research process. A key aspect of the research focus of this piece was how smartphones (and iPhones in particular) form part of an historical lineage of telecommunications, beginning with signal fires and optical telegraph systems. This focus provided a set of materials, in the form of codes, historical artefacts and contemporary devices to explore. These in turn offered their own particular *spaces for work*. In the next paragraphs I will describe some aspects of the development of *NBM* which were instrumental in formulating the concept of spatio-temporal materiality as described in this thesis.

Prototyping *NBM* in, and with, the times and spaces defined by the technological history of telecommunications motivated further theoretical work and *vice versa*. I have claimed that theoretical and practical research have been integrated through the development of the facets of materiality and one particular part of the production process provides the clearest demonstration of how this iterative and reciprocally dependent process was conducted. The smartphone application which is the core of the *NBM* installation is built around particular temporal arrangements. To recognize the Morse Code transmission from the lamp I constructed a brightness recognition and timing system which is based on a pre-arranged agreement, a protocol, on which information will be exchanged. The app relies on a given and pre-understood duration for a basic unit of Morse – the dot[51]. When the app detects that the light source has been illuminated, it begins a count. When the light source is extinguished, it ceases the count and checks the interval to decide whether the previous illumination was a dot or dash duration. A similar process checks the interval of the gaps between dots and dashes (these have semantic meaning in Morse and define, inter-flash, inter-character or inter-word pauses which are of one, three and seven units in length respectively). Given the technical integration of this timing mechanism into the piece itself, the regulation of

[51] An experimental version of the app actually attempts to “learn” the duration of this unit in order to be adaptable to different sources of message. Unfortunately I was unable to make this version stable and reliable enough for exhibition.

information by timing is both the subject of the piece and is fundamental to its materiality. This timing structure is written, as code, and physically enacted by the phone as the regulating clock signal of the phone's processor provides a basis for mechanisms, defined in software but compiled and then embodied in solid state silicon chips. *NBM* is built to respond to particular spatio-temporal arrangements (the particular divisions of time as mediated through light flashes) because these are, in this physical sense, written into its system.

In practice, the constant difficulty of programming the system to respond correctly to the unpredictable physical circumstances in which the system was embodied further cemented the concept that these spatio-temporal arrangements were a kind of environment in which I was working. An example can be drawn from the way the piece was technically adapted to cope with variable light conditions. I attempted several iterations of variable smoothing techniques to adequately cope with the irregular light readings from the smartphone camera. Un-weighted-sliding-averages of various sizes and update speeds, band-pass filtering and infinite impulse response smoothing were all experimented with. Each produced slightly different kinds of responsiveness to the lamp, each with its own problems and advantages. After many days adjusting, testing, and re-writing code, these various approaches began, metaphorically, to take on the feel of a terrain, which I was exploring. This impression was, of course subjective, however it must be stressed that it was not arbitrary. The particular features of the timing mechanism were distinct features in that landscape and were specific to that technology. It is in this sense that I highlight that the development of various encodings and communications technologies, actually defined new arrangements of spatio-temporal materiality which should be considered the object of an *archaeological* study (not just a new narrative). I once again invoke the notion of an archaeological focus to emphasise a close attention to the material detail of historical study. A methodological commitment to physical experimentation and empirical observation of technological action. The playful experimentation with the 'nuts-and-bolts' of telegraph technologies provoked a *qualitatively different experience* of that history.

The process of building, debugging, testing and rebuilding this app required me to understand, implement, and experiment with the material arrangements produced by the Morse Code protocol, and the technologies through which it has been transmitted, as I described above. Engaging with this literature also generated a desire to better contextualize the work, technically and historically. To this end I reviewed further historical literature that provided both conceptual development to the piece[52] and also content for the messages which are broadcast by the lamp. A very brief overview of the spatio-temporal-material implications of this history will now be offered in order to describe its relevance to contemporary telecommunications which were the thematic focus of *NBM*. Above, I have described the spatio-temporal arrangement of the lamp and timing mechanism in *NBM* in terms of its exploration in practice. The following aspects of the material history of telecommunications are offered because they highlight other spatio-temporal arrangements, the consideration of which was seminal in developing the notion of spatio-temporal materiality developed here. In many ways the description of this history given through the following sections may seem like a digression but it

[52] Particularly informing the use of a military lamp and later points in which I will relate the work to slow technologies (Hallnäs & Redström, 2001).

Figure 12: A Chappe Telegraph Tower near Saverne, France (Copyright Office de Tourisme de Saverne & sa Région 2013)

is included as evidence of the practice-based research trajectory that was responsible for informing the development of the facets of materiality described here. *It is exactly this kind of digression which is often both necessary and, indeed, integral to research through design as a methodology*. Such research, if it wishes to be genuinely experimental, must be prepared to take cues from the material at hand, to be, to a large extend, lead by such materials, though guided by experience and a research focus.

The first well-documented telegraph system was the Chappe (Standage, 1998) telegraph which consisted of series of small towers, on the roofs of each of which was installed a contraption of moving wooden semaphore arms {see Figure 12}. An operator relied on a series of arm positions to relay encoded letters to the next station, positioned within sight of the first and messages were relayed along the chain.

The development of this optical telegraph eventually allowed Napoleon's army to manage logistical resources across the expanding French military conquests (Standage, 1998, p. 16). The adoption of the optical telegraph network has been described as a "strategy which finally released wars from the stone age of command flow" (Kittler, 1996, p. 8). For the first time, the speed of transmission of complex commands, issued from any start point in the network exceeded the speed of a horse (Kittler, 1996, p. 8). The chain of towers was incredibly well developed and, at its peak, covered large areas of France through arterial routes to Paris {Figure 13}. Around forty years later the development of the electrical telegraph was similarly stimulated by military funding. Samuel Morse's failed ambitions as a salon painter diverted his career into that of an inventor at a time when the rumblings of war—first between Mexico and the United States and subsequently between the North and South—proved to be a financial stimulus for his new communication medium (Gere, 2006, p. 49) as the Napoleonic wars had for the Chappe brothers'

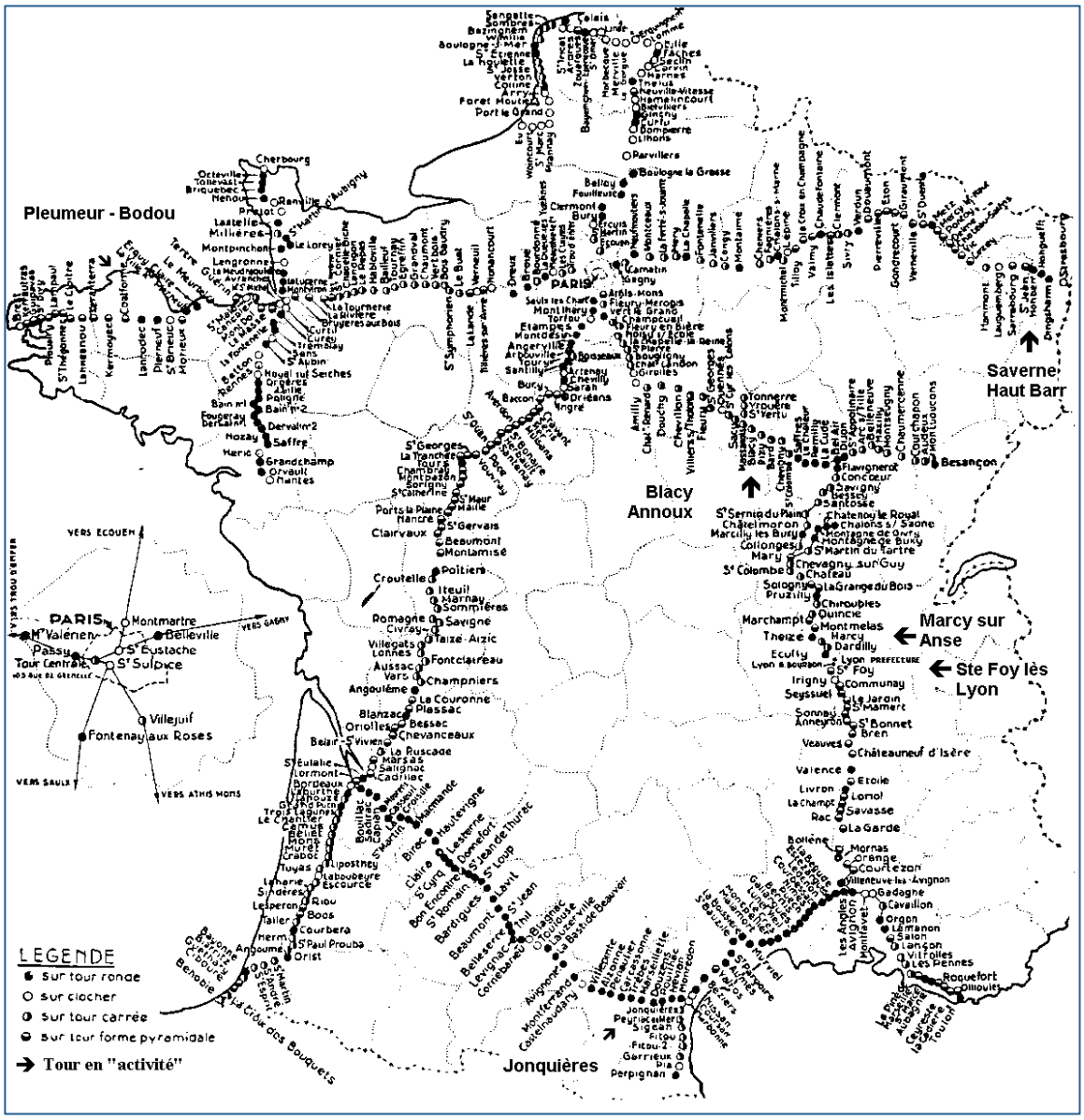

Figure 13: The Chappe Telegraph Network in Napoleonic France (date not available[53])

invention. The telegraph broke the reliance on human relays (such as in Chappe towers) and brought about unprecedented speeds in information transfer.

The new spatio-temporal *arrangements* of the Chappe and electric telegraph networks, in the U.S., France, and elsewhere, I propose, established *a topological*

[53] I contacted the publisher of this map at École Central Lyon but he was unable to provide a date.

precedent. The network, as an information highway, replaced the roads as the site of information exchange.[54]

The timing code which forms the core of the *NBM* app has already been discussed but a particular aspect of telegraph history, combined with the process of technically producing the app develops the concept of spatio-temporal materiality further. Standage (1998, p. 9) describes how the Chappe brothers, before arriving at the solution of semaphore arms as the most efficient way of encoding and relaying messages, experimented with a combination of synchronized timing devices and color-coded discs. The recipient of the message would watch for the change between black and white and take a note of the precise position of the stop-watch, translating this number via a pre-arranged code. What is historically significant about this process, is that by tying the change of a physical state to a regular time interval, the brothers introduced two completely new spatio-temporal arrangements of materiality, which are exercised, two hundred years later, by the iPhone which forms the basis for *NBM*. First the regulation of information by time interval, effectively prefigured the notion of bandwidth (without which, Shannon's seminal (2001 [1948]) work, for instance, would not have been possible). Second the notion of a regulating clock signal to manage information processing was effectively born with this invention. In integrated circuits, different chips must be able to communicate with one another at the right time and for this purpose, a clock signal is referred to. It is no exaggeration to say that without the notion of a clock signal, there would be no microprocessors and hence, no digital computers. However, I do not claim that the Chappe brothers version of serial 'genealogically' lead to the development of the signal clock. Instead I suggest that this material *arrangement* of physicality and time can be traced back to this historical moment. The study of the Chappe's invention was extremely significant during the development of not only *NBM* itself but of the associated facet of spatio-temporal

[54] This brought about its own problems, which will be discussed later in this chapter.

materiality. The commonality between the physical encoding systems of the Chappe brothers' early experiments and contemporary serial engendered a sense that this was a reproducible pattern, a kind of motif, that could be implemented in artworks, adjusted and refined.

In summary, with the Chappe brothers' early experiments with discs, with the development of Morse Code and with the deployment of new kinds of network topology, new *eigenzeits* (following Ernst, 2011) and new spatial patterns were produced. I have suggested that to see these technological artefacts and systems in these terms provides artists and designers with a space for exploration, a site for work which affords particular kinds of technological experimentation. Phrased differently, these spaces can be considered sites in which to *intervene* by mimicking existing functionality (as in *NBM*), rearranging, deforming (such as in glitch art), or transforming them. There is precedent for such an approach. For instance; algorithmic art (such as that of Reas, 2012) adopts formal mathematical rules and makes small adjustments, deriving aesthetic effects. Similarly spatio-temporal materiality provides a focus on arrangements of time and patterns of space to be 'tweaked' or used directly rather like samples in hip-hop music. Spatio-temporal materiality consequently offers a way of seeing materials as more than qualities for interpretation, but as embodied arrangements.

4.3.2 Performative

The term 'performativity', which was used in earlier sections without substantial explanation, has a long and complex history in academic literature. The core concept of performativity though involves a breakdown in the notion of language as a pure representation, a medium by which ideas are conveyed. Its adoption and exploration as a facet of materiality is motivated by findings from integrated practice-based research and literature review that it offers ways of integrating materiality with the creation of meaning. It was initially suggested, in Chapter 2, that there are distinct ways of considering materiality as possessing intrinsic meaning. Later sections sought to integrate this concept into an ecological dimension by locating the role of such material meaning in an ANT-like approach,

where that material meaning was described as a source of agency in particular network configurations. Essentially, a mix of the intrinsic, ontological meaning of materials, and the particular situatedness within a network, of the same, was characterised as a defining aspect of an ecological description. In the following sections, it will be shown that performativity is a mechanism through which this mixture of material meaning and network situatedness is enacted. Technological performativity, as it will be described here, is way of exploring meaning making.

Performativity emphasises that meaning is often created as part of an *act* where context or manner (Austin, 1962, p. 6; Searle, 1976) are conceived of as essential to the constitution of meaning. It is in this sense that performative utterances are "non-referential" (Butler, 1988, p. 521). They maintain a more complex and contextually defined relationship to the world than a signifier/signified connection. Crucially, performative utterances are not representations of meanings, they mutually create them and iteratively[55] reinforce them.

Applied away from language, performativity has been conceptually applied to the action of technology (Drucker, 2013; Thrift, 2003, pp. 121-136) to consider how:

"A more flexible sense of what the world is being extemporized by 'nonhuman' actors which are increasingly acting within the corral that used to be called human, making new materials that are not one thing or the other but weave together elements of both." (Thrift, 2005, p. 233)

Thrift is suggesting that technology is *creating meaning* through new forms of action. He has described, for instance, the operation of software as "writing acts" (Thrift, 2005, p. 242) (presumably in response to Austin's 1962 "speech acts") wherein computers are imbued with performative power to shape the world around

[55] Butler gives the example of women's identities being iteratively reinforced through gendered language (Butler, 1988, p. 521).

them. Performativity, “properly construed” to borrow Barad’s (2003, p. 802) (rather sharp) phrase, refers to the idea that technology actually contributes to the constitution of meaning within particular contexts. For Thrift the integration of written language (in the form of computer programmes) and its instantiation in physical, technological action (as computer hardware computes, stores, communicates, or actuates machinery) is illustrative of a key benefit of performative approaches. When Butler (1988, p. 521) calls utterances “non-referential” and Thrift and Barad call systems “anti-representational” (Thrift, 1996; Barad, 2003, p. 808) they offer a way of thinking about design which integrates its material with an environment in which cultural and technological action are interleaved. Consider, for instance, the first item of the list above, to “compute, store, communicate, or actuate”. To compute is to *enact* mathematical *meaning*. It is based on physical, material, processes but acts in a mathematical tradition with its own culture, practices and materials. As such it is responsible for an ongoing construction of what maths *is* and *does*. Although performativity stresses a sense of activity, *it is exactly this iterative constitution of meaning which marks it apart from a plain sense of action*.

The production of *Mark Inscriber* (henceforth *MI*) offered a number of specific ways in which performativity was developed as a concept to inform a practice-based approach. The work was produced in dialogue with theoretical research into historical (and pre-historical) counting and inscription processes. The following paragraphs describe this research and in doing so provide evidence of the development of the concept of performativity to technologies (in this case of counting) informed by an archaeological approach to these.

MI was inspired by the premise that technologies of representation are also technologies of storage, (recalling Barad, 2003, p. 808; Butler, 1988, p. 521; Thrift, 1996) and that this is, perhaps, never more apparent than in the context of technologies of counting and inscription. To illustrate this point, in the context of the pre-historical development of counting and mathematics, some research has

described how counting objects, props used to support counting or represent numbers (such as tally sticks {see Figure 14}), were not mere representations of counting, but rather, aspects of embodied or distributed cognitive processes, as in (Wilson, 2002). Counting is physically instantiated in records of accounts, livestock or calendars. These artefacts support cognition certainly, but also perform other kinds of action. Such records are not ‘representations’ of abstract numbers but are active as parts of ecologies of commerce and exchange culture. This material interleaving with every day practice, over time, evidences counting technologies as embodying specific kinds of historicity.

Figure 14: Tally sticks in the Alpines Museum der Schweiz, CC Sandstein 2009

Counting, I argue, is objects and practices together: The adoption of material props for counting (such as stones, scratches, baked pots, fingers and toes, grains of rice, or dots on stone tablets) was essential for the development of mathematics:

Historically, the verbal expression of numbers in many cultures was derived from the objects themselves. Mayan and Aztec languages for instance, maintained the word ‘stone’ in their counting words. So instead of ‘one, two, three’, we have ‘one stone, two stone, three stone.’ (Mohanty, 2010, p. 4). In modern Japanese, materiality and counting are similarly caught up through the use of ‘counting particles’ or ‘counters’. These suffixes are added to numbers and give additional information about the thing being counted. A selection are listed in {Table 1}:

Mai (まい)[56]	Thin or flat things (such as paper)
Hon (ほん)	Tall round things (such as bottles)
Dai (だい)	Large machines (such as cars)
Hikki (ひき)	Small animals (such as squirrels)
Satsu (さつ)	Books
Ko (こ)	Small things (such as eggs)

Table 1: Japanese Counting Particles

With the use of such counting particles, counting is inextricably[57] linked to physical form. For some cultures counting remains so tied to objects that they remain unable to count past ten (fingers) or twenty (fingers and toes) (Mohanty, 2010, p. 7). This combined status as object and practice is even reflected in the etymology of the word ‘to tell’:

[56] All the counters would normally change pronunciation depending on what they are suffixed to. Here only one pronunciation is given.
[57] Although generic counters (as well as ordinal and cardinal numbers) do exist in Japanese, using them as when a specific counter is available sounds very unnatural.

“To tell, we learn, as a transitive verb does not mean only ‘a live account in speech or writing of events or facts’ (that is, to tell a story), but also ‘to count things’ (to tell a rosary, for example). The very nature of digital operations and telling thus coincide.” (Ernst, 2003, p. 32)

In summary, the materiality of counting objects[58] is inherently historical in the sense, described at the opening of this chapter, of embodying historicity. Research through *MI* provided a way of thinking (and acting) about inscription as a counting event. The machine *performs* counting through its dramatic and futile mode of operation. Because it does not count any *thing*, it effectively turns attention to the *thingness* of counting, its material historicity. The physical marks left by the machine echo historical tallying practices but the machine is purposefully over-engineered. By juxtaposing contemporary computing and historical counting, *MI* attempts to align the two on the same material-historical trajectory. Through these aspects, *MI* provided an approach to thinking about the material significance of numbers in contemporary computing technology.

Following (Ernst 2003, p. 30), the historicism embodied by *MI*, is not only in the way that it can be positioned as part of a historical *narrative*. That historicism is materially *inscribed*. As a machine driven by a computational device, its own materiality, in the form of memory cell transistors embedded in chips, has formal relationships with tallying practices[59]. In the building process of the machine, this concept was made apparent through one particular aspect of the build, the control of a stepper motor to drive the chain mechanism. Stepper motors rely on coordinated sequences of activating and deactivating electro magnets, which, according to their polarity, brake or drive a ferrous core in rotation. The particular stepper used for *MI* had two of these magnets, which were controlled with signal

[58] Both in the sense of ‘counting (verb) objects (noun)’ and ‘counting objects (compound noun)’.
[59] By formal materiality I refer to Kirschenbaum’s (2008) notion of logical arrangements, rules or orderings described in 2.1.4.

codes sent to a microcontroller. The following code lines from the software show the assignation of a control pin to each of the wires connecting to the magnets (each magnet has two wires).

“`AccelStepper(uint8_t interface = AccelStepper::FULL4WIRE, uint8_t pin1 = 2, uint8_t pin2 = 3, uint8_t pin3 = 4, uint8_t pin4 = 5, bool enable = true);`” (McCauley, 2008)

To correctly run the motor, one must understand which connecting wires pertain to the same magnet by testing for a valid circuit with a multi-meter. Another, more brute force way, is to apply a current to one wire, while connecting the other to ground. If the wires are connected to the same magnet, an audible click can be heard, indicating that the magnet has activated and is attempting to rotate the core. This explanation is provided to explain that even during the testing of components, the conceptual development of *MI* was integrated. The technical development incorporated a material investigation of digital counting. Understanding the physical set up of stepper motor wires was actually a way of understanding the arrangement of rules and components which produced a count.

During this process, I became conscious that once again, I was relying on an encoded signal to activate the piece. By applying the current, manually, I was effectively defining two bits (as shown in Table 2), valid only in the context of the machine.

CODE	RESULT
00	NO CHANGE
01	MAGNET POLARISES POSITIVELY
11	NO CHANGE
10	MAGNET POLARISES NEGATIVELY

Table 2: States When Testing a Stepper Motor

The states of the wires as zero or one was only relative to one another and the magnet itself – one wire was *more* grounded than the other, and a certain potential difference (and current) was enough to power the magnet to overcome friction. In essence I had created a tiny space of performativity, in which my understanding of an encoding (binary) was being put into action in a technological context.

Similarly, in the computing hardware driving *MI*, the internal spatial arrangement of chips is directly comparable to the use of space to infer order and magnitude in tally marks. In this sense the machine actually articulates its own formal, material history, doing for counting what Parikka describes below in the context of media storage.

"…the archive is not only understood in the macro-historical fashion of past media excavations but increasingly as tapping into the machine itself as a layered, temporal and time-channelling machine of synchronization of culture and its structures of power. A historical mode of writing finds itself rejuvenated not in a narrative historical interest of knowledge not only writing counter histories of media but in looking at temporality as a complex object of media cultural analysis …." (Parikka, 2011, p. 70)

The performativity described here is approached quite differently to Drucker's (2013) description. Although Drucker emphasizes the importance of material "substrates" of technology she treats these principally as "points of departure":

"Material conditions provide an inscriptional base, a score, a point of departure, a provocation, from which a work is produced as an event." (Drucker, 2013)

Drucker's approach is, in this sense, comparable to those from (Jung & Stolterman 2011; 2012; Robles & Wiberg 2010; and Wiberg 2013), examined in Chapter Two, which focus on a hermeneutic approach to qualities and form. This work is

referenced again here to stress that material qualities, in that research, form a basis for meaning making where meaning is understood as:

"…a subjective interpretation about qualities and values of a material artifact, indicating how material artifacts are experienced and understood in personal and social life." (Jung & Stolterman, 2011)

To genuinely focus on the ways in which material performs acts, we must escape from the, implicit or explicit, notion that its agency is limited to an initial provocation which is then carried forward by human actors who then produce interpretation among themselves. Materiality does not 'fade away' while we conduct our analyses or interact with objects. This fact is demonstrated through further aspects of research undertaken in the production of *NBM*: In an early development of the work, the signal lamp was hand operated and the piece conceived of as a performance (in this case literally as distinct from being 'performative'). My colleague[60] and I both learned Morse Code through practice sessions during which I noticed that the iPhone app would 'misread' our individual transmissions in quite consistent ways. I had discovered a problem with our 'Morse fists'. It has been remarked (Kirschenbaum, 2008, p. 3) that the view of 'abstract ones and zeros' comprising the realm of the digital is technically naïve. At the level of electronics, there are only relative voltages (which are, of course, better referred to as potential difference) and the difference between a one and a zero is a convention that must be supported by electrical components[61] whose function it is to maintain the difference between them. The logical abstraction of the code is, in this sense, in tension with its material form which labors to support the former. Similarly with the

[60] I acknowledge the invaluable help of Kole Chen in testing this working with me and providing feedback on appropriate transmission speeds.
[61] I acknowledge the contribution of John Bowers in kindly explaining the Schmidtt trigger to me which has this function in analogue to digital conversion.

Morse telegraph, the quinary logic[62] represents only one aspect of the system. The code is, in fact, a *practice* which is not expressible in five bits. Morse operators develop what is known as a 'fist'; small idiosyncrasies in the lengths of their dots, dashes and pauses which can actually identify them to another (experienced) operator. The recognizability of various operators by their fists came to have strategic significance in wartime, since the origin of messages could be associated with the operator.

"…in a moment of crisis, when someone very high up asks, 'Can you really be absolutely certain that this particular Luftwaffe Fliegerkorps [German air force squadron] is outside of Tobruk and not in Italy?' you can answer, 'Yes, that was Oscar, we are absolutely sure.'" (Gladwell, 2005, p. 29)

In this sense, the Morse fist is an instance of technical performativity at work. A combination of the bodily attitude[63] of the operator and the particular straight key {see Figure 15} used, and the environment in which the operator works, is responsible for the production of meaning. The messages transmitted by the operator certainly have their own sense but I argue that their embodiment in this particular technical system equally defines that meaning.

Performativity summarised, in this context, has a number of features and implications. Performativity, as expressed in this thesis, is *not just linguistic, interpretative or representational*.

"Performativity, properly construed, is not an invitation to turn everything (including material bodies) into words; on the contrary, performativity is precisely a

[62] Morse Code has five states; dot, dash, inter-flash, inter-character or inter-word pauses.
[63] By which I intend their physical, ergonomic form, their training, personality and, no doubt, a host of other factors.

contestation of the excessive power granted to language to determine what is real." (Barad, 2003, p. 802)

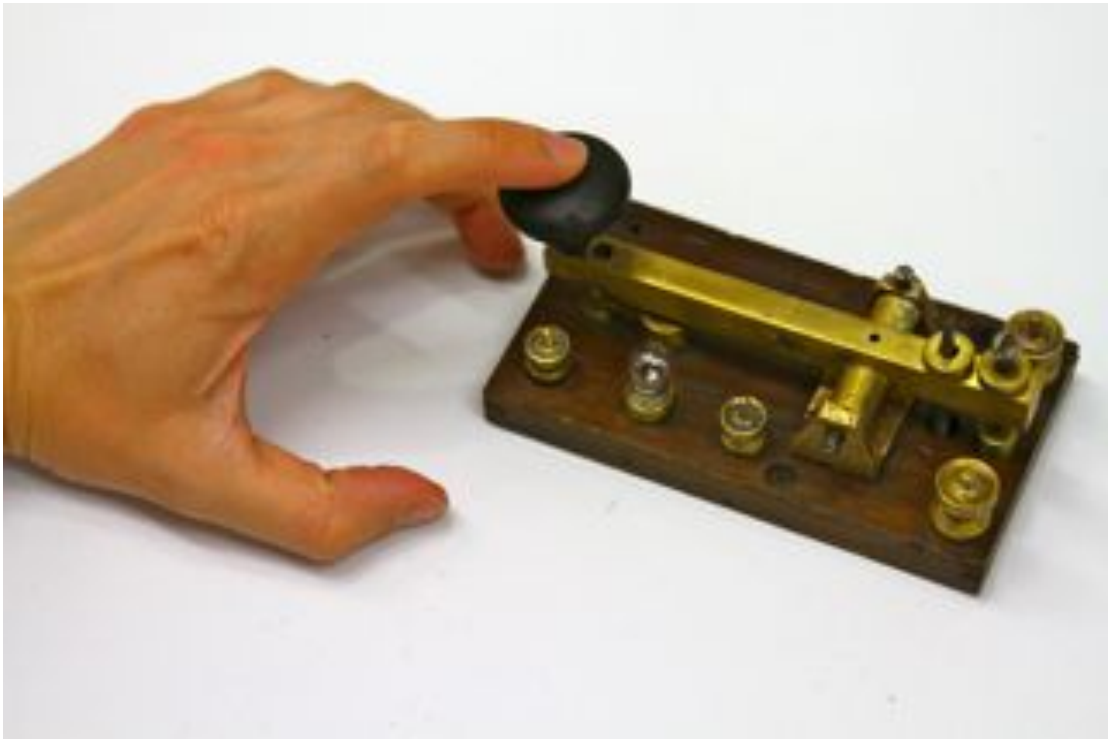

Figure 15: A Telegraph 'Straight Key' (the finger position shown is unfortunately incorrect, keys were actually used with a grip between thumb and index finger)

The concept provides a way of construing meaning, not with reference to some anterior reality which is then carried forward in representation (Butler, 1988, p. 521; Barad, 2003, p. 804) but as part of processes which are materially produced. The material foundation of counting practices, as well as the agential capacity of a Morse fist are proposed as demonstrations supporting this claim.

Performativity is also *iterative and reifying*. It is an "ever-reiterated assertion" (Butler, 1988, p. 520) (following Merleau Ponty, 2002). Part of the trouble with seeing materiality in purely (or mostly) interpretative terms, is that it tacitly undermines its *cumulative* agential potential. Just as Butler describes the body as a continual and incessant *materializing* of possibilities." (Butler, 1988, p. 521) (emphasis in original), I suggest that technological materiality constantly reasserts

its own potential, building up iterative patterns of material. In the history of counting and inscription for instance, the development of counting is bound to iterative material processes as one counting prop is replaced by another and surrounding contexts of exchange and barter develop to match in sympathy.

For making-practice these main performative aspects of non-representation, iteration and reification, suggest an historical (or more properly *archaeological*) theoretical and experimental/practical engagement with the materials with which one is working. A kind of constructive archaeology in which historical research is revitalised by being remade in new combinations. This strongly implies a particular kind of making-practice which is agile, iterative, and speculative. Given its basis in *material* (as described here), *action* and *context*, performativity construed as *for practice*, emphasises the need for functional prototypes whose actions can be studied, and whose materials are carefully chosen. To appreciate their performativity, new material combinations must be set up, turned on and examined in operation. In the pieces above this prototyping process was integrated with the media-archaeological research described so that material (in the forms of smartphones, lamps, codes, wires, circuitry, solenoids, computers) was put into action (through building, testing, exhibition), and contextually explored (through integration of historical research into the former two processes). This process was exemplified by the description of the process of testing stepper motors. The next section will describe how the concept of materiality as distributed was developed in practice.

4.3.3 Distributed

The next facet of materiality developed here is, again, drawn initially from Drucker's (2013) two identified categories. Distributed materiality refers to the host of interdependencies in which digital objects are enmeshed. It was suggested in Chapter Two that there are a number of interconnections between the concepts of performative and distributed materialities and this section will build on this, highlighting aspects of practice-based research which influenced and developed this notion. The development of *NBM* as well as providing a process through which

to think about material performativity also, unsurprisingly (given the context of telecommunications), was significant in developing a notion of distributed materiality in the context of creative practice. To explain this, a short reminder of some of the core ideas outlined in 2.1.4 will first be offered, before its relationship to *NBM* is described.

In her 2013 definition of distributed materiality, Drucker leans heavily on the work of Jean-François Blanchette (2011) whose long and technically rich account proposes modularity[64] in computer design as a connecting framework through which to conceptually integrate notions of digital materiality within an ecology, an economy even, of finance, skills, hardware and efficiency. Blanchette's influence is also acknowledged by this thesis which builds on his work by both relating it to other facets of materiality (and other similar research such as Thrift, 1996; Fuller, 2005), and by exploring its relevance to creative making-practice. In the quote below, Blanchette highlights how considering the distributed character of materiality, also motivates an understanding of it as ecological.

"A material analysis foregrounds how systems design must necessarily engage in the oldest political problem in the world: the allocation of scarce resources among competing stakeholders." (Blanchette, 2011, p. 2)

[64] Blanchette (2011) in, almost exasperating detail, notes how the technical infrastructure of modern computers (in the form of von Neumann architectures) is reliant on modularisation of the hardware stack – a way of separating the various layers of software abstraction from the their existence as electrical or magnetic charge, to binary code and thence 'upwards' until they eventually reach the application layer. This modularity has deeply material implications since it involves a continual trade off between efficiency and ease of access for programmers, which is protected by international standards (such as transmission protocols like TCP). The so-called 'abstraction penalty' (the inefficiency implicit in higher level programming languages) is itself a powerful argument against the putative immateriality of digital technologies. If digital technologies were truly immaterial, their language of expression and mode of execution would have no bearing.

Blanchette's example seeks to describe the integration of distributed and interconnected materiality, with a wide variety of different kinds of actors. Drawing on Latour's focus on the way that actors "modify states of affairs" (Latour, 2005, p. 71) rather than on *a priori* 'motivations' for action, Blanchette's identification of the material components of his "problem" is proposed as related here, to Latour's investigation of what "might authorize, allow, afford, encourage, permit, suggest, influence, block, render possible, forbid…" (Latour, 2005, p. 72). Similarly the various groupings, alliances and relationships between them strongly resemble Bennett's description of publics. His notion of layering is therefore enriched by a connection to ideas of agency, derived from ANT and developed in Chapter 2.

If distributedness for Blanchette is expressed as layered modularity, a way of designing for impossibly complex wholes with thousands of inter-relating parts, I propose that a corollary effect of this aspect might be called 'infrastructural invisibility'. Invisibility, in this context, is an overlooking of those material agencies described above by Latour (2005, p. 72), a failure to look for action in the right place, and I will describe a specific example in the history of the telegraph network in later paragraphs. In fact, this kind of infrastructural invisibility can be understood, in ANT parlance, as punctualization, the capacity of network actors to appear naturalized and inextricable from their network situation (recall Callon, 1991, p. 152; Law, 1992, p. 379).

In the period discussed below, a lack of technological precedent caused 19th Century British Imperial policy makers to misunderstand the nature of vulnerabilities in the electrical telegraph network. In the following paragraphs I will describe a number of ways that distributed materiality played a role in this scenario. I will show that there was, in essence, a kind of *educational invisibility* brought about by a lack of familiarity with the performance of complicated, distributed, technical systems. Following this arose a kind of infrastructural invisibility, related to what Fuller (2008, p. 4) calls "naturalization" and which is implicit in Kittler's (1992) "discourse networks". I provide some initial background

for these ideas before relating them more closely to the study of the 19th Century electrical telegraph.

Kittler describes how technologies effectively disguise their artificiality[65] by influencing culture to the extent where they seem inseparable from it[66]. Such attitudes invite direct comparison to Marx's critique of commodity fetishism (1999 (1887), pp. 29-35). Cohen (2000, p. 116) describes how, for Marx, commodities come to appear to have exchange value in their own right because the social milieu effectively disguises the fact that this exchange value is a product only of labour.

"It appears that men labour because their products have value whereas in fact they have value because labour has been bestowed upon them. Men do not recognise their own authorship of the value through which alone they relate, and which therefore regulates their lives as producers. They are thus in a quite specific sense alienated from their own power which has passed into things." (Cohen, 2000, p. 116)

Marx's example is acknowledged here as a theoretical foundation for this principle of infrastructural invisibility but I build on this to propose some particular technical senses in which it is brought about in terms of distributed materiality.

The study of a particular instance of 'infrastructural invisibility' became part of the development process of *NBM* through a material-historical/archaeological study and influenced the final installation. In the following paragraphs I will describe at length how a strain of such invisibility, related to immaterial thinking was part of the history of telecommunication[67] and how the study of this, integrated with the

[65] "artificial" in the sense of being made things, things made with artifice.
[66] This was described in Chapter Two
[67] Later I will compare this phenomenon to contemporary critiques of ubiquitous computing (as in Dourish & Bell, 2011, Star, 1999).

development of *NBM*, provided rich material for understanding how distributed materiality can inform practice. Although much of the discussion below is not directly drawn from the physical prototyping process of *NBM*, I continue to claim that it *was* an aspect of practice-based research. Although the general focus of this thesis is on the during-the-build, hands-on development, I have also stated that literary research was often initiated following, and directed by, that building process. The concepts developed by comparing contemporary and historical communications networks, described below, were only possible because that work was scaffolded and supported by on-going technical experimentation.

Central to this critique of attitudes to infrastructural invisibility is the notion that users and developers of the expanding international telegraph network in the mid 19th Century saw its materiality as *subjective*. That is to say they considered it very much as something which is *done to*, rather than something with potential for agency of its own. The telegraph network was seen as something essentially *pliable*, subject to feats of human engineering. Such a subjugation of materiality is also implicit in Morse's moniker of the 'Lightning Man' and his telegraph the 'Lightning Wire' (Gere, 2006, p. 47). I suggest that the adoption of metaphors of light and speed are telling because they implicitly abstract the massive (in the literal sense) physicality of the technical infrastructure of the telegraph system focusing only on its effects for users. This abstraction, of the entire system is core to its achieving a state of punctualization. I am arguing that one of the things that allowed the technical materiality of the network to become, in essence, a black box, was its status in the public imaginary (mostly through hyperbolic newspaper descriptions) as *an effect* of speed. Not only was speed a key figurative trope in describing the electric telegraph, a new sense of connectedness was also given much media attention (Gere, 2006, p. 48)). The laying of the first transatlantic telegraph cable in 1858, for example, heralded massive celebrations and prompted the famous New York hotel, Astor House, to produce a banner reading, "The Atlantic Telegraph transmits the Lightning of Heaven, and binds together 60000000 of human beings" (Gere, 2006, p. 48). To summarise, I propose that a focus on

figurative descriptions of the growing telegraph network was both a product of, and a contributor to, an immaterial stance towards it by public and policy makers alike.

The telegraph network though, in contrast to these figurative media tropes, was a product of industry. It required new construction materials (Tully, 2009, p. 57) and new kinds of understanding to deal with the interaction of what was a network of unprecedented complexity and decisions faced in the 19th Century and which are as relevant now as then because of the irremediable realism (Meillassoux, 2010) of their materiality. There remain, phenomena which pertain to particular materials, in action, and together in combination. It is exactly these moments at which the ontological meaning of those objects is at its most evident. In the context of the international telecommunications network this is most obvious when considering the physical distribution of the network. Considered from a topographical perspective we can observe that the similarity between the international telegraph network in 1869 {Figure 16} and the {Figure 17} map of contemporary internet submarine cables is not coincidental. Even a casual inspection reveals that the two maps are literally grounded by material features of geography (note the stopping off points at mid-Pacific islands for instance). The high cost of laying undersea cables continues today to afford new kinds of advantageousness as proximity to or isolation from major data hubs contributes to the effectiveness of businesses now in the internet age as then in the age of the telegraph[68].

[68] So significant is this that some more geographically isolated states, such as Iceland, have formed consortia to finance the laying of new cables (Farice 2013). The “seamless connectivity”, afforded by such cables then comes at a price tied to the raw material of the cables, cost of shipping fuel and work-hours (most recently costing around $300m from London to New York (Williams, 2011)).

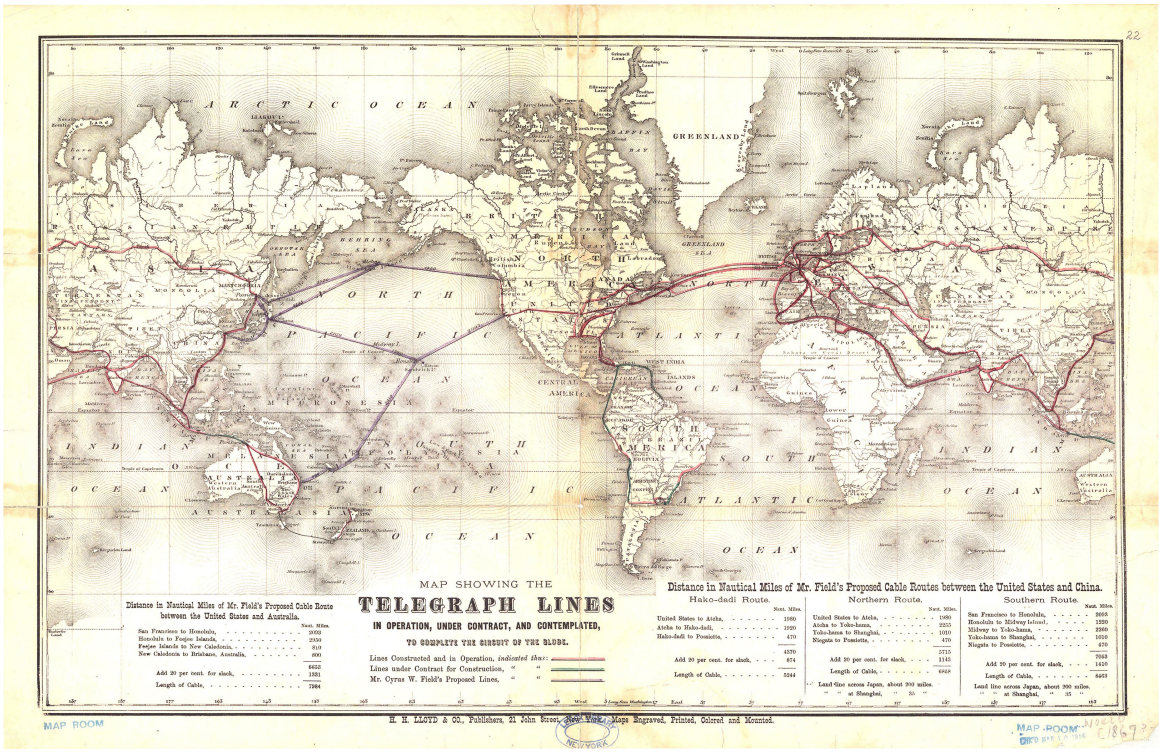

Figure 16: Map of Telegraph Lines in 1869. HH Lloyd & Co Publishers

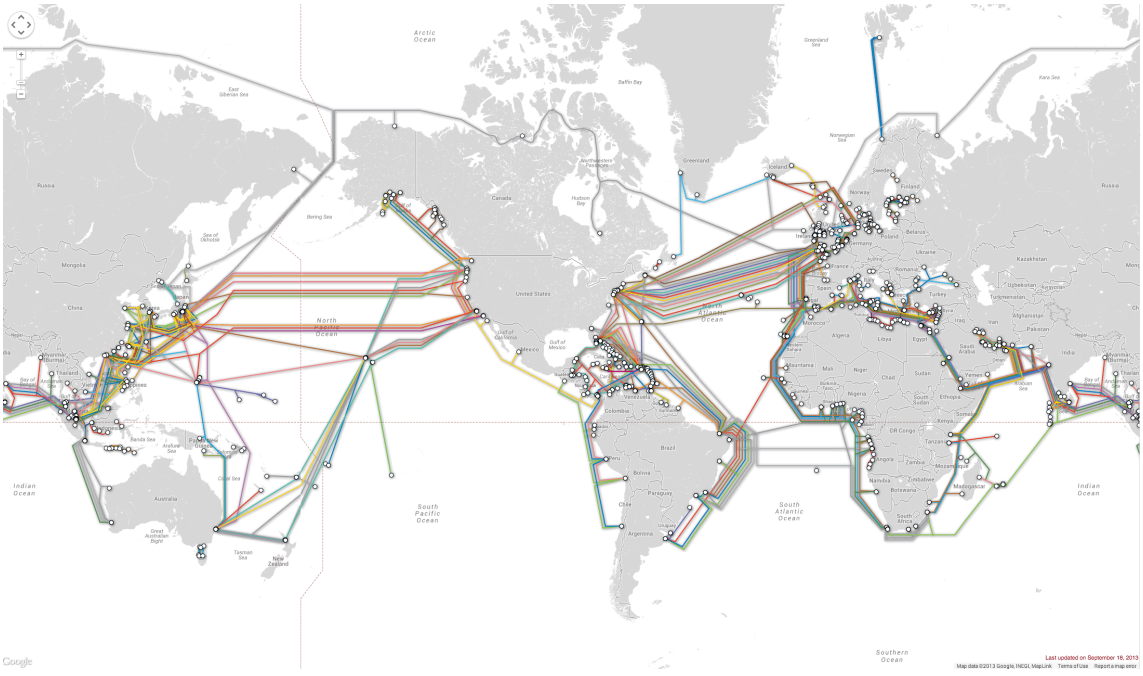

Figure 17: Submarine Cable Map. Copyright PriMetrica 2013

The increasing distributedness of the telegraph network brought about a series of problems, founded in material issues, whose nature was consistently misunderstood. The expansion of the British empire was logistically supported by a corollary growth in the international telegraph network. The telegraph cables were, for the most part, private enterprises (Kennedy P. M., 1971, pp. 729-30) which leased them along with the corresponding relay stations making them directly comparable to contemporary Internet Service Providers (henceforth ISPs). When the British military began to more fully understand the strategic advantage afforded by telecommunications (to themselves and to their enemies) they began to push for more and more cables to be laid underseas, since this would avoid having to cross the territory of other nations over land with whom they might later be in conflict.

"…the British government could hardly be expected to look with enthusiasm upon a system in which the link with their most vital possession passed through several foreign countries, and they therefore warmly welcomed the laying by the Eastern Telegraph Company of a submarine cable which virtually avoided all contact with Europe." (Kennedy P. M., 1971, p. 731)

The fear of foreign interference on land pushed the cables underseas where they would be relatively safe from sabotage. Here they could benefit from existing defence infrastructure and the weak points where they came on land could be effectively fortified.

"Some incidental protection would be offered, the Colonial Defence Committee felt, by the fact that the cables took the normal shipping routes, which were patrolled by the Royal Navy's cruisers; in addition, the deployment of a few guns near cable landing-stations would deter raids upon those lines lying in shallow water. Nevertheless, the navy would not always be on hand and a later body of experts recognized that." (Kennedy P. M., 1971, p. 731)

This eventually lead to an infrastructural 'push' to bring the cables under centralized British control of an 'all red line'[69], which would be managed and defended by the Empire and would serve to further consolidate its power. However, this project was misguided for a number of reasons. By consolidating their communications infrastructure, the British actually made themselves more vulnerable to the point of sabotage and accident becoming "almost tempting" (Kennedy P. M., 1971, p. 732). Earthquakes and ship accidents (Holpuch, 2013; Johnson, 2008) continue today to disrupt the contemporary internet infrastructure and the effect is exacerbated by what is, actually, a *legacy* network topology. In essence the British failed to understand the significance of what was a material topological problem, a question of a kind of distributed materiality, where the functioning of every node (in this case relay station or telegraph office) is dependent on others. What had started as a mesh {Figure 18}, with multiple potential routes from A to B, was redefined as a bus (with branching tree elements). As such the network was only as robust as the weakest point on the main trunk lines, cables which were thousands of miles long.

The contemporary internet architecture is designed to avoid this problem. With the advent of algorithmic routing, data packets are able to reach their destination via numerous routes dependent on the current state of traffic and consequently cut offs (due to accidents for example) and bottle-necks should be avoidable[70].

[69] The "red line" was the name given for the British telegraph network. "Red" recalled the colour usually chosen for the Empire on maps of the world.
[70] The entire system has vast amounts of built in redundancy (data packets are frequently duplicated, and many many multiple routes exist between end points).

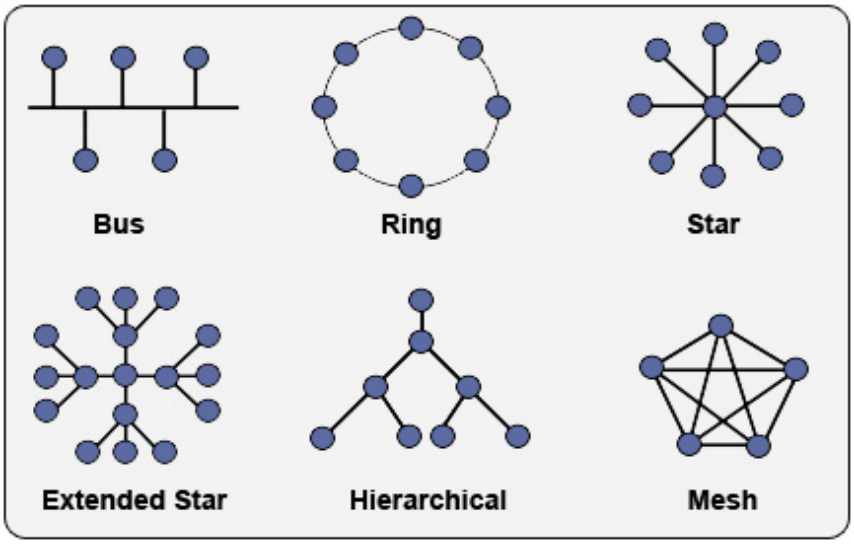

Figure 18: Some Simple Network Topologies. Copyright Sudarshan Softech 2013

The architecture is designed to balance out traffic but it operates in a physical infrastructure which is centralised and vulnerable. The internet, is not a topological drawing but a dynamic and unbalanced system. The sheer quantity of packets travelling to and from popular servers creates particular demands in terms of, for instance, electricity supplies, quantities of switches or numbers of strands in a fibre optic cable[71].

I have suggested that there were two, related, paradigmatic attitudes inherent in historical conceptions of the electric telegraph network which had negative consequences for its administration. These were first, that figurative visions of infinite speed and connectivity replaced understanding of the foundation of the telegraph network in an unbalanced and dynamic material world. Secondly, on the level of policy, an assumption that the main danger to the telegraph was sabotage

[71] The topology of the internet has developed such that ISPs have become the major customers to the owners and leasers of what has become known as the "internet backbone", the 1st tier massive "trunk lines" . The term trunk line, while drawn from the days of telephony, is appropriate since it continues to be telephone companies such as AT and T who build and operate such services. This has in turn led to a whole economy of exchange and traffic trading between these operators.

brought about a topological error of consolidating network branches. This account has been included to evidence that material thinking, or lack of it, is *a historical paradigm*. The attitudes described above indicate *a failure to see the materiality of the telegraph network as something which possessed significant agency as part of a dynamic ecology*.

I will now go on to describe some of the contemporary ramifications of these historical attitudes. It is this contemporary relevance which is explored not only through the theme of *NBM* but by a choice of materials, namely the use of the smartphone itself and also the selection of messages which are broadcast in the installation.

The use of a smartphone as the receiver of messages in *NBM* has two particular significances. Firstly, I proposed that the iPhone functions as a what might be described as a *metonym for futurity*. It is continually evoked in the media and in Apple's own advertising as futuristic. As the continual market leader, it sells on a promise of 'always on' infallible connectivity. Secondly, I suggest that smartphones are the most visible and concrete example of (Weiser's 1991) vision of ubiquitous computing (henceforth ubicomp) and that consequently, adopting them as a material for making is a way of engaging with and critiquing this vision[72]. Supporting this claim is Adam Greenfield's (2006, p. 167) observation that some Japanese ubicomp research avoids the term smartphone, preferring "ubiquitous communicator". In the following paragraphs I will describe how both of these aspects relate to the 19th Century telecommunications history described above.

Mark Weiser (1991) outlined a vision of a 'ubiquitous computing' which would pervade our daily lives through instantiations at different scales - tab, pad and

[72] This is consistent with my earlier claim that this thesis was both *for* and *with* contemporary computing technology.

board being the canonical examples (Weiser, 1991)[73]. Weiser's scenario emphasizes interconnectedness both between various computing systems or units and also between one's daily life and the multiple instances of technology designed to support it. This vision (criticised as a myth by Dourish & Bell, 2011) of an overarching, seamless interconnectivity finds contemporary expression in the phenomenon of 'Cloud Computing' and also the near-ubiquitous adoption of smart phones and other mobile devices such as tablets *and is directly comparable to the figurative tropes employed to describe the telegraph network*. The choice of an iPhone is intended to simultaneously position *NBM* in relation to this ubicomp vision and align the same with a particular attitude towards technology, the punctualisation of complex distributed technology into black boxes,[74] which has been discussed as paradigmatic of the development of the 19th Century telegraph. *NBM,* therefore, uses an iPhone as a rhetorical device employed to invoke notions of futurity and seamless connectedness. By doing so it mimicks the rhetoric of some ubicomp research with technology proposed as calm, unobtrusive (Weiser & Brown, 1996) and indistinguishably woven together with life (Weiser, 1991). I have suggested that Apple, as a brand, sells on this vision. The company's 2011 message, "It just works," repeatedly emphasized the infallibility and seamlessness of their technology (Siegler, 2011). Apple's 'iCloud' cloud computing service can be considered as perhaps the most visible example of the effects of cloud computing to consumers as their advertisements slickly demonstrate how a photograph, for example, taken on one's iPhone, syncs automatically across all of one's other Apple devices. As such, Apple as much as anyone, perform a function with these adverts of developing in their audience a particular understanding of the world connected, in specific channels, through technology. Crucially though, the

[73] To call this research 'seminal' barely approaches the truth, standing as it does at over ten-thousand Google Scholar citations at the time of writing (the follow-up paper Weiser & Brown, 1996 has nearly 800).

[74] In the next section, I will describe in more detail how this vision of distributed materiality carries with it particular kinds of fragility and how these form part of the functionality and theme of the piece. Dourish & Bell's (2011) criticisms will be addressed in more detail at that point.

understanding brought about by such demonstrations is completely a-technical. It focuses *only on the effect* of such technological systems while disguising the vast physicality that they imply. As such it has much in common with the rhetoric employed in describing the 'lightning line'. The system is presented as an effect, that of speed and connectivity, rather than as a physical thing. By adopting a historical messaging protocol and transmission technique (the lamp) juxtaposed with the iPhone, *NBM* is intended to critique the 'black box level' engagement with communication systems which is implicit in the kinds of user experience proposed by Apple, as seamless, hyper-connected, and futuristic.

In summary, the research process of *NBM* involved a technically-focused, archaeological study of telecommunications history which highlighted some specific effects of paradigmatic attitudes to distributed materiality. I have proposed these as objects to be critiqued through practice and described how *NBM* embodies such a critique by literally putting contemporary and historical technologies into communication. Through the previous paragraphs I have attempted to highlight how distributed materiality describes the technical interdependence of the many heterogeneous materials which contribute to a technological system. In the context of early telegraph networks (optical and electrical) I have named only a few of these materials as including islands in the Pacific, submarine cabling, routers, and mobile phones. The combination of these materials causes new and unexpected events to occur and I have suggested in this section that lack of awareness of the interactions of these various materials has both contemporary and historical relevance. These effects, though, unpredictable as they may be, can also be productive for art and design not only from the perspective of critiquing the cultural phenomenon which gives them a particular reading but also as producing new spatio-temporal arrangements as described in a previous section. These can be creatively exploited and, indeed, this is the basis of Brucker-Cohen (2003) and Oliver's work (2011; 2012) described in Chapter Two. Such works exploit kinds of *fragility* which are produced alongside distributed materiality. In the next section I will develop some theoretical concerns

approaching a definition of *fragile* materiality and begin to consider what it might offer to makers.

4.3.4 Fragile

In Chapter Two I gave examples of how fragile materiality has afforded creative opportunities to artists. This section will build on those initial points, describing how a number of integrated practical possibilities and theoretical concerns around fragility were a product of the research described in the previous three sections. Earlier, I undertook a media-archaeological study of the telegraph. Central to that examination was the proposal that there was a reciprocal relationship between literary and practical investigation in the research process of *NBM*. The study of the development of the electrical telegraph network was initially motivated by a technical interest in how Morse and Vail's system operated, which in turn, was a consequence of an earlier iteration of *NBM*'s design involving a wire transmission rather than an optical one. The course of that research in literature, though, suggested particular ways in which fragility might be used and thought of through practice and these will now be discussed.

Materiality implies fragility in a wide variety of ways. I have already mentioned the phenomenon of 'bit rot' which is offered by (Manoff 2006) as a counter argument to the putative immateriality of digital artefacts. In the previous section I described how the telegraph and contemporary internet are fragile through vulnerability to physical accident (such as the severing of submarine cables by ships' keels) and also through data bottlenecks caused by legacy network topologies. I also suggested that the use of the smartphone positioned *NBM* in relationship to research into ubiquitous computing and now add that there are particular kinds of fragility associated with this paradigm which might be called combinatory or algorithmic. By algorithmic or combinatory I mean the capacity of software and hardware to produce unexpected effects, magnified by the mass interaction of

modular components[75]. Pervasive systems, of which smartphones form a part, are particularly vulnerable to such fragility. Not only is the combinatory interaction of modular parts a problem for distributed materiality, their very heterogeneity carries with it an inherent fragility. In a world of ubicomp, different brands coexist, varying technical standards are in place, and old and new equipment sit side by side. Dourish and Bell (2011) describe how the "myths" of pervasive computing, those of seamless integration of ubiquitous computers, have necessitated a state of blindness to the defining characteristic of interconnecting technology: *messiness*.

"The lesson of the real world of ubicomp is that we will always be assembling heterogeneous technologies to achieve individual and collective effects, and they will almost always be messy". (Dourish & Bell, 2011, p. 26)

For these authors and for (Star, 1999), *mess is an intrinsic feature of infrastructures* which must be maintained, regulated and worked in. The fragility here is derived from maintenance, regulation and use, all of which have the potential to go awry. As (Berry, 2011; Manoff, 2006) have noted, maintenance requires money and systems are only as robust as they are well maintained. In the context of the 19th Century telegraph network, the relationship between money, vulnerability and maintenance was involved in a complex interchange between the material infrastructure of the network and its situatedness in a tense period of global political power. The agency of the infrastructural materiality was therefore implicated in a broader (and messy) context of extremely heterogeneous agents and actions.

[75] For instance, at the time of writing, several large scale temporary failures of computing infrastructure have occurred, including Microsoft's Exchange ActiveSync (which manages email and calendar synchronisation), the Nasdaq stock exchange, Google Search, Amazon, and Apple iCloud (Garside, 2013). The problem with Microsoft's servers was short-lived but the problem persisted for three days as mobile phones stepped up their attempts to communicate. The problem was therefore greatly exacerbated by the behaviour of thousands, perhaps millions, of individually "greedy" programmes. Such a fragility is brought about by the interaction of millions of interacting 'rules'.

An additional fragility suggested as inhering to distributed materiality, particularly in the form of infrastructure, is regulation. Regulation is intended to produce consensus on technical standards and requires institutions to propose and enforce it. The material demands of a complex and interdependent set of material relationship necessitate a supporting regulatory infrastructure recalling (Winner, 1980, pp. 130-131). Star also points out that a close examination of infrastructure involves an understanding of it as a site of relational, professional, practice pointing out that:

"…infrastructure is a fundamentally relational concept, becoming real infrastructure in relation to organised practices…" (Star, 1999)

Even in the context of building *NBM* regulation was an issue. The extent of the modularity of the work is only partly represented by the physically separate phone and lamp in the exhibition installation. In its development a number of additional modules existed including an app for "spoofing" the lamp by flashing a white circle on a computer screen as well as iPad, iPhone and Android emulators to which I would regularly deploy the software during testing and debugging. Because of the various sites of testing and their particular technical performances I encountered constant problems with version control and regulation. Most versions of the software relied on a pre-given timing variable defining the length of one Morse dot. In some versions this was defined in milliseconds but in others as a given number of frames. The differing performance of various hardware meant that I was constantly adjusting this in different versions and in some cases actually defining ratios comparing one set of hardware with another (such as an iPad running at a frame rate 1.7 times the speed of a particular iPhone). In essence I was obliged to create a regulatory infrastructure in the microcosm of the build!

Infrastructure, in summary, is a lens through which the fragility of distributed materiality can be examined and a number of features discerned. The particular

sense, which I emphasise, is that to technically integrate distributed technologies requires particular kinds of *work*. The smooth functionality of technical systems is artificially[76] maintained through specific kinds of professional practice, in terms of regulation and maintenance. There is a tension between the material demands of the system and the use it is being put to. In relation to making-practice, this work can be seen as an on-going negotiation with the irremediable realism of the system's materiality. That is to say that such work can be seen as a reaction to the fact that materiality defines particular kinds of physical arrangement and that to bring different materials into correspondence demands a corresponding amount of work to bring this about. In Chapters 2 and 3, I proposed a view of making with materiality as exactly this kind of engagement with pre-existing ontological meaning as a matter of attitude for makers.

NBM contributed to the development of these understandings of fragility into the installation in two ways – firstly by acknowledging fallibility as part of the work itself, and secondly by thematically referencing historical moments in which fragility has become manifest. I suggested earlier that there was a tension between the logical abstraction of Morse code and its deployment as part of a technical practice in a broader system. I now add that even the development of the code itself was enmeshed in material concerns. Where Morse relied on a single wire transmission for his telegraph system, the Cook and Wheatstone model (in its most successful instantiation) made use of a parallel system of five wires which, in combination, caused a needle to point to the appropriate letter. These differing systems of communication strongly resemble current serial and parallel systems and with similarly counter-intuitive efficiencies. Parallel systems that have the potential to transmit several (usually eight) signals at the same time often turn out to be less efficient than serial systems because the increased complexity causes unexpected effects (such as interference). Similarly, Morse's telegraph succeeded because its

[76] Again, I use artificial to invoke "artifice" in the sense of both "*cunning, trickery*" (Oxford Dictionary of English, 2010) and "*craftsmanship, workmanship*" (Oxford Dictionary of English, 2010).

design, while inefficient, was simple and adaptable. This fragile aspect of materiality therefore has a throttling effect on communications, now in 2013 as then in the 1830s. In the installation design of *NBM* the serial communication is both slow and fallible (as visitors walk between the lamp and phone, occluding the lamp). However, it also demonstrates the practicality of the code – a parallel system would be extremely difficult to implement in a signal lamp. In this sense *NBM* embodies historical, material dilemmas which are demonstrated by the serial versus parallel efficiency trade off. Efficient versus cheap. Logically elegant versus materially stable. Simple and adaptable versus fast. Redundant and repeated versus independent and safe. Such distinctions are perhaps similar to the development "iron triangle" (cheap, fast or good: choose one) as described by (Greenfield, 2006, p. 166). As Blanchette suggests (here referring to inescapable features of contemporary technologies), "[there is a] dialectical tension with the evolution of […] material resources and with the efficiency trade-offs their abstraction requires." (Blanchette, 2011, p. 2). In all of these tensions we encounter the intractability of the material world.

NBM in the gallery installation also *references* examples of fragile materiality. I have already suggested that the use of the iPhone, considered as metonymic of futurity, was a rhetorical device intended to provide a kind of impressive persuasion. The recorded history of telecommunications is also rich in rhetorical flourishes. Significant technical tests or public demonstrations were often accompanied by grandiose, almost bellicose, language. The drama of these pronouncements is matched only in the records that survive of messages describing how materiality has proved fatally fragile. A mixture of these messages are transmitted by the signal lamp.

1. "If you succeed you will bask in glory" (Sheppard, 1986, p. 10) (message sent by the Chappe brothers during testing)
2. "What hath God wrought?" (Gere, 2006, p. 48), (message sent by Morse and returned by Alfred Vail at the opening of the Baltimore Telegraph line)

3. “Come at once. We have struck an iceberg. Sinking.” (distress call from the Titanic)
4. “Europe and America are united by telegraphy. Glory to God in the highest; on earth, peace and good will toward men” (Sheppard, 1986), (first message to be sent across transatlantic telegraph cable)
5. “TORTURE” (Kennedy J. D., 1974), (distress signal blinked by US Airforce Commander Jeremiah Denton during a television “confession”. Commander Denton was shot down and held captive by the North Vietnamese in 1966)
6. “Congratulations and success to the Pacific cable, which the genius of your lamented father and your own enterprise made possible. Theodore Roosevelt.” (inaugural message for the opening of the first transpacific telegraph cable)

From these six messages above we can observe the two different strains. Messages one, two, four, and six are expressions of technological triumph. Three and five signal catastrophic technological vulnerability and failure (in example five, Denton’s helicopter was shot down and he was lucky to survive). The sharp duality between a hubristic belief in the power of technology as an expression of mankind’s effort and God’s will and the terse defeated tone of the distress call is employed for dramatic effect in *NBM*.

There is a final fragile materiality embodied in *NBM*. The Victorian telegraph network, like contemporary smartphones, was reliant on scarce resources. In order to supply sufficient qualities of a naturally occurring plastic, gutta percha, which was used as an insulating material for the transatlantic cables, the British telegraph builders were to completely denude various forests in South-East Asia. So essential was this plastic to the success of the submarine cables that, had it not been ‘discovered’ (which is to say taken forcibly from the local populations who had been using it for centuries), there would have been substantial delays to the telegraph’s development until a synthetic substitute could be developed (Tully, 2009, p. 57). The over-foresting of this resource, as well as decimating local

habitats, eventually caused a supply crisis for the material, again prefiguring other kinds of contemporary fragile materiality through the use of scarce resources, unsustainably extracted. Today the publicity around mineral extraction for the production of Apple iPhone components has been explored in photographic and theoretical work (e.g. Holmes, 2011).

In summary, fragile materiality has a number of features: The distributed and modular nature of technological systems, such as the electrical telegraph network and the contemporary internet, means that they are subject to two particular forms of fragility: heterogeneity and scarcity. The sheer heterogeneity of materials, each with its own physical properties and frailties, combined in varying technological standards, presents a massive design challenge to have them work predictably both individually and in concert. This is exactly the challenge which Dourish and Bell (2011) suggest is being conveniently overlooked in the context of designing for ubiquitous or pervasive systems. Such distributed systems also have the capacity to suffer what I have called combinatory or algorithmic fragility, a kind of material butterfly effect[77]. Fragility is also implied by the dependence of technological artefacts and systems on resources. I have given illustrative examples of how particular artefacts (iPhones and telegraph cable insulation) are (or were) enmeshed in broader ecologies of agriculture and mineral extraction and supply chain logistics.

4.3.5 Future-Oriented

The final facet of materiality that I will discuss is its future orientation. Future orientation, as I suggested in Chapter Two, suggests that if meaning and materiality are related, then to make with materials is to accept an involvement with future meanings, and that to do so carries an sense of ethical responsibility. This position was founded (following Heidegger, 1971; Meillassoux, 2010) in an

[77] Bennet (2010, p. 27) gives a detailed of example of such fragility in the form of a catastrophic power outage in the U.S.A. in 2003, in which a variation in demand caused successive failures of equipment which, in turn, put greater strain on the remaining network.

understanding that meaning is ontologically grounded, suggesting a view of making as a kind of 'intervention' into pre-existing meanings. I also described how Keane (2005; 2013), notes that the binding of semiotics to material causes meaning to be always orientated towards unpredictable futures. The interdependence between signs and the world means that signs are processual: "signs give rise to new signs, in an unending process of signification" (Keane, 2013, p. 413). Signification is bound with materiality in mutually dependent processes.

This previous review work was reinforced by the process of working with an antique artefact, the signalling lamp. The lamp itself, as a messaging medium clearly has an explicit relationship with the creation of meaning through encoded language. Perhaps a more interesting approach, though, is to consider, as I did, how its own materiality produces its own kind of meanings, rather as was noted in the discussion around the Morse 'fist' in 4.3.2. To become part of the installation of *NBM*, the lamp was retrofitted. An LED bulb replaced the original (broken and obsolete) incandescent and a control circuit linked the trigger to a microcontroller. This process physically combined the long history of the lamp with other material pasts embodied by the bulb and circuitry. The lamp was effectively reformed as a new hybrid object. Its potential for action was altered and consequently so was its capacity to produce different kinds of meaning. Whereas previously, the reliance on a human signaller restricted the speed and complexity of messages sent, the lamp could now potentially transmit at very high frequencies[78]. Because it could be far more quickly extinguished and illuminated than an incandescent bulb, the LED bulb, combined with the control circuit, afforded this feature. In essence, the nature of the lamp's agency was reconfigured which led me to consider how the concept of agency itself is fundamentally future-leaning. The production of action in the world necessarily involves contingency and knock-on. Building on Latour (2005, p. 76) we can begin to define a more detailed account of the particular *kind* of future-reaching effect produced by material things.

[78] Although the low camera frame rate would prevent them being interpreted.

"…the 'matter' of most self-proclaimed materialists does not have a great deal to do with the type of force, causality, efficacy, and obstinacy non-human actants possess in the world. 'Matter', we will soon realize, is a highly politicized interpretation of causality." (Latour, 2005, p. 76)

To decode, or at least observe the particular ways that matter "might authorize, allow, afford, encourage, permit, suggest, influence, block, render possible, forbid, and so on" (Latour, 2005, p. 72) is, in short, to be always already in a conversation about the future.

This intervention into the near future through the remaking of an historical object caused me to contextualise this process in relationship to design practice. Design is a future oriented activity. This takes two forms. First there is the immediate, and perhaps more prosaic, sense of imagining shortly-to-be-made objects. Second there is a wider more ambitious view of design as a "world-making" activity (Agid, 2012). Such worlds are worlds of the future. However, implicit in this view is that design is as an essentially abstract activity, divorced from the contingencies of material engagement. To 'make worlds' is to imbue the maker with unrealistic mastery over materials. This tendency has been criticised recently. Ingold (2013, p. 69) describes it as a "hylomorphic" fallacy in design methodology, pedagogy and theory. Hylomorphism, by Ingold's description, is the view that in "the making of artefacts, practitioners impose forms internal to the mind upon a material world 'out there'" (Ingold, 2013, p. 20). He proposes a more nuanced expression of future-orientation in relation with materials. In this, designers employ a kind of "foresight" (Ingold, 2013, pp. 66, 69-72) wherein experienced practitioners plan ahead in response *with* materials. Such a view has obvious commonality with Suchman's (2007) notion of situated action in which plans are conceived of as "cultural resources produced and used within the course of certain forms of human activity" (2007, p. 13) as opposed to "cognitive control structures that universally precede and determine actions" (2007, p. 13). Indeed, Suchman chooses to introduce her

(2007, pp. xi-xii) reworked account of situated action by invoking both (Bowers, 2002, pp. 32, 44) and (Ingold, 2000, pp. 312, 413).

Dourish and Bell have also noted the problems associated with what I characterise as a kind of extreme form of hylomorphism, the common trope in design research of designing for proximate futures (2011). They observe that in ubicomp research, some designers effectively sidestep fundamental design obstacles by locating the design in some notional future scenario where the obstacle has conveniently been overcome. Bluetooth pairing is tricky? No problem. In the proximate future we will have newer, more seamless peer-to-peer phone communication protocols. Mobile phone battery life is too short to take phones into the wilderness? No problem, in the proximate future, battery life will be extended even as batteries become inconceivably small and light. It is not coincidental that all of the problems ostensibly overcome by this trick are exactly those identified by (Fuller 2008; Blanchette 2011; and Dourish and Bell 2011) themselves, as irredeemably *material*.

4.4 Facets as Framework

In this section I have given a short introduction and definition to the five facets of materiality which I have developed both from literature and through my own practical research. This research combined experimental making and historical and theoretical research in an integrated process. Not only did this process shape the development of the facets, it began to suggest practical examples of how they might be applied to other making-processes as a framework. The development of the facets of materiality was integrated with an archaeological approach examining historical materiality in action, providing rich examples which could be compared to contemporary artefacts and systems. Historicity was also proposed as inherent to materiality in its performative, distributed and future-oriented aspects.

The integrated development process of the material facets with *NBM* and *MI* was necessarily partial and opportunistic. Based, as it was, on a materially-focused making-process, it was subject to the availability of resources and constrained by

money and technical know-how. It was lead by particular opportunities, described in 4.3.1 as ‘spaces for work’. This process was acknowledged as messy and opportunistic and while the relationships between facets and design process was expressed clearly, in many cases this development was both lengthy and iteratively reinforced by other aspects of the build. Correspondingly, the result of this method is that the descriptions of the facets of materiality developed are not intended to exhaustively pin down all possible implications or applications of them. The next chapter follows the application of the facets, as a framework, to the production of a third artwork and consequently further develops the facets themselves. Its main focus, though, is on their application.

Chapter 5. Material Design and Making

The previous chapter tried to describe specific aspects of making-processes which played a role in the development of the five facets of materiality proposed: *spatio-temporal, performative, distributed, fragile, and future-oriented*. The convoluted and occasional nature of the making-process was acknowledged and it was again stressed that there is a tension between the formal description offered in this thesis and the day to day practice of programming, sketching, laser cutting, data scraping, soldering and wiring, which I attempt to address partly by including as much of the practical details of the activity as possible. In the sections that follow, I will describe the application of the facets of materiality in the form of a design framework to the making of a separate work, *Neurotic Armageddon Indicator* (henceforth *NAI*).

5.1 Research and Frameworks

At the time of making NAI, the production of *MI* and *NBM* had contributed to the development of a series of concerns which were loosely formalized under the facet names described. I have already noted that there are many correspondences between the various facets (particularly between distributed and fragile) and it was only at the writing up stage of this thesis that these were so definitively taxonomized. Similarly, in this chapter, I describe the application of these facets as a design framework but rely on the term's connotations of *guiding principles* rather than *strict rules*. The solidity of the framework, therefore, continued to be developed through the research described below. As such the main factor separating this chapter from the previous is an understanding that the facets developed were something with a more detailed conception of their *application* rather than being primarily features of *description*. It is in this sense that they began to be applied as a framework and in this way that their continued formalization and exemplification throughout this chapter hopes to render them most useful to other practitioners.

It has been repeated throughout this thesis that a key methodology employed was research through design, and justification for such an approach was provided in Chapter 1. In order to remain as close as possible to the practice described, this chapter will be organized by the developmental processes involved in making the artwork rather than according to some other conceptual schema. Taking the works themselves as things from which to begin, what began in the previous chapter as annotations (Bowers, 2012), will be developed and explored for their potential usefulness to other designers and makers.

Before describing the application of the facets of materiality as a framework, building on remarks in 1.4, I will first suggest some ways in which a practice-based approach is congruent with the broader subject of materiality.

5.1.1 Making-processes

Ingold's (2013) account of making-practices emphasises the way that the process of making can be lost when looking at 'finished' artefacts.

"Much can ride, in English on the indefinite article. Building is an activity; it is what builders do. Add the article, however, and the activity is brought to a close. Movement is stilled, and where people had once laboured with tools and materials, there now stands a structure - a building - that shows every sign of permanence and solidity." (Ingold, 2013, p. 47)

An identical point is made by (Dewey 2005 [1934], p. 53). This view of objects, in design, as static and permanent, Ingold maintains, is problematic because it disregards their location in dynamic environments in which they continue to evolve, decay, warp, leak water or fall down. I add that this view of dynamic, vibrant (Bennet, 2010) material allows for a particular *aesthetic connection* with making-practice. If we recognise that design processes do not end with 'static' objects then our crafting activity can also be seen as part of a continuity of aesthetic experience. That is to say that in a sense we are constantly engaging with both past and future, we are already 'repairing' what we build. The frequent use of the term 'tinkering' in

the world of DIY electronics[79] already carries a suggestion of interaction with a world of vibrant agency *during* the making-process. To tinker is to make with things which are already in process. Part of the process of making things then is an understanding that one is intervening in an already dynamic system. This observation builds on the points made in Chapter 2.

I have used the building process of the artworks described here to conduct a particular kind of research through design (Frayling, 1993/4). This took the form of not only theoretical research, in the form of reading and writing, but in the production of what might be called 'critical objects'. A critical object is one which does something *oppositionally* in order to find things out. It is a reconfigured, repurposed, rebuilt or recombined technology which embodies a critical response. It is a thing which does something new. As such there are similarities in this approach with that of Dunne and Raby, (Dunne, 1999; Dunne & Raby, 2001; Dunne & Raby, 2013). In the final chapter I will highlight some differences between the approach taken here and these last. Where there is commonality though is in the use of objects to intervene in the development of technological culture. Some possible results of this intervention will also be discussed in the final chapter.

I assert that an approach which articulates criticality through objects of art and design is fundamentally different from one based on 'critique'. By 'critique' I mean an approach which is based on using only what are essentially linguistic, discursive devices (such as dialectics for example) to 'deconstruct' objects of discourse. Part of the argument presented here is that certain kinds of criticality can only be produced by a material engagement with the subject at hand and that in the context of contemporary technology (at least) this material engagement must physically rework that subject. This claim is justified by the assertion that, particularly in the context of technology, the main advantage of a practice-based

[79] See for example the pages of http://instructables.com, or http://makezine.com.

approach is that it provides an opportunity[80] to genuinely remake and study the object of interest. To 'take apart' technology (as I attempted to take apart the electrical telegraph) encourages exactly the kind of integrated theory and practice promoted by this thesis. The previous chapter was, as much as anything, intended to demonstrate that without the physical building processes of *NBM* and *MI*, the theoretical findings described would not have been achievable.

This approach, based on building rather than critique, is aligned with Latour's assertion that "what performs a critique cannot also compose" (2010, p. 475). Latour (2010, pp. 475-6) argues convincingly that a problem with critique (which he identifies with much modern contemporary academic scholarship, particularly in the humanities) is that it is often predicated on a belief that with a successful deconstruction, a truer reality will be revealed[81] (Latour, 2004). Latour's 'compositionalist' stance, by contrast, emphasises that *there is no such reality* calling attention instead to the construction of differences (as described in Chapter 2) which allow such realities to be made possible. This position is highly comparable to (Barad, 2003). It is in this sense that Latour discusses a transition from "matters of fact" to "matters of concern" (Latour, 2004). These latter exactly focus on the active construction of difference. These constructions are our concerns.

"While critics still believe that there is too much belief and too many things standing in the way of reality, compositionists believe that there are enough ruins and that everything has to be reassembled piece by piece." (Latour, 2010, p. 476)

To take Latour's 'compositionalism' so literally (as a building practice) may not be perfectly in the spirit of his intention but I argue that there is a strong commonality

[80] I do not claim that such a process *inevitably* leads to criticality.
[81] For Latour, critique *"*ran out of steam*"* (Latour, 2004) with postmodernism which was *"*fully equipped with the same iconoclastic tools as the moderns, but without the belief in a real world beyond.*"* (Latour, 2010)

between his method and the particular kind of making proposed here in response to the facets of materiality and in the later discussion of experiential ecologies. Latour's description of the practice of knowledge construction (in the sciences particularly) emphasizes the importance of the role played by material (such as papers, instruments, laboratories) in the activity of constructing knowledge (1987; 1988; 1993). It is exactly this sense which is sought after in this practice-based research. These objects are proposed as *critical*, not in the sense of 'critique' but as *essential*. They are proposed as constructing, as part of an ecology, new arrangements of knowledge, however limited. After a brief description of the artwork discussed throughout this chapter, the following sections will attempt to describe this process of construction, paying particular regard to the guiding role of the framework for materiality proposed.

5.2 Neurotic Armageddon Indicator

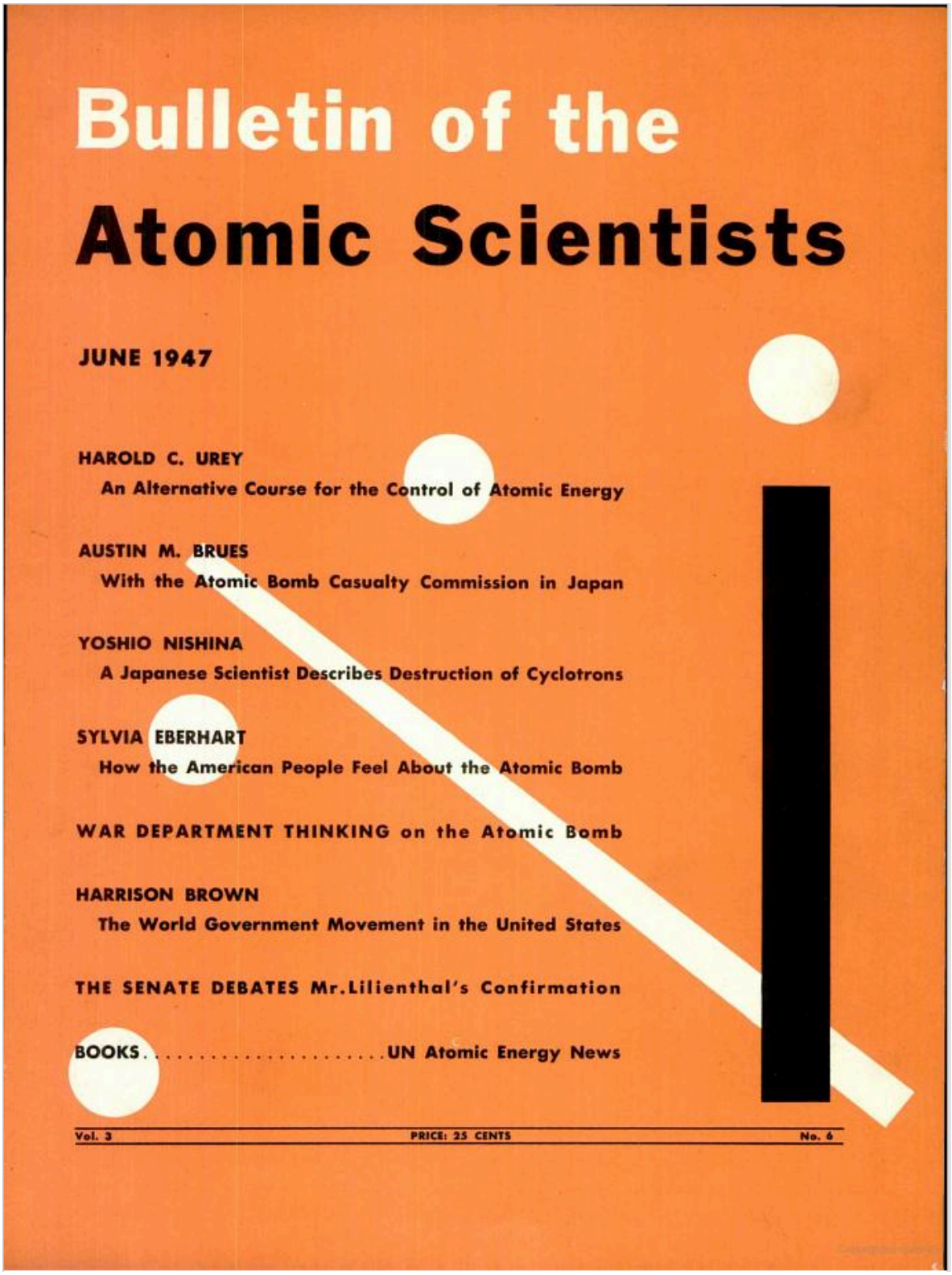

Figure 19: Cover of the Bulletin of Atomic Scientists showing the Doomsday Clock, Copyright Bulletin of Atomic Scientists 1

5.2.1 Background

To discuss the research process involved in producing NAI the history and operation of the original Doomsday Clock must first be briefly described, and with it, its host journal, *The Bulletin*. In line with earlier arguments that materiality is inherently historical, motivating a media archaeological approach, a short background will now be described against which later points can be related.

In 1945 *The Bulletin* was created as a monthly newspaper by a group of scientists who had been or were still involved with the Manhattan project.

“To explore, clarify and formulate the opinion and responsibilities of scientists in regard to the problems brought about by the release of nuclear energy, and To educate the public to a full understanding of the scientific, technological and social problems arising from the release of nuclear energy.”
(Bulletin of Atomic Scientists of Chicago, 1945)

The Bulletin is not peer-reviewed but publishes articles by “leading scientists and security experts” (Bulletin of Atomic Scientists, 2013) that seek to present persuasive arguments to the lay person. In 1947 with the transition from a newspaper to a journal format, *The Bulletin* began to feature the Doomsday Clock on its cover {Figure 19}

The clock “symbolizes the urgency of the nuclear dangers that the magazine's founders--and the broader scientific community--are trying to convey to the public and political leaders around the world.” (Bulletin of Atomic Scientists) It is ‘set’ at irregular intervals by the Bulletin’s board of sponsors which includes eighteen Nobel laureates. The closest that the clock has ever been to midnight was in 1953 when the United States chose to pursue the hydrogen bomb (two minutes to midnight). The furthest away was in 1991 with the end of the Cold War (17 minutes to midnight).

5.2.2 Anti-representation: Performances

A key concern which arose during the production of NAI, and in response to the original Doomsday Clock, related to the distinction between representation and performativity. I have already described a series of related ways in which materiality can be approached as performative and some of these are now applied as a concern informing practice. Taking the research and production of NAI as a focus, I will now describe some of the material factors which constitute performativity in the context of both NAI and the original Doomsday Clock, and how their consideration affected the making-process. In doing so, I will attempt to highlight how this performativity can be read not only as something manifest for human consciousness but as it "becomes reified in actions, body stances, general anticipations" (Thrift, 2003, p. 241). That is, as part of an *event* in which the clock effects different kinds of agency, building on the account given for networks of agency in Materiality: a Definition in Action. The focus of this section's analysis will be on the consequences for *making* in this context of performative events and I will describe how I developed NAI in response to the various performative materialities of the Doomsday Clock.

The performative approach to the clock adopted while making NAI is cast against a "representational" perspective wherein a pre-existing 'thing' (in this case an idea about proximity to nuclear Armageddon) is "expressed" in a representation. To describe the Doomsday Clock as a "representation" of proximity to Armageddon is to suppress its performative functions. This, of course, is a question of focus. This thesis describes a particular kind of working methodology which is centred around a set of material concerns. Performativity offers a way of studying the operation of media as it plays out on a techno-cultural level. A "representational" approach to NAI might have suggested a more developed analysis of the *use and experience* of the particular visual form of the clock across different media. It may have focused on audience reactions to its form, or its associations in different cultural contexts. These are all significant aspects of the work and I acknowledge that my adoption of the particular physical form used was informed by a particular personal taste and

design language. Such points are de-emphasized in the following discussion because although they affect some of the choices of materials in the specific, they do not substantively affect the methodology. For instance, in later paragraphs, I will discuss the material history of the LED 7-digit display. It is acknowledged (in 5.2.3) that the Doomsday Clock itself exploits a filmic trope (of the ticking countdown to a bomb) which has significance as a recognizable representation of danger or catastrophe. The discussion that follows; however, rather than focusing on this trope *per se,* for instance by tracing its history in visual culture, focuses instead on how the material of such displays affords particular kinds of statement[82]. The findings of this analysis are specific to the kinds of material involved but the approach is not.

To ask what those functions include is to ask what the Doomsday Clock *does* and through that activity, following (Barad 2003), what it actually *is*. A short summary of the clock's performative functions might include the following:

- It *quantifies* the level of nuclear threat in an easy-to-understand visual metaphor supported by clear design language.
- Its distribution across television news, print and the web *brings the journal itself to a broader audience* than might normally be expected of an academic journal. This is facilitated by its uncomplicated design which is reducible to a small size while remaining recognizable.
- It *contextualizes* the work of the journal as being both *about* and *against* nuclear proliferation.
- Through its design language it represents the journal and itself as having historical roots in the 1940s or 1950s and this *contributes both to its context (of having relevance to war time) and its legitimacy* (i.e. it has a 60 year pedigree).

[82] Much as Kittler does with his analysis of the gramophone, film and the typewriter (Kittler, von Mücke, & Similon, 1987).

The list of performative functions of the Doomsday Clock above is not intended to be exhaustive but rather to demonstrate how a concern with performative materiality differs from an approach based on representation. While the latter might focus on the clock as a figurative trope, the former emphasizes the particular kinds of actions afforded by the clock's material form, and the network in which it sits.

The making-process of *NAI* began from this point and continued by focusing on specific material aspects of the Doomsday Clock and asking how they might be adapted or reconfigured to produce a different performance. To develop this aspect, I included reflection on aspects of spatio-temporal and fragile materiality. By combining these three facets, performative, spatio-temporal and fragile, I aimed to creatively explore the material foundations for the Doomsday Clock's performative functions and rearrange or replace them in a critical object. The *NAI* project was not begun with the intention of 'critiquing' the Doomsday Clock in the sense of *evaluating* it on moral, political or cultural grounds. Instead, the Doomsday Clock was investigated because there were a number of interesting material issues involved in the various physical forms the clock has adopted, which are clearly vital to its role as an actor, particularly as regards its success in the media. Particularly rich for investigation is the way that the construction of knowledge embodied by the clock is easily describable as a process conducted between various sites, people and materials. In this sense it represented an ideal fit for examination (and reworking) according to Latour's 'compositionalist' stance (2010) described above.

5.2.3 Foundations

If the Doomsday Clock is not to be seen as a representation of an idea then an account must be made for its performance as a thing, the material basis for this performance must be uncovered. The performativity of the Doomsday Clock itself is founded in a number of material factors which provided me with *sites to intervene* as described in Chapter Four's exposition of spatio-temporal materiality. Earlier I described a significance of spatio-temporal materiality as the way that new

arrangements of space/time are embodied by new technologies and suggested that the implication for makers of this view was that they could be adopted as literal places for work, configurations of various materials to be explored and experimented with. An exploration of one such spatial arrangement in the context of *NAI* came with the comparison of the form of the clock, as a minimal wall clock design, to a filmic vision of a typical bomb timer.

The Doomsday Clock itself exploits a filmic trope, that of the ticking countdown timer (to a bomb explosion). In the print journal itself, the clock takes the form of a minimal, 1940s-style clock of which only a section is shown {Figure 19}. A very similar design is reproduced on the Bulletin's website {Figure 26}. This clock design performs as a kind of recognizable trade mark across different media and serves to associate them as different parts of a whole. An initial question for making NAI was how the physical form of the clock could be altered to both maximize the impact of its message and in doing so to explore how that message is materially performed in the Doomsday Clock itself. In popular film culture, the ticking time bomb, commonly takes the form of an LED display (usually red) such as those shown in {Figure 20 to Figure 23}. Given the strong association between the form of the red LED display and the recurrent plot element of the ticking time bomb, it would seem logical for the Bulletin editors to have used such an LED display as the image of the clock. In 1947 however such displays were not yet commercially available (Zheludev, 2007). I took a creative decision to 'update' the clock to this technology and explore this, as an alternative site for intervention, which could simultaneously serve as a lens through which to re-examine the Doomsday Clock itself.

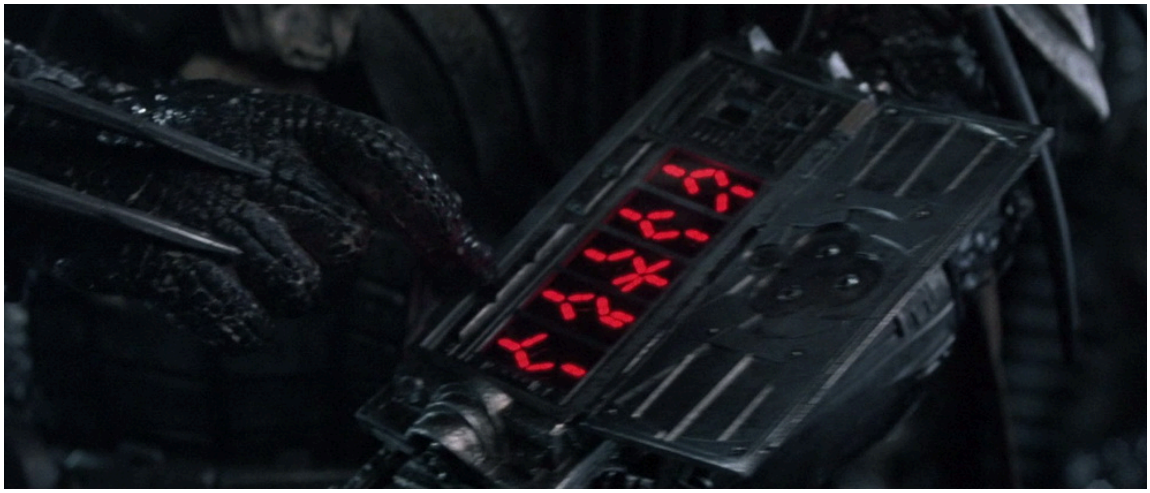

Figure 20: Bomb Timer from the movie, “Predator”. Copyright 20th Century Fox 1987

Figure 21: Bomb Timer from the movie, “The Fifth Element” Copyright 20th Gaumont 1997

Figure 22: Bomb Timer from the movie, “Broken Arrow” Copyright 20th Century Fox 1996

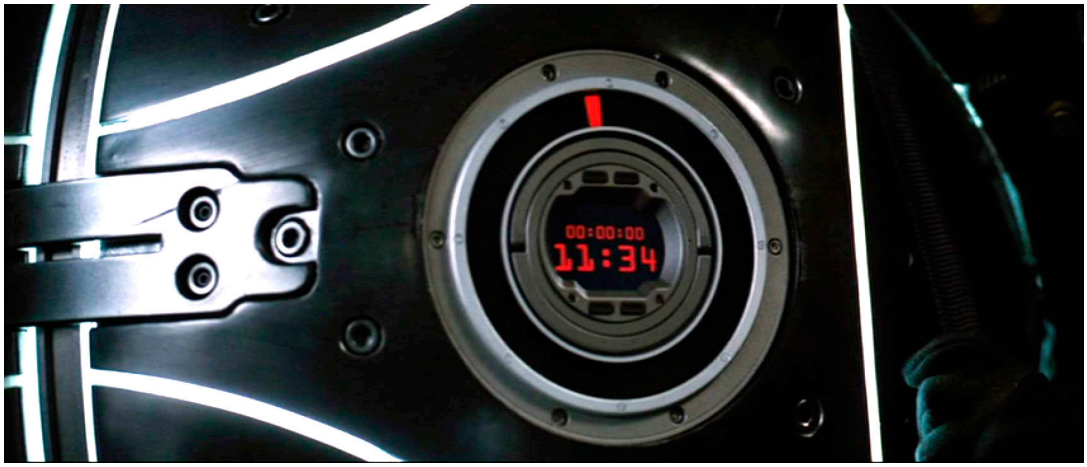

Figure 23: Bomb Timer from the movie, “Batman the Dark Knight” Copyright Warner Bros 2012

Figure 24: A Seven Segment LED Display (this particular model combines four displays in one package). Copyright Sparkfun 2013

I have suggested that a purpose of rebuilding the Doomsday Clock was to actually investigate it as a performative artefact rather than as a representation of an idea. Earlier I described how the Bulletin journal was the location of a fairly complex series of processes which culminate in the setting of the Doomsday Clock: First a basis of evidence is established through the commission and publication of articles.

Then a panel is convened to discuss this evidence[83] and agree an assessment of the level of current threat. Finally, this assessment is quantified as a metaphorical expression – the number of minutes to midnight. The Doomsday Clock itself is in this sense, future-oriented. Its expression of the time as well as the events it was created to prevent are all in relation to the future.

I claim that the translation of discursive processes to a single number presents an opportunity to rework this process of quantification and to try to associate it more tightly with its physical form. This multi-sited production of the clock, in Latourian terms, should be seen as a process of knowledge construction. The painstaking work which must be undertaken to produce this knowledge relies on the affordances of a wide variety of heterogeneous materials. Examples include transportation to allow the committee members to meet, telecommunications networks, their server which must be robust enough to cope with the traffic resulting from media attention to the clock and so forth. To investigate every aspect of this process of construction would be an impossible task, nonetheless the building process of *NAI* explored some of its later stages particularly regarding the internet infrastucture.

The LED displays described earlier, as well as having particular *figurative associations* afford particular kinds of action. Crucially, it is impossible (or nearly so) to use them without some kind of control software and hardware. As such they define a design space which is *necessarily computational*. Not only do they 'evoke' a mechanistic sensibility, they actually rely on control mechanisms to function correctly. In this sense, LED displays are also future-oriented because of their 'expectation' of computational control.

A clock of this sort is a mechanical (or electrical) device. It is necessarily causally connected to the physical world. I conceived of this necessity as part of the spatio-

[83] The Bulletin does not describe this process in any detail.

temporal arrangement of that technology (of LED displays). A dependency on computer (or electronics) control is an identifiable feature which marks it apart from other similar technologies (such as a single LED for instance) and motivates an adoption of this feature as prominent in the design.

This aspect of the materiality of the 7-segment LED provided an opportunity to present a particular kind of fiction through the artwork. That was that the *NAI* is part of a real mechanism actually connected to the end of the world, even though that mechanism is not itself articulated through the design. This idea was described in gallery interpretation in direct relation to the original Doomsday Clock in an attempt to highlight the value of exactly that lack of mechanism in the original! I argue that such a fiction would not be possible with an *image* of a clock.

Returning to the Doomsday Clock itself, the *image* of the clock (such as that on the cover of the journal) by contrast is therefore always, in some senses, a metaphor, referring back to some anterior materiality rather like the phicons which function as "icebergs" in a metaphorical "ocean" (Ishii, Lakatos, Bonanni, & Labrune, 2012, p. 38). A *virtual* clock (such as the one presented on the Bulletin's website) however is something else once again. It *may* be causally, programmatically connected to time keeping software, or some algorithmic process or it *may* be solely an image which must be replaced to give an illusion of time[84]. What appears to be the same clock *in interpretation* is in fact only the *effect* of two completely different materialities.

NAI was designed to exploit this ambiguity (between a clock which is a function of code mechanism and one which looks identical but is not) and to make that ambiguity manifest. By parodying the 'mechanical' aspects of a clock, NAI seeks to

[84] To break this down further, the 'mechanical' 'programmatic' clock could also function by defining shape translations which are eventually rendered to pixels or by loading a number of pre-rendered images – this, in fact, appears to be the case with the Doomsday Clock. It is produced by a JavaScript programme.

transcend a status as a representation and embody a kind of material critique. It attempts to construct a particular kind of new version of the Doomsday Clock while making that process of construction its own subject. It is in this sense that it is aligned with Latour's (2010) proposal of compositionalism over critique. Rather than being, in any sense, positioned against the Doomsday Clock, *NAI* takes new, related materials and arranges them in complement to the original. The use of optoelectronics constructs *NAI* as explicitly and necessarily part of a system of technological intra-communication between the scraping server, the microcontroller and the display. The aesthetic claim of the work is dependent on the technical, causal connection between these technologies.

5.2.4 Fragile=Hackable

A second beginning point for a materially-oriented engagement with the Doomsday Clock was suggested by an application of ideas of distributed and fragile materialities to the context of the web edition of *The Bulletin*. From a material perspective, the transition of the journal from print to web was a fundamental one with implications as to how, when and by whom the journal is viewed, where the data is stored and, crucially, how its content is disseminated and protected. I have described how the clock image hosted on the website bears only a superficial resemblance to the print version and is, in fact, produced by a set of inter-connecting browser functionalities. Similarly, the text, images and other content of the journal may have stylistic commonality with the print journal but their foundation in different kinds of materiality means that they are *open to a very different kind of making intervention*. In the following paragraphs I will describe how a fragility, inherent to the systems composing the Doomsday clock and the context in which it sits on the web, afforded such an intervention. Crucially, I propose that *a generalizable feature of this intervention* is an expectation from providers of web content that clients will conform to particular rules or expectations. The subversion or disregard of such expectations affords ways of articulating a critical response to these fragilities, which have implications for our use of such technologies.

The server-side part of *NAI* 'scrapes' the webpage to check the clock time. In technical terms, the programme that does this actually conducts a very similar function to a normal web browser. It requests html content from the server (via HTTP) and then renders it according to a set of pre-determined rules. The 'giving over' of content is implicit in the functionality of a web browser and the implicit expectation of the host is that that content will be displayed according to world wide web rules which are defined by W3C[85] standards. That *expectation* though is a point of fragility. The system relies on an unknown, anonymous client requesting data which is served according to agreed technical standards. Beyond those standards (HTTP protocols) there is a messy technical 'grey area' which can be creatively intervened in. The distributed nature of the webpage's materiality – the division between client and server sides is what allows web scraping and consequently is what affords the repurposing of website content into creative projects like *NAI*[86].

Websites also operate an 'honor' system to attempt to regulate this client/server relationship by using a 'robots.txt' file {see Figure 25}. This file sits at the root directory of a site and provides codified instructions to machines accessing the system as to where they can and cannot go and how often. These rules however are rarely enforced as to do so requires specialist technical implementation. The fragility of the system is also therefore connected to the financial or skills resources of the institution involved who may be more or less able to detect and repel intrusion for instance through IP address blocking[87].

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[85] W3C "is an international community where Member organizations, a full-time staff, and the public work together to develop Web standards" (W3C, 2012)

[86] Arguably this opportunity is also implicit in the creative use of application programming interfaces (APIs). APIs are normally intended to supplement web pages with data. The Twitter API (Twitter, 2013) is an example in point where a wide-spread adoption by media artists has resulted in the data provided by it being leveraged into a wide variety of unforeseen uses, often off the webpage.

[87] The 'robots.txt' file for the Bulletin asks (among other things) that there is a delay between crawling this of 10 seconds, and disallows various queries.

```
#
# robots.txt
#
# This file is to prevent the crawling and indexing of certain parts
# of your site by web crawlers and spiders run by sites like Yahoo!
# and Google. By telling these "robots" where not to go on your site,
# you save bandwidth and server resources.
#
# This file will be ignored unless it is at the root of your host:
# Used:    http://example.com/robots.txt
# Ignored: http://example.com/site/robots.txt
#
# For more information about the robots.txt standard, see:
# http://www.robotstxt.org/wc/robots.html
#
# For syntax checking, see:
# http://www.sxw.org.uk/computing/robots/check.html

User-agent: *
Crawl-delay: 10
# Directories
Disallow: /includes/
Disallow: /misc/
Disallow: /modules/
Disallow: /profiles/
Disallow: /scripts/
Disallow: /themes/
# Files
Disallow: /CHANGELOG.txt
Disallow: /cron.php
Disallow: /INSTALL.mysql.txt
Disallow: /INSTALL.pgsql.txt
Disallow: /INSTALL.sqlite.txt
Disallow: /install.php
Disallow: /INSTALL.txt
Disallow: /LICENSE.txt
Disallow: /MAINTAINERS.txt
Disallow: /update.php
Disallow: /UPGRADE.txt
Disallow: /xmlrpc.php
# Paths (clean URLs)
Disallow: /admin/
Disallow: /comment/reply/
Disallow: /filter/tips/
Disallow: /node/add/
#Disallow: /search/
Disallow: /user/register/
Disallow: /user/password/
Disallow: /user/login/
Disallow: /user/logout/
# Paths (no clean URLs)
Disallow: /?q=admin/
Disallow: /?q=comment/reply/
Disallow: /?q=filter/tips/
Disallow: /?q=node/add/
#Disallow: /?q=search/
Disallow: /?q=user/password/
Disallow: /?q=user/register/
Disallow: /?q=user/login/
Disallow: /?q=user/logout/
```

Figure 25: A Screen Grab of the Robots.txt File from the Bulletin of Atomic Scientists Website 2014

The combined process of research and making described here was enabled by approaching *The Bulletin's* home page with a view to the fragile and distributed aspects of its materiality. The practical process of developing a simple Python web scraper also helped to develop ideas of how fragile and distributed materiality might be practically applied as a framework. For instance acquiring the basic skills necessary to scrape the bulletin's page made me aware of the existence of the 'robots.txt' file. This in turn contributed to a theorization of the client-server relationship as a messy, distributed and fragile one which could be creatively exploited. In this way a reciprocal relationship between framework and application was developed.

5.2.5 'Live' Data

A final aspect of the Doomsday Clock's materiality is also related to the client/server division which I have been describing as an example of distributed materiality. In addition to this latter, there is a related, spatio-temporal approach to the materiality of the Doomsday Clock which I explored through the design of NAI. In this final, spatio-temporal aspect of the Doomsday Clock's materiality I used the making-process of *NAI* to construct a material critique of notions of 'liveness' in visualisation. Visualization is referenced because its purpose is to represent data in understandable ways. There is therefore congruence with the motivation behind the Doomsday Clock itself.

Many seminal visualizations (such as, Koblin, 2005; Stamen Design, 2006) rely on live data, and point to 'liveness' as a key point for engaging audiences. Viegas and Wattenberg, for instance, describe their *Wind Map* as a "living portrait" (Viegas & Wattenberg, 2013) using liveness as evocative of the relationship between visualization and the real world. Taking the concept of liveness as central to their work, Lise Autogena and Josh Portway created a simulated 'live' ecosystem in their work *Black Shoals* which was driven by live data from the stock market.

"Digital creatures, a form of artificial life, inhabit this world, feeding on the light released by the stars, breeding, dying and slowly evolving – while trying to learn to

live in this strange artificial ecology into which they've been born." (Autogena & Portway, 1996)

Jacobs *et al*. describe how central the concept of liveness was, for the experience of an artwork driven by environmental data.

"…the artists also emphasized how it was vital that the work should make a live connection […] in order to support a localized and viscerally real experience." (Jacobs, Benford, Selby, Golembewski, Price, & Giannachi, 2013, p. 135)

They also describe how the artists involved struggled with what was effectively a moral dilemma. The live feed for their project was occasionally unreliable and their solution was to 'patch' the data feed with pre-recorded data when the feed connection failed. Some participants however reported that this undermined the artistic and ethical integrity of the project (Jacobs, Benford, Selby, Golembewski, Price, & Giannachi, 2013, p. 135).

Liveness, while seen as crucial for Jacob *et al*. is not examined by them from a material standpoint. The authors and artists above discuss liveness in the way that it is relevant to engaging audiences and by doing so, focus on liveness as a phenomenal event. I suggest that a more detailed analysis of the material basis for liveness might enrich the concept[88]. I will now discuss some material aspects of liveness as they related to making *NAI* and in doing so hope to both contribute some further nuance to this concept, and describe how a focus on spatio-temporal materiality suggested this additional research direction.

[88] Other aspects of liveness – for example the appreciation of live vs pre-recorded music have been the subject of recent research into public interactions e.g. (Reeves, Benford, O'Malley, & Fraser, 2005), (Hook, Schofield, Taylor, Bartindale, McCarthy, & Wright, 2012)

There are two distinct material temporal aspects to 'liveness' which I identify: latency and sample rate. By latency, in this context, I refer to the delay or 'lag' between an event occurring and its representation being manifest in a visualization. *Wind Map* (Viegas & Wattenberg, 2013) for instance, has a latency of about an hour – the weather data is processed by the visualization engine around an hour after the wind was detected by a network of sensors[89]. In NAI the latency is the time taken for the scraped data to be downloaded from the server and processed by the microcontroller. This latency is represented visually by an LED indicator light at the bottom right of the unit, labelled 'CHECKING WITH BULLETIN OF ATOMIC SCIENTISTS' which flashes when a new packet is received {Figure 3}. In NAI this latency also defines the sample rate, as soon as one packet is returned, another is sent. Any digitally encoded data is sampled at a given rate. On a commercial CD for instance a measurement is taken 44100 times a second. The combination of sample rate and bit depth determines the fidelity of the recording (Roads, 1996). In visualization practice however, these 'sample rates' differ enormously from project to project depending on the hardware involved (in the form of sensors and microcontrollers for instance) and the programming rules set up to control and 'poll' the hardware. As Jacobs *et al.* (2013, p. 135) describe though, these material specifics are unlikely to be visible to audiences, in fact they may be purposefully obscured. Although connection failure is not made explicit in the design of *NAI*, it is implicit in the minimal indicator light which flashes only when a packet is requested.

NAI performs a *parody* of liveness by continually, visually[90] polling a static data source (the Doomsday Clock webpage). It goes through exactly the same technological processes (such as HTTP requests, data processing) as would many

[89] The designers make this latency clear on the project's home page (Viegas & Wattenberg, 2013).
[90] The indicator light is intended to emphasise the live connectivity. It flashes irregularly depending on the timing of the data packets. The concept of latency as I apply it here is as a variable delay in the reception of data rather than as a comparison to some standard.

live data visualizations based on remote data. However, by relying on a data source which will almost never change its performative function is affected, becoming a kind of meta-commentary on liveness itself. With the continuous, ‘checking’ of time, I attempted to introduce a fictional, anthropomorphic quality to the clock. This is the ‘neurosis’ of the piece’s title. This ‘neurosis’ is intended not to refer only to the proximity of Armageddon which it is ostensibly checking but also to a state of *temporal* uncertainty. This fictional ‘uncertainty’ is proposed as the clock’s reaction to the fundamental incommensurability of the different kinds of time with which it interacts. Those kinds of time are; an audience expectation of liveness; a latency in updates, the possibility that the clock may actually change very occasionally, the opposition between the high speed of the internet connection and the slow update cycle of the Doomsday Clock. By adding this anthropomorphized persona to the clock I identify with Bennett’s suggestion that:

“A touch of anthropomorphism, then, can catalyse a sensibility that finds a world not with ontologically distinct categories of beings (subjects and objects) but with variously composed materialities that form confederations.” (Bennet, 2010, p. 99)

The resulting neurotic personality which I developed for the device was a useful tool in thinking about the materiality of liveness in relation to the clock. Bennet’s “confederations”

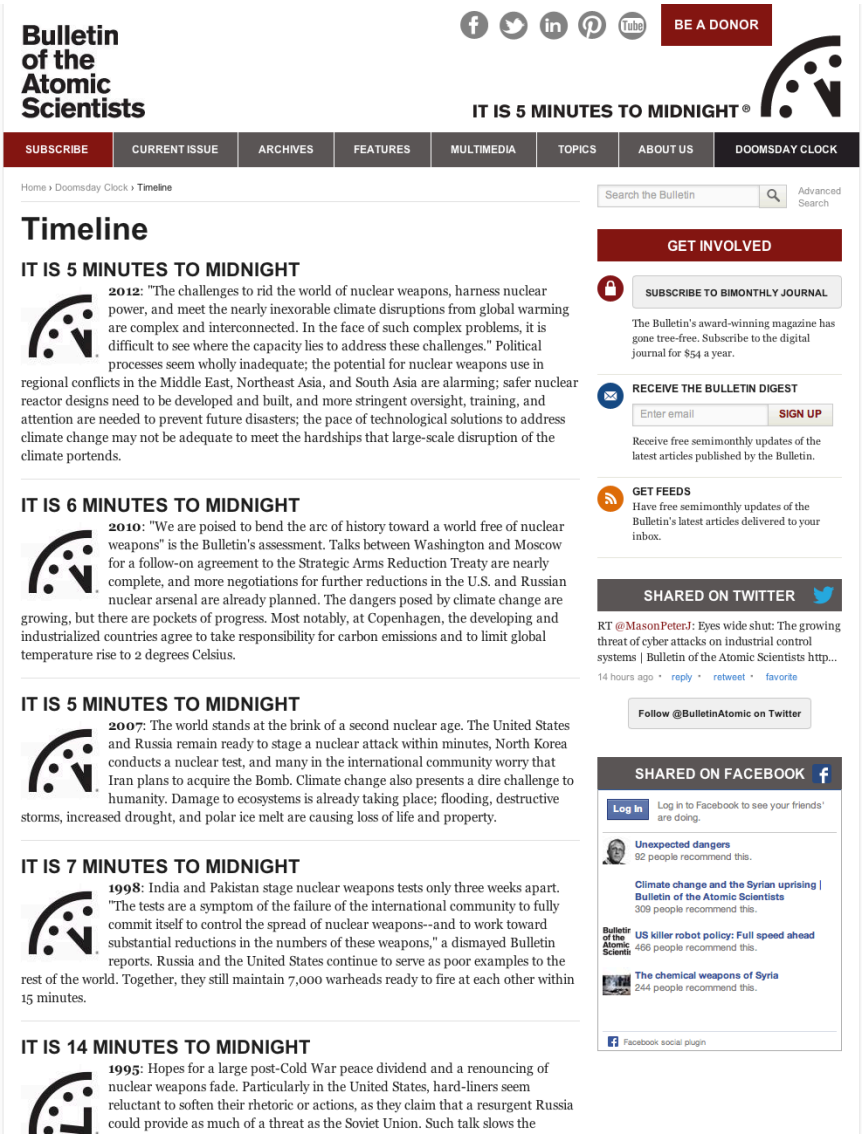

Figure 26: A screen grab of the current journal featuring the Doomsday Clock timeline.

5.3 Framework Summarised

This chapter has described how research described in the previous chapter which developed ‘facets’ of materiality was applied to a particular artwork development process as a framework.

- Spatio-temporal materiality was discussed in relation to the concept of liveness in data-driven artworks.
- Performative materiality informed the development of NAI in contrast to the original Doomsday Clock and its representation across different media.
- Fragile and distributed materialities afforded an understanding of infrastructural weaknesses in web technology which encouraged the ‘hack’ behind NAI.
- Future-oriented materiality contributed to an understanding of the connection between LED displays and computational control.

I claimed that this process would demonstrate how such a framework could be applied in practice and that this would be potentially useful for other makers. The process described here is obviously specific to the thing which was being creatively explored; the materiality of the Doomsday Clock. As such the particular making tactics employed to re-purpose the clock’s sense of liveness, or fragility, for example, are not likely to be directly repeatable. The value of the framework described however, is that it is adaptable to a variety of design scenarios and as such there is an implicit expectation to generalise methods by which it can be applied. There are some aspects of the methods adopted here which are generalizable (and I have provided some brief examples of areas where they might be applied) but I am resistant to the idea of a series of methodological recommendations for the following reason: An important appeal of materiality as a basis for an approach to making is that, as Ingold has suggested, it offers a way of integrating thought and action in the context of the physical world. A material approach, rejects the dualism of ideas and material and I have cited a number of authors who offer their own justifications for why this dualism is artificial. Some of

those justifications are ontological, as in Heidegger's 'thrownness' (1954; 1996 [1927]). Others are phenomenological as in Merleau-Ponty's bodily approach to meaning (2002). If the 'hylomorphic' tendency of some design practice is to be avoided, making-practice must be responsive to the performative materialities with which it is involved rather than trying to idealise materiality to fit convenient conceptual structures. Instead, the practice proposed by this thesis is intended to restage various performative materialities, creating new correspondences and consequently, new meanings.

In the context of *NAI*, I have described how this 'responsiveness' afforded two interconnected 'places to start'. These were; a theoretical and thematic focus for research; and a set of materials and technologies to use. The facets of materiality which I have proposed provided a way of both finding these 'places to start', and of providing a basis for analysis. For example the concern with the way that technology brings about new divisions or definitions of time (part of what I have defined as spatio-temporal materiality) informed the making-process of *NAI* firstly by influencing the selection of the Doomsday Clock as a base, and then by suggesting ways that its particular kind of temporality was materially embodied through scripts, files and client/server relationships. The spatio-temporal facet also suggested the relationship between this small ecosystem of technologies and the time performed by them, and other practical projects (particularly the visualizations cited) and the concepts developed with them.

The value of the facets of materiality as a framework, is in the way that they can inform different stages of a making-process from inception to development. I have shown how they were useful for provoking initial research, for choosing which technologies to work with, and for deciding how to intervene. In the following, final chapter, I will explore materiality *after the making-process* of these artworks. I will offer a retrospective look at how materiality, taken as a central concern in an art and design practice has broader implications into the way that such a practice and the things produced with it, fit into an 'experiential ecology'.

Chapter 6. Conclusion: Experiential Ecologies

So far, the development of five facets of materiality (*spatio-temporal, performative, distributed, fragile, and future-oriented*) has been described through literature review and practical research. Their application as a framework has been detailed and the implications of such a framework for other makers has been discussed. In this final chapter, developed after the practical research was completed, a developing series of implications of this research will be explored through a central question, '*if makers adopt a materially-centred approach as described, what are the implications for the ways made things form part of wider ecologies, and how does, or should, this affect the research process?*' This question will be approached first by asking *why* makers could or should think about their work in ecological terms. Justifications given will subsequently be discussed in relation to the *experience of research* and ethical implications, already introduced, will be revisited from this perspective. Lastly, implications on how such a consideration may *actually influence methodology* will be discussed. After the exploration of these key themes for the chapter, some checks and balances to the concept of experiential ecologies will be offered, and some directions for future work proposed. For the purposes of this analysis a retrospective discussion of *Refractive Index* will be undertaken to ground and illustrate how ecological concerns already inflect the work produced.

6.1 Why Ecologies?

At different points within this thesis a variety of terms describing interconnected groups of people and things (often without *a priori* differentiation between the two) have appeared in references to existing research. Ingold, for instance, describes both meshes (2009) and lines (2007) to invoke his particular characterisation of the relationships between material and practice. Latour discusses not only "networks" (2012, p. 3) but "entanglements" (2005, p. 84). Winner mentions "configurations" (1980, p. 135). I employ the term *ecology* because it suggests a number of features which were both reflective of, and productive for, the practice described in this thesis and these will be briefly outlined in the following paragraphs. In doing so

however, I qualify the use of this term by stating that its application is exactly as relevant as it proves useful. There are no doubt phenomena evoked by the term which are not reflective of the practice described here and this is duly acknowledged.

A starting point for an ecological perspective in this practice-based research was a reaction to the sense of being as a lab researcher (literally, physically) surrounded by an array of technological components, various in, for instance, size, shape, power consumption, and composite material. There was, and is, a sense that not only were these items connected to one another (both literally as in the networking technology and more loosely in their potential for correspondence) but that those particular connections *were an emergent feature of the particular combinations present*. In this sense, the comparison with an ecology in the sense of, for instance, a micro-climate seemed apt. Similarly my own position in, and engagement with this ecology as exploratory (recalling Gaver's 1991 work on affordances) and interventional felt congruent with the dynamic interactivity suggested by the term. In common with (Sharrock & Anderson, 1993) I use 'ecology' to evoke a navigable environment of artefacts whose organisation is itself a feature of interest. In summary, I use 'ecology' for its resonance with a world of 'vibrant stuff', messy, lively, explorable and never abstractable. That 'stuff' is the materiality which I have attempted to engage with.

6.2 Experience

The experience of ecologies is not only our own, but that of objects themselves. As unfamiliar as it may sound, objects *do* have experience. Experience is both the subjective understanding of what one has undergone and the state of having being enmeshed (as in Ingold, 2009) in affairs. To make, and perhaps to interact with technologies in an experiential mode is to adopt an orientation concerned towards the histories of objects and to a treatment of them with care and attention. It is undeniable that this engagement adopts an ethical position which is, in fact, contrary to some Western traditions (following Keane, 2005) as was discussed in Chapter 2. A suspicion of our materials as being somehow, implicitly unethical is, I

maintain, disruptive to making-practice. Not only does it lead to a view of the material as a site on to which to project interpretation (as discussed in Chapter 5), it forces makers into a disjointed relationship to their own practice. Makers, adopting the views described by (Keane 2005), would need to reconcile their daily tasks of cutting, measuring, coding, soldering, and sawing with a criticism that such tasks are secondary to particular kinds of knowledge expressed only in literature (and perhaps through drawings). This denigrates the knowledge making embodied in such activities.

Experiential ecologies are proposed as a way of thinking about the integration of practice, through materials, into larger contexts. They are a way of recognising that practice is always, already historically engaged and that such engagement can be a source of both inspiration and responsibility. The 'experience' of ecologies, in summary, is conceived of as both the experience of practice and the experience of artefacts.

6.3 Motivating Factors: Behind Ecologies

To this point, I have offered a number of methodological and theoretical imperatives for the foundation of making-practice in material concerns. In the previous chapter, particularly, I described the specific research directions which were suggested by facets of materiality and used these to demonstrate their value to making. At the very beginning of this thesis though, I offered some contextualization to my art and design practice in the form of motivating factors. In particular, I suggested that making has been seen as a particular form of arriving at, and contributing knowledge to the world. In the following paragraphs I will propose that the sense of creating knowledge through practice is, itself, a form of ecological engagement and that this in turn supports particular *attitudes* for makers with implications for *methodology*. Heidegger provides a clear starting point for this discussion:

"From earliest times until Plato the word techne is linked with the word episteme. Both words are terms for knowing in the widest sense. They mean to be entirely at

home in something, to understand and be expert in it. Such knowing provides an opening up." (Heidegger, 1954)

To produce artefacts with this perspective, I have argued, is also to engage with meaning and I have discussed a range of research which contributes to an understanding of the blurred distinctions between making, objects, action and thought. Made artefacts, we have seen, embody historical meaning (Keane, 2005), produce action in performance (Barad, 2003), and support the organisation of knowledge (Sharrock & Anderson, 1993). Latour, offers a description of the result of the many ways in which objects come to play a role in an ecological 'entanglement' noting the problem with tight distinctions between these realms:

"It would be incredible if the millions of participants in our courses of action would enter the social ties through three modes of existence and only three: as a 'material infrastructure' that would 'determine' social relations like in the Marxian types of materialism; as a 'mirror' simply 'reflecting' social distinctions like in the critical sociologies of Pierre Bourdieu; or as a backdrop for the stage on which human social actors play the main roles like in Erving Goffman's interactionist accounts. None of those entries of objects in the collective are wrong, naturally, but they are only primitive ways of packaging the bundle of ties that make up the collective. None of them are sufficient to describe the many entanglements of humans and non-humans." (Latour, 2005, p. 84)

It is perhaps the contested nature of the role of objects as part of our ecologies which prompts Haraway to claim that "What counts as an object is precisely what world history turns out to be about" (Haraway, 1988, p. 588, quoted in Barad, 1996, p. 164). The principal motivating factor behind an exposition of ecologies in the context of making with materiality then is the recognition that not only is *techne* a form of knowledge production but that the production of artefacts is also involved in the production of *society*, in the broadest sense, *as an aggregate of agential relationships*.

In early Chapters I defined agency as the capacity of materials (related to their ontological meaning), within a particular network context, to 'overstep their limits'. That is, in ANT terms, to depunctualise strongly embedded actors[91]. Informed by the definition of material facets and a description of their application I have tried to show how making-practice can recombine and reapply materials to effect this kind of agency. The understanding of this kind of intervention *as an ecological contribution* as well as a way of constructing knowledge substantively affects this process insofar as the mode of practice, that is the attitude of makers is (potentially at least) affected. This argument was begun in Chapter 2 and Chapter 3 but in this final chapter, I will assimilate a series of points, raised separately throughout this thesis to offer some specific ways that this mode of practice might manifest itself *in methodology*. Before doing so, though, I will explore in more detail some of the philosophical precedent for a particular notion of *mode* or attitude, providing background justification for the claims to appropriate methodology which will follow.

6.4 Ecological Attitudes: The Experience of Research

I have claimed that the understanding of a materially-informed practice-based intervention as an ecological engagement motivates a particular kind of attitude in the practitioner. I would, in fact, go further and suggest that this notion of ecological engagement is highly commensurable with a making-practice which seeks to embody a critical response to contemporary technology, to be *for* and *with* it as discussed. Over the next paragraphs, I will discuss a number of precedential approaches to the relationship between making-practice, and ecological role. In doing so I will show how this relationship has been conceived of in *political, ethical and aesthetic* terms. Building on these points will allow me, in the following section, to discuss their implications for methodology.

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[91] Although this relationship of agency and punctualisation might be considered canonical ANT (such as Callon, 1991; Law, 1992; Latour,1987), I restate, that my contribution is in attempting to reconcile this position with attitudes to the ontological foundation of meaning found in some speculative realist philosophy (Meillassoux, 2010) and in (Heidegger, 1927; 1996 [1927]).

In Dewey (2005 [1934]) and in his interpretation by (McCarthy and Wright 2004), fulfilling and authentic engagement with art or technology is derived through aesthetic continuity, through experiencing artworks (or technologies) as related to past experiences. It is ecological inasmuch as the past experience of things necessarily contextualizes them in accordance to their past relations. We experience a work of joinery, for instance, with knowledge of carving and craft tradition which is, in turn, contextualized in terms of the particular situations in which it occurs, for example as part of religious practice as with Shaker furniture. Dewey also points out that to make, is to attempt to fit future experiences (2005 [1934], p. 54). The ecological aspect of Dewey's work is consequently future-oriented. For Dewey, aesthetics is a connecting factor which unites both the practice of making and the materials involved in a connected whole.

In a different context, Dewey (1991 [1927]), in describing the essence of a public, noted that public action is spurred by a recognition that connections have been formed between people beyond those originally involved. In this sense our behavior (including our practice of work) is implicated with notions of responsibility for its consequences.

"When [...] consequences are intellectually and emotionally appreciated, a shared interest is generated and the nature of the interconnected behaviour is thereby transformed." (Dewey, 1991 [1927], p. 27)

Dewey was speaking very specifically about a kind of reaction to the unintended consequences of actions in human communities but an ecological perspective to making suggests regarding such an "appreciation of consequences" (Dewey, 1991 [1927], p. 27) in broader terms. To see an ecology as a 'shared interest', as a 'public', is to care about what happens in it, to see it as a mesh of things in which one is actively involved. To make in such a context is to take responsibility for an intervention in the production of meaning. As I suggested, this notion of

responsibility seems more than appropriate for a practice which is engaged in a material investigation of the historical and contemporary action of technology.

Heidegger's suggestion, meanwhile, is that an authentic relationship with technology, is to be achieved through avoiding the "enframement" of nature (Heidegger, 1954, p. 9). This enframement can be described as a 'cutting off' or diversion of nature's energetic potential, what Heidegger calls a "setting upon" (1954, p. 12) or a "challenging forth" (1954, p. 7):

"…the sun's warmth is challenged forth for heat, which in turn is ordered to deliver steam whose pressure turns the wheels that keep a factory running." (Heidegger, 1954, p. 7)

For Heidegger, engagement with technology, in ecological terms, is fraught with ethical problems. It frequently implies an inauthenticity of encounter to the extent where it conceals fundamental "truths"[92]. (Heidegger, 1954, p. 15). The ethical implication of designing for materiality is to decentralize human beings from a privileged moral superiority. This ethical aspect is exacerbated by the fact that art and design are not theories or objects but *practices* intended to produce action in the world. They embody and promote the ethical values with which they are made. Values are implicit in the production and deployment of objects which reify particular cultural standpoints. Although I have repeatedly asserted that things are not 'representations' or 'expressions' of social or cultural forces, they nonetheless interact in, and are products of, ecologies alongside people. and their relationships with those people are drawn together in what Bennet (after Dewey 2005 [1934]) has called political ecologies. There is therefore an inescapably ethical dimension

[92] This, Heidegger relates to an interruption of *poiēsis* the transformational coming into being of things from a state of primordiality (1954, p. 18). Full discussion of this cannot be offered here so I restrict my remarks to acknowledging the positive but risky processes of *techne* as they appeared for Heidegger.

to making. Dourish and Bell note (2011, p. 166) for instance how the meme of the smart house implicitly promotes an artificial norm of a large, modern American-style house with a married, white, heterosexual couple with two kids living in it. Such visions have been critiqued for being both androcentric (Berg, 1999) and ignoring cultural difference (Lee & Šabanović, 2013). This norm becomes part of an on-going design practice, an ecology in fact. This practice in turn seeks to design for an ideal rather than with notions of materiality in mind. Dourish and Bell point out that it is exactly the questions of material infrastructure that derail such idealism. In the example of the smart house, this infrastructural problem is in the messiness, expense and specificity involved in trying to retro fit smart technologies on to 100 year old British housing stock. They observe that smart home projects frequently embody "visions of domestic life that celebrated technology and its transformative power at the expense of home as a lived and living practice" (Dourish & Bell, 2011, p. 166). I add that it seems ironic in the extreme that by being un-adaptable to other housing typologies, these projects fail even to fulfil their own visions of the "transformative power of technology". At work is a kind of fetishized technological ideal which I connect to design practices which are disconnected from making relationships with materiality.

I have also suggested that an ecological engagement with materials implies a view of making as a combination of existing meanings with a view to their future orientation. This idea is also suggested by Heidegger.

"Technē […] reveals whatever does not bring itself forth and does not yet lie here before us, whatever can look and turn out now one way and now another. Whoever builds a house or a ship or forges a sacrificial chalice reveals what is to be brought forth" (Heidegger, 1954, p. 6)

Heidegger, however, claims that 'modern' technology 'challenges' this process of revealing by unnaturally forcing nature into new configurations. I have some sympathy for Heidegger's, admittedly romantic, ideals of connection to nature

through craft (Heidegger, 1954, p. 8) but recognize that to realize them would take a fundamental reorientation of the world's economy. What is perhaps most valuable about Heidegger's approach is first his recognition of the role for *techne* as a privileged kind of engagement with our environment, and added to this, his exposition of this process as having potential to damage that relationship in fundamental ways. In summary, a making-practice, particularly one involved with contemporary technologies, is already fundamentally involved with a challenging of the natural world.

The preceding paragraphs have provided a background summary of literature which describes a series of attitudinal considerations for making. In all of them, I have suggested ways in which they resonate with ecological ideas, or indeed, reference them more or less explicitly. The stated purpose of this thesis though is to provide a useful resource for creative technologically-engaged practice in art and design and consequently a discussion of some methodological implications seems appropriate. As with the applications of the five facets of materiality identified, the discussion in the following section is not to be considered exhaustive but rather, following the features of ecologies identified as helpful (i.e. as emergently organized, messy, navigable) and the literature review undertaken in Chapter 3, to provide a number of productive points of interest.

6.5 Methods of Experiential Ecologies: The Research Process

I have said that the aim of this section is to take a number of concerns developed from both literature review and some of the attitudinal concerns discussed above and consider their implications for methodology. Chapter 3 found that much previous research (including Bentley, et al., 1992; Heath & Luff, 1991; Pycock & Bowers, 1996; Sharrock & Anderson, 1993 and Suchman, 2007) discussing notions of the ecology was concerned, in different ways, with avoiding Cartesian dualisms between mind and body, between subject and object. This objective was approached in different ways from social, cognitive, and systems-oriented (as in cybernetics) perspectives with varying degrees of correspondence or tension between these. A key finding from this research though was that much of this

previous research, thanks to its disciplinary position, described particular professional arrangements of work and the consideration here of a different kind of practice motivates new methodologies. Particularly, I have described how ethnographic research such (Bentley, et al., 1992; Heath & Luff, 1991) was positioned in an era and context where ethnographers and sociologists were professionally distinct from the software engineers who would be asked to implement their recommendations. There was consequently a formal separation between research, design recommendations and software engineering. Over the past chapters I have outlined a particular mode of practice which integrates the three. Crabtree *et al*. (2009) present a strongly-worded critique of methodologies which effectively mix ethnographic techniques and humanities-inspired notions of critique that is "theoretically generated statements about the social and cultural world" (Crabtree, Rodden, Tolmie, & Button, 2009, p. 886), for example in their discussion of (Bell & Dourish, 2006). To be explicit; this is not what I propose. Instead, I sympathise with much of the rich background informing the ethnomethodological studies of the era, and in particular the view of the world informing descriptions of situated action (Suchman, 2007) whose emphasis on an active, contingent, sense-making engagement with the world has rapport with my understanding of critical making-practice, with my definition of ecologies (given above) and with the definitions of agency and affordance developed throughout this thesis. Given the positive motivations for considering ecologies in the context of the practice described in this thesis, which build on findings in Chapter 3, it seems congruent to explore their implications for research methodology.

Some precedent for such an approach may be found with Tim Ingold who provides some excellent examples of the interaction between materiality and making. I identify strongly with Ingold's position but outline significant contributions beyond it, which are described below. Ingold implies, in his descriptions of the interaction between materiality and making, *ecological aspects*, not least through his evocation of Heidegger's (1971) "things" (Ingold, 2013, p. 85) and their etymological connection with 'gatherings' or 'meetings'. However, the close

relationship between making and specific features of materiality, *together* with their ecological implications is not explicit in this work. Ingold (2012) is at pains to describe ecologies which emphasise the 'thingness' of non-humans and in particular their definition of "gatherings of materials in movement, as distinct from objects" (Ingold, 2012, p. 439) but does not provide specific indication as to how one *makes* with them. For instance in (Ingold, 2013, pp. 47-59) he provides an excoriating critique of the failures of architects to design understand that;

"…buildings are part of the world, and the world will not stop still but ceaselessly unfolds along its innumerable paths of growth, decay and regeneration…" (Ingold, 2013, p. 48)

However after a lengthy and rich description of how Renaissance craftsman distinguished themselves from the architects of day by their specific, materially engaged, making-practices he does not return to the original problem, offering little way forward. In that sense Ingold has two halves of the puzzle. On the one side he provides a description of how some making-practices react to materiality. On the other, a sense of how materiality can be considered part of an ecology. What I add is specific approaches to materiality which bridge the gap between those two halves by building on the points made in the previous section.

I identify with Ingold in agreeing that making, as an activity undertaken with a materialist perspective should approach the future users of a thing *through an engagement with that thing's thingness*. This may be an awkward construction, but with it I indicate the following. Through a careful attention to the ecologies in which things are constituted, and in particular their historical and future oriented aspects designers may avoid making well-meaning but hylomorphic practices. Any design practice which is founded principally on verbal discourse is, as I have already suggested, doomed to attempt to *express* ideas produced in material form. This fundamentally mischaracterizes the making-process. To reiterate, making should not be understood as a process of 'realizing' an idea. Rather, ideas are realized

throughout processes and in continuation with past experiences. They are extended through physical making and do not exist in 'dialogue' but in coextension. That is to say, ideas and making are not just inseparable but are mutually constitutive. This characterization has much in common with Donald Schön's notion of the "reflective practitioner" (Schön, 1995). Schön's detailed description of the design processes of architecture students (1995, pp. 79-92) is a telling example of the way that the process of design develops with and responds to the constraints and demands of the material world.

My criticism of Ingold's work, as I have said, is that he does not reflect in sufficient detail on the nature of making with materiality as part of an ecology[93]. I posit their integration as necessary given the ecological considerations which I have highlighted as a consequence of particular implications of making with materiality[94]. Perhaps more vitally I am able to offer a significant contribution by integrating Ingold's concepts with other ecological ideas in *an integrated theoretical and technical account of making with contemporary technology*. I argue that the rich technical detail provided in this thesis develops a particular ecological sensibility which would not be possible without it. At the beginning of this chapter, I foregrounded the rich diversity of materials as part of my sense of what an ecology is. In this context the technical engagement described is fundamental to developing that sensibility. Over the following paragraphs I will discuss the impact of ecological ideas on methodology during the making of an artwork and ask to what extent these were already implicit in the making-process. Particularly I will focus on the sense of an exploratory engagement whose navigation is informed by not only developing technical skills but a particular sense of *political, ethical* and *aesthetic* ecological contribution.

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[93] This criticism may be unwarranted since he makes no claim to reconcile these things.

[94] For instance, in Chapter Two, affordance was related to Suchman's description of "*the contingency of action on a complex world of objects, artifacts, and other actors, located in space and time*" (Suchman, 2007, p. 177).

Ingold's description of ecologies as comprising *"gatherings of materials in movement"* (2012, p. 439) provides a useful starting point for describing the making of *Refractive Index* (henceforth *RI*) in ecological terms[95]. If *RI* is a "gathering of materials", (2012, p. 439) what materials are gathered, what is the various stuff from which our ecology is composed and how? *RI* is discussed throughout the following paragraphs because, of all the creative work undertaken, it provides the clearest example of an ecology related to the facets developed. The diversity of sites, technologies, architectures and creative interventions provide a rich grounding for the discussion.

I have previously suggested that to make with materiality is to acknowledge that meaning is already embodied in materiality and one's role as a maker is, effectively, to reconfigure it. The project itself had a number of sites of infrastructure which presented an array of materials each with their own features. Perhaps most important was the BBC infrastructure comprising of the screen itself and the hardware which supported it {Figure 27}, a video mixer, the CCTV camera control, and the BBC-owned PC which ran our software. Allen describes his intention to draw attention to the architecture surrounding the displays (Allen, 2012). The piece is intended to "mark[…] the physical effect that public media displays have" (Allen, 2012). In my terms, the city architecture surrounding the screen, as well as the screen itself, is conceived of as part of the ecology of the piece.

During the development of *RI* much prototyping work was carried out in situ, in the control rooms for the screens in adjacent buildings. The project became, at times, a (near) live coding exercise as we operated as a team with on-the-ground team members feeding back 'on-the-ground' details about the effects of the light on city

[95] As a coder on the project, I can only offer my own theorization of its aims and effects. Ecological approaches to the project are my own original work. Where ideas are influenced by Allen himself, I will attribute them in text.

architecture. Materials were gathered as the aims and needs of the project brought together a collection of technologies. As the project evolved, as ideas unfolded, materials were brought forward into play or were reduced in importance. The ecology of making this work was an integration of practical coding, tweaking camera angles and screen performance, and feedback between artists.

With the above materials gathered together, we worked within the confines of what was available. The screens had a set resolution and refresh rate. Their gain could be adjusted to make them brighter. In some sites, the project team corresponded with city authorities to extinguish all surrounding streetlights. Many phases of iterative testing were carried out on one particular screen site. The power of the PC running our software was assessed by trial and error with more demanding computation sacrificed at times for speed. The colour profile of the screens too, became a subject of conversation, design, and experimentation as we trialed the effects of different hues or luminances. All of these elements were both points of orientation and potential sites of intervention. In ANT terms some of these might be described as the punctualised black boxes against which actors might be aligned and deployed. The (semi-obsolete) systems graphics cards for instance shaped almost every aspect of our intervention by restricting or defining the kinds of action which could be carried out through the screen infrastructure. In this sense the ecology expresses a kind of *micro-politics*. There were actors in this network (such as the graphics cards) whose state of punctualisation positioned them as Callon's authors (1991, pp. 140-2). They were able to put other actors in play through their capacity to "combine, mix, […] degrade, compute" (1991, p. 141). In this way, an understanding of ecologies as political, inflects an ecological engagement with them. In our case, we adapted our working methods to work in concert with existing points of punctualisation or at times to attempt to conflict with them. For instance, in debugging programmes on site, I would frequently seek to cause the graphics card to produce an error and by doing so hope to get closer to the source of the bug. In essence I was co-opting the frustrating intractability of the hardware to produce the kind of action I was trying to achieve.

These infrastructural components also embodied meaning and the perception of such meanings as potential sites for engagement was key to an understanding of our intervention as ecological in terms of the *navigability* of the ecology. As a media artist, designer and coder, I engaged with these material elements with a techno-historical perspective, informed by methodologies from media archaeology. channel[96] colour and was responsible for sensitizing me to the notion of digital colour as a techno-historical entitity. This kind of sensitivity is perhaps what Ingold might describe as “foresight” (Ingold, 2013, pp. 66, 69-72) as discussed in Chapter 4. This background afforded particular kinds of encounter with materials in the ecological. For instance, my understanding of colour, has been developed by

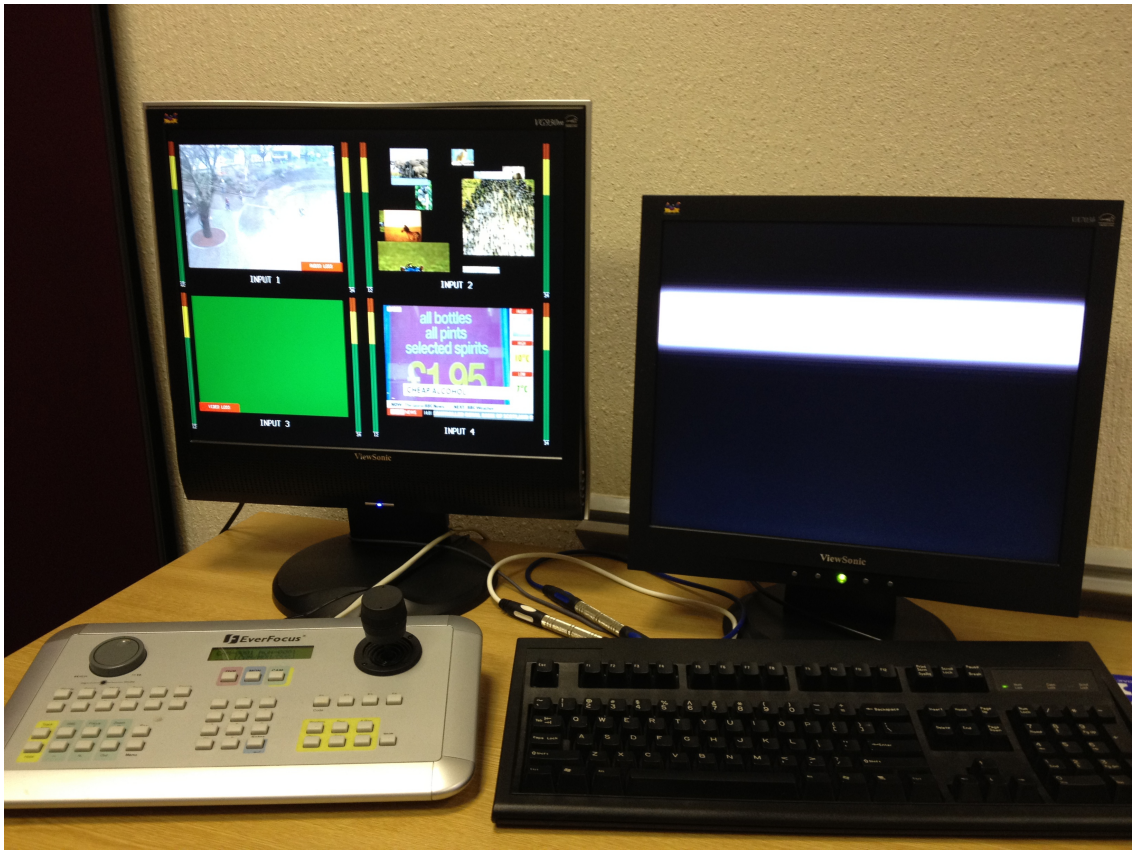

Figure 27: The Control Panel for a BBC Big Screen

[96] 8 bits-per-channel (24 bit ‘true colour’) means that each channel (red, green, blue) has a possible value of 0-255 making a total of 16777216 possible colours.

both experience of programming graphics and from an interest in what Erkki Huhtamo calls “screenology” (2004), a techno historical study of the origin and development of the screen through proto-cinematic devices, to film, to analogue TV and thence to computer graphics. A full discussion of screenology is beyond the scope of this thesis but it is mentioned as relevant here because of its implications for the navigability of ecologies of (screen) material. Essentially my capacity to ‘navigate’ the features of technical colour in the ecology around *RI* was afforded by an integrated technical and cultural understanding of what colour is. In the context of *RI* this knowledge provided not only technical insight but a way of contextualizing our work in the history of computer graphics and display technology. The methodological implication of an ecological description for our activities in terms of navigability described above therefore seems congruent with approaches found in media archaeology. A media archaeological approach focusing on the historical behavior of particular technologies I suggest has the potential to develop the kind of “foresight” (Ingold, 2013, pp. 66, 69-72) into the performance of technologies valued by Ingold. Such a methodology is also a good compliment to Dewey’s description of aesthetics and experience (2005 [1934]). The contextualization of current practice as part of a history of making found in media archaeology is not only a practical benefit but, as described, situates practice in relationship to that history. It is consequently proposed as particularly appropriate for a critical making-practice which is actually *about* the current and future development of that history.

The preceding paragraphs have outlined a number of suggested congruences between ecological theories and experimental making methodology. I have suggested, in summary, that media archaeological approaches have much to offer the practitioner working within such ecologies and have outlined a number of theoretical considerations to support this. The development of the five facets of materiality through the earlier part of this thesis are intended to nuance a media archaeological approach by suggesting specific features of technological material with which to engage. Before offering some final thoughts around future work, in

the next section I will discuss some checks and balances to the proposals offered up to now.

6.6 Checks and Balances

6.6.1 Away from Naïve Holism and Naïve Materialism

A reasonable objection to the idea of ecologies may be articulated thus: How is the notion of an ecology, which emphasises local phenomena, agents in action, alliances and so forth distinct from a kind of 'naïve holism'? With the term 'naïve holism' I mean a vague intuition that things happen contextually, that things affect each other, that in essence, everything is 'connected'". A similarly 'naïve' materialism could be described as the view in which un-nuanced physical causality is posited in terms of mechanistic agency. That is to say where physics is substituted for culture. (Drucker 2013) describes such a view as 'literal materiality' and criticises its inability to provide a basis for any kind of discursive account of how humans interact with materials.

To counter accusations of naïve holism we can first look to other ecological accounts: We have already seen how other kinds of ecology have been useful in providing new approaches to understanding the distribution of cognition and the organisation of tasks (Hutchins, 1995; Sharrock & Anderson, 1993). Other authors have noted implicit ecological aspects to aesthetic experience of art or technology (Dewey, 2005 [1934]; McCarthy & Wright, 2004). Still others offer insight into the way that ecologies are brought together and regulate themselves, (Dewey, 1991 [1927]; Bennet, 2010).

What differentiates my account of ecologies from both accusations of 'naïve holism' and from the previous authors' accounts is embodied in the integration of technical details of creative making-practice and the theoretical concerns described. Through the development of the five facets of materiality I have described specific ways in which various human and technological actors interact in ecologies of making. For instance, the description of the making process of *Refractive Index* above highlighted the combination of the specific understanding of

colour which I have developed through programming experience with the development of programmes for big screen hardware in the context of the aims of the project. I propose that is through exactly through this kind of rich detail that naïve generalities about ecologies can be avoided.

6.6.2 User Centredness

I have claimed that design methods based on interpretation and verbal discourse risk reifying a hylomorphic tendency. I have described the difficulty in 'applying' ideas in practice through materials, as a 'square peg, round hole' problem. The risk, though, is that a practice founded so strongly in materiality disregards the end-users of designed technologies or audiences of artworks. I suggest though that experiential ecologies offer some counter to that risk. I have described how Dewey's notion of "appreciation of consequences" (Dewey, 1991 [1927], p. 27) points to an understanding of ecological responsibility. It is an acknowledgment that making, as part of an ecology, when viewed as a 'public', has resonances to others. An engagement with historical practice, to some degree at least, provides clues for future work in approaching this problem.

Perhaps though, it is at exactly the point at where such 'clues for future work' prove unreliable that an art and design practice such as the one described here can prove useful. I claimed, at the beginning of this thesis, that this practice was 'for and with' contemporary technology in that I use non-linear design technologies in the form of programming and electronics (with) in order to create critical objects positioned to query the role of technology (for) in our lives and the lives of others. It may be that the lack of user-centredness to this approach affords a particular kind of creative freedom, as McCarthy and Wright have suggested (2004, p. 42). Materiality and experiential ecologies are not posited as a one-size-fits-all solution to all design practices. They provide a solid foundation for embodying critical action.

6.7 Future Work

Over the preceding chapters I have approached materiality and ecologies from my perspective as an artist and designer. My professional experience has encouraged

me to pursue a particular kind of interaction with the world, that is, through making artefacts and I have tried to describe this practice openly and with an analysis that will provide insight for others. Through the research undertaken, I have encountered a number of benefits. The study of materiality has allowed me to be productive, to follow new lines of work and to connect what I do with other practices and theories. It has also changed my relationship with many everyday technological practices outside my work, for example in the way that I use my smartphone. It has made me feel a tighter sense of continuity between my life and work. The value it has had for me is in line with Dewey's description of the mechanic who is 'in tune' with the engine on which he is working (2005 [1934], p. 4). It is the sense of fulfilment which comes from a deep engagement in one's practice. Part of the essence of this practice is to consider the way that one's making enters an ecology of other things with which it interacts. It is therefore a design practice which attempts to go beyond the 'next larger context' (Greenfield, 2006, p. 164).

6.7.1 The Characteristic Work Being Done

The practice-based research described in this thesis can be summarised as follows. A critically-engaged, creative making-practice has been described which takes techno-historical engagement with technology, nuanced by specific approaches to materiality, to produce artefacts of art and design which embody a critical response to contemporary technology. As has been repeated, they are *for* contemporary technology in contributing to an on-going understanding of what it can and should be, and *with* technology in the sense that they use technology in a flexible and creative way through programming, building and electronics. Over the next paragraphs I will describe some implications of this practice as it relates to the field of technological research and development more broadly, and position it briefly in comparison to other work with a view to possible future correspondences.

6.7.2 The Future

A question implicit in the claim that this practice is *for* technology is: To what degree are the specific implications from these works of art and design, 'results' for the development of technology, in industry for example? For instance, in the case

of *Null By Morse*, is the final intention to feedback into the commercial design of smartphones, for instance by positioning the user experience in terms of “slow technology” (as in (Hallnäs & Redström, 2001))[97]. If so, by what mechanism is this feedback to occur? Are exhibition visitors expected to leave the show with their attitudes permanently altered towards the device in their pocket? Are the object, documentation and research papers intended to influence later works of design?

I have argued consistently throughout this thesis that agential relationships are reliant on the state of the network in which they are situated. In this sense, I resist the inclination to describe the influence of this work as if it were based an abstract transmission of ideas. Its agency will be determined by the alliances that it finds with other congruent work and this will be achieved through particular material channels. Through the publication of research papers and their availability and visibility in search engines. Through the discussion of exhibition artworks in influential online blogs[98] and through the usefulness of code resources which I have made available freely online {see Appendix 2}. With that caveat there are, however, a number of areas where I suggest a distinct application, described in the following paragraphs.

Early in this thesis (1.3) I discussed how the research described was partially motivated by a comparison between my undergraduate and postgraduate education as an artist on one hand and my work within an interdisciplinary research lab on the other. A key criticism was that poor integration between taught theory and practice as well as a lack of developed discussion of research methodologies served students poorly in their development as artists. There are a

[97] I adopted this position here: (Schofield, Null by Morse: historical optical communication to smartphones, 2013).
[98] The inclusion of *Neurotic Armageddon Indicator* on the popular blog *Creative Applications* prompted 10000 views of the video documentation in less than a week. http://www.creativeapplications.net/objects/neurotic-armageddon-indicator-nai-proximity-to-armageddon/.

number of areas in which the findings of this thesis could productively find a place in art pedagogy in undergraduate and postgraduate level.

Becker (1984) describes how artists, particularly from the second half of the 20th Century, have situated their practices within a broader ecology (an art world) in which skills, materials, audiences and markets combine. Professional artists, often, are not only artists. They are educators, graphic designers, architects, illustrators, games designers, workshop leaders and youth development workers. Art practitioners work in different fields and their practice often adjusts to fit as they learn new skills and make a living. The creative work described in this thesis was produced, as I have stressed, within a variety of contexts strongly recalling those described by Becker. Some works were commissioned for galleries, some were submitted for academic conferences, some were the products of collaboration. The product of this was two-fold. Firstly, I acquired a diverse set of technical skills, necessary to produce the commissioned work and support collaborators. Secondly I gained a strong sense of how the variety of financial, technical, material and human factors formed an ecology around the work and this understanding supported both my creativity and my capacity to collaborate and work in different fields across art and design subsequently. I suggest that two interconnected factors afforded this crucial professional development and have implications for fine art pedagogy. First the focus on materials described by media-archaeological research methods strongly encourages the development of skills in response its findings. For instance, the focus on the technological history of the telegraph in Chapter 4 resulted in my learning to develop for mobile platforms and building various control circuits. These were not inevitable outcomes but the close focus on the material specificities of the technologies involved, heavily influenced this approach. Pedagogically therefore, the approach described here, is useful for confronting students with a set of technical and theoretical problems to solve. The engagement with, and resolution of, these supports their professional development in terms of acquiring new skills and competencies and also leads to my second point regarding their development as artists: that is the integration of theory and

practice. I strongly contend that the methods undertaken in the creative work described in this thesis provide a way of teaching combined theory and practice that is both adaptive to student needs and that actually helps students produce work rather than paralysing them as they try and fit theoretical square pegs into practical round holes. Many A-Level, foundation level and undergraduate programmes in Fine Art provide a component of art history intended to ground students' understanding of their work within a historical context, helping them to understand what has come before, how it was inter-related and how it was contextualised by other historical events. Media archaeology does similar work for our techno-cultural heritage and by doing so supplements art historical study by helping students understand how their work is bound, through the development of shared tools, materials and skills to an extended set of creative and technical practices.

In the introduction to this thesis I asserted that this work was intended for practitioners whose work is engaged with building, crafting, constructing, or sculpting conceived of as a contribution to knowledge irreducible to words, working across art and design. In these final remarks I will return to this point and describe implications for specific communities. In particular I will discuss the application of this work in future research within Critical Design, Interaction Design more generally, ethnographic approaches within HCI and within media art.

There are many ways in which the research aims of the works described here could be described as 'Critical Design' as described by Anthony Dunne and Fiona Raby, (Dunne, 1999; Dunne & Raby, 2001; 2013). Critical design aims "to make us think. But also raising [sic] awareness, exposing assumptions, provoking action, sparking debate, even entertaining in an intellectual sort of way, like literature or film" (Dunne & Raby, 2013) with the purpose of subverting design culture. Dunne and Raby are insistent that proximity to everyday life, particularly in the form of designed products, distances Critical Design from art. I have avoided describing work in this thesis as Critical Design for this reason. The distinction made between

art and design by Dunne and Raby, I find to be both ahistorical and placing unfortunate demands on Critical Design itself (to generate a series of artificial distinctions between the two), a position also adopted by (Bardzell & Bardzell, 2013). Following (Latour, 2004) I also question the productiveness of Dunne and Raby's approach and ask what truths they expect to uncover behind our "assumptions" (Dunne & Raby, 2013). Critical Design as described in (Dunne & Raby, 2013) is ahistorical firstly because it implicitly ignores a generation of 1960s art practices which were concerned with exactly the combination of art and life (for instance as described in (Kaprow, 2003)), often using comparable techniques of satire, absurdity and provocation. The practice described here finds commonality with the aims of Critical Design described above but hopes to answer Bardzell and Bardzell (2013) by introducing the approaches described through this thesis to Critical Design methodology, emphasising material engagement and media archaeological enquiry. These latter, I argue are one thing which could be 'critical' about Critical Design. This thesis shares an interest with Critical Design in the role that made objects can play in articulating technological futures. It is, as I have said, *for* technology as well as *with* it. Bardzell and Bardzell (2013) articulate a critical vision for Critical Design which leans heavily on a critical tradition from the humanities and literature in particular, including influences from the Frankfurt School (p. 3298) and postmodernism (pp. 3301-3302). Their proposal, effectively, is to draw established critical strategies such as dialectics (p. 3301) from the humanities and apply them to design criticism. There is certainly valuable potential in this approach but with it comes a risk that the artefact becomes merely something to talk around, to be interpreted after the fact. If Critical Design has value, then its criticality must also be wound into the process of making, of designing. I propose that the framework of materiality articulated in this thesis could provide a useful counterpart to the literary criticality proposed by Bardzell and Bardzell (2013) by situating the design process in relation to other, older techniques, materials and theories in the specific and contingent circumstances of making creative work. As much as anything, the framework describes an

orientation towards exploring this particular kind of situatedness and this, I suggest, represents a positive direction for Critical Design in the future.

In Chapter Two I discussed an on-going interest in the Interaction Design and HCI communities into materiality and craft history (such as in (Robles & Wiberg, 2010); (Wiberg, 2013)). This thesis identifies with this orientation and attempts to nuance some of the approaches already adopted with a more rigorous conceptualisation of materiality itself according to the facets described. Although craft is of interest within Interaction Design, there is significant inconsistency regarding how the lessons we learn from it actually inform design practice. Zoran (2013) for instance is at pains to describe a lengthy engagement with the practices and traditions of Botswanan basket making, seeking to "demonstrate that tradition can be merged into a hybrid, contemporary 'making' practice that respects its double origins" (2013, p. 324). In this work however there is an unfortunate methodological separation between the designer's initial anthropological work and the process of designing an artefact. The designs produced are to some degree formally sensitive to the Botswanan baskets but the process of their making - their 'craft' - owes little to the older of its two "origins". My criticism of Zoran's work[99] is that his genuine engagement with the traditions of basket making in Botswana is not truly integrated into his designs except as an initial inspiration. His baskets are reflections of the formal qualities of craft, not an engagement with its practices and history. By contrast the framework introduced in this thesis offers a way of more tightly considering the relationship between traditional craft materials and contemporary technologies. For instance, applied to Zoran's work, performative materiality would encourage a focus on the particular performative action of the palm leaves which are the primary basket-making material. One might enquire for instance how their properties of tensile strength, fibrousness or roughness afford particular kinds of relationships to be made with other materials. Continuing, one could examine how

[99] I in no way wish to denigrate the obvious creativity of Zoran's work. His work makes significant steps towards integrating traditional craft and 3D printing. My criticism is that his methodology is not entirely consistent with his stated aims.

these properties have positioned the material with respect to their enduring use in Botswana and crucially, compare this to the 3D printing materials Zoran employs in his generative baskets. This brief example is intended to illustrate some of the ways that the material framework described here might facilitate a more genuine methodological relationship between contemporary computational technologies and traditional craft. In summary, materiality and the methods from media archaeology described give a way of experimenting with a wider range of cultural, historical and technical factors in the making of crafted objects. Crucially it promotes an experimental position, supported by a guiding framework, towards the agency and performance of made things, a position which, surely, is strongly compatible with the aims of Interaction Design.

Earlier in this thesis I noted the comparison between the practice described here and the professional organisation of work described in early ethnographic studies of workplaces including air traffic control centres (Bentley, et al., 1992; Sommerville, Tom, Pete, & Bentley, 1992) and offices (Sharrock & Anderson, 1993). Motivated by the significant contributions of this latter work into theorising our ecological relationship with technological environments, and the empirical (though not objective) orientation of this thesis, future work should more closely examine methods from this work and ask if, and how they might be adopted, adapted or transposed into the very different combination of making and research described here.

Much discussion of media art in the context of HCI focuses on the experience of finished work. Lessons are drawn for public interaction e.g. (Reeves, Benford, O'Malley, & Fraser, 2005; Taylor, Schofield, Shearer, Wright, Boulanger, & Olivier, 2014), for the experience of live events e.g. (Hook, McCarthy, Wright, & Olivier, 2013) or, as discussed, for reflecting on visualisation (Jacobs, Benford, Selby, Golembewski, Price, & Giannachi, 2013). Despite this interest, there is comparatively little work which explores the *process* of art making to inform HCI rather than focusing solely on its products, perhaps because this is simply very

difficult to do, particularly in a way which is specific enough to be a genunie account of the process, but generalisable enough to be of use to others. There is however a clear interest in such processes as evinced by the frequent citation of Ingold's (2007; 2013) work in HCI publications, e.g. by (Benford, 2010; Pink, et al., 2013; Crivellaro, Comber, Bowers, Wright, & Olivier, 2014). As was discussed in relation to Critical Design, the framework of Materiality proposed here provides a way of analysing and describing making processes as well as guiding them. This thesis informs the production of media art work by providing some guiding principals. However, this also has the side effect of providing the kind of on-site analysis of the *production* of artwork which HCI has found productive in studying its *outcomes*.

More generally, future work should examine the relationship of this research to other possible communities both in design and outside. Perhaps its chief value is in public engagement[100], or as tools for advocacy as with some visualization work (such as Calvillo, 2008). The potential of the framework of five-facets of materiality should also be considered in the light of on-going and upcoming paradigms of technology. (Drucker, 2013) has already attempted to apply material thinking to interface design and a number of other areas immediately suggest themselves: The growing discussion around "digital personhood" (for instance in (Wallace, McCarthy, Wright, & Olivier, 2013)) for instance through its focus on our personal relationships to digital objects seems a relevant test ground for the approaches described here. Similarly the increasing realisation of the so-called "Internet of Things" (Atzori, Iera, & Morabito, 2010) from cultural technical vision (as in Weiser, 1991; Weiser & Brown, 1996), to hobbyist appropriation (for instance in the many projects described on Instructables, 2014) to increasing commercialisation for instance with programmable lights (Phillips, 2014) and sockets (Belkin International

[100] As in the project Material Beliefs (Goldsmiths, 2013) wherein Critical Designers entered bio-science laboratories and used their design responses to engage publics via exhibitions.

Inc., 2014) could usefully be considered from an integrated materialist and ecological perspective.

The work produced here is proposed as situated in dynamic ecologies. It is intended to play an active role in them not through intrinsic worth but through the things it does, through putting people in new listening relationships to their environment (*The Quiet Walk*), or remaking people's smartphones as telegraph receiving devices (*Null by Morse*), through repurposing urban displays as re-modellers of architectural space (*Refractive Index*), or damaging gallery walls as an extension of the material history of counting (*Mark Inscriber*). As I have said the definition of experiential ecologies has been arrived post-creation of these works. The process of making new works, contextualised by this idea, is for the future.

Chapter 7. Works Cited

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Chapter 8. Appendix

Appendices 1: Documentation and 2: Git code repository may be found on the accompanying DVD.