THINKING OUTSIDE THE BLACK BOX: THE APPARATUS BETWEEN ART AND SCIENCE

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Abstract

In the dominant mode of art discourse the apparatus features as a blind spot. It is most often treated as an indexical trace of the image, as a readable text or conversely an unreadable formal gesture. This practice-led research draws on conceptions of the apparatus developed in the philosophy of science and technology. In doing so, it offers a new approach to understanding the apparatus in practice by foregrounding the material presence of technologies, their 'performative agency' and the perceptual dimensions of spectatorship.

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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

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> Apparatus (pl. -es): a plaything or game that simulates thought [trans. An overarching term for a non-human agency, e.g. the camera, the computer and the 'apparatus' of the State or of the market]; organization or system that enables something to function.
>
> Vilém Flusser, *Towards a Philosophy of Photography*, 83

Introduction

This practice-led research interrogates my studio-based engagement in terms of a performative, creative engagement with apparatuses. My discussion of the apparatus considers a range of conceptions and constructions of the apparatus from outside artistic discourse. Starting with Vilém Flusser's transdisciplinary definition of the apparatus, this research considers embodied, transformational and translational accounts of the apparatus drawn from philosophies of science and technology. In addition, the discussion involves an historical account of apparatuses that crosses the disciplinary boundaries between art and science. The apparatus is positioned as a liminal object between these disciplines. The theoretical and historical aspects of the research are both informed by, and inform the creative outcomes. The project comprises creative works (weighted 50%) and a written exegesis (weighted 50%). The result is a hybrid model for engaging with the apparatus.

Background to the Practice

This research project emerged from my interdisciplinary contemporary arts practice, which involves making, modifying and repurposing technologies in a low-tech, DIY manner. The ambition of my practice is to bring the audience face to face with the apparatus, or immerse the spectator within its workings. This involves a performative viewing experience, in which audience members engage with the apparatus in order to experience its operations. Studio and gallery spaces thus become laboratories of perceptual affect. By intervening in the operations of apparatuses, I deconstruct and reimagine the processes by which experiences are mediated or generated.

This practice-based engagement with the apparatus responds to conceptual, material, discursive, historical, processual and perceptual dimensions of these technologies. More broadly, my artworks engage with the historical entanglement of art and science. For instance, it engages with technologies of representation that employ the basic principles of optics or, alternatively, it creates apparatuses, such as the *camera obscura,* which are historically significant in the histories of both disciplines. The work functions as a focal point for these histories and connections; it does not however narrate or explicate such histories. The operations of the apparatus and the processes it is subjected to are not merely means of delivering some other content. Instead, they are essential elements of the works' plural and entangled "contents." The issue under consideration is articulating the intricacies of these entanglements, which operate in between the opposing poles of form and content.

Figure 1: Christopher Handran, *Splitscreen Obscura,* 2013. camera obscura projection, light shade, screens.
Figure 2: Christopher Handran, *Slideshow,* 2012-13. digital video, media player, slide viewers, plastic, enamel paint.

This research seeks to deepen and extend an engagement with the entangled histories of art, science and technology. Motivated by an interest in scientific imaging technologies and their connection to 'lower' technologies of everyday life, this research considered the potential of philosophies of science and technology for developing and articulating this practice-based approach.

Relationship to Previous Research

The current research project builds upon foundations laid in my Master of Arts (Research), entitled *Looking into the Light: Reinventing the Apparatus in Contemporary Art* (2013). This project focused on questions of spectatorship, and sought to develop generative studio methodologies for extending the spectator's experience of the apparatus.

The Masters Research analysed formulations of the apparatus in the work of Vilém Flusser, Michel Foucault, and Cinematic Apparatus Theory. The research considered the construction of optical, embodied and spatial experiences of the apparatus in the work of contemporary artists Carsten Höller, Pipilotti Rist and Olafur Eliasson. Through the development of creative works, I formulated five key strategies to foreground the spectator's experience of the apparatus:

1. Playing against the Apparatus: continuing and extending my deconstructive approach to the apparatus;
2. Replaying the Apparatus: reinterpreting historical examples of apparatuses constructed by artists, such as Brion Gysin's *Dreamachine*;
3. Apparatus and Objecthood: emphasising the physical presence of technology;
4. Face to face with the Apparatus: inviting physical interaction through the construction of stereoscopic viewing devices; and
5. Inside the Apparatus; the construction of installations that immerse the spectator in the workings of an apparatus.

These strategies were developed in order to consider the specific modes of spectatorship constituted by the apparatus. Now integral parts of my studio processes, these strategies recur in the current research, but they extend beyond the question of spectatorship. Instead, I explore an expanded conception of the apparatus in the course of the research drawing upon conceptions of the apparatus from philosophies of science and technology.

Extending into new territory and taking a different approach, this PhD research project builds on two key elements of my Masters research, which provide a foundation for the current research. First, the role of the apparatus is often overlooked or downplayed in our everyday engagement with photography as well as in photographic and art theoretical discourse. It operates as a blind spot within these discourses. As a consequence, questions of visibility, embodied experience and the presence of the apparatus remain central. Secondly, the category of technical images—defined as images produced by means of apparatus (Flusser, 1983)—offers a comprehensive and far-reaching alternative model. This model traverses image categories (such as analogue/digital, still/moving), apparatuses (ranging from photographic to computer), and between disciplines (for example, art and science).

The work of Vilém Flusser remains an important element of the research, but the current research project extends my consideration of his thought into a new context. The current research also benefits from a wealth of recently translated material by Flusser. Drawing on this newly available material, Flusser's thought will be considered in relation to new territories being explored in this research, through my consideration of models of the apparatus drawn from the philosophy of science and technology. This PhD research also builds upon two different meanings of 'apparatus,' which was central to film theory's ideological critique of the apparatus (see Baudry 1974, 1976). While the Master's research dealt with this conception of the apparatus and its connection to spectatorship, these concerns are beyond the scope of this research. The dual nature of the apparatus is therefore treated here as a phenomenological, rather than ideological, relation.

Overlooking the Apparatus

Within art discourse, the experiences produced and mediated by apparatuses are all too often reduced to conceptions of the image as a readable text, or conversely as an unreadable formal gesture. Examples of the former include both semiotic and psychoanalytical analyses, which liken the technical image to a text to be 'read'. I suggest that this restrictive focus constitutes a dual indexation of experience: the logic of photographic indexicality enforces a one-to-one relation between an image and its experience, while the value of that experience is simultaneously indexed to its record. In other words, the image comes to replace both the subject it represents and the apparatus that produces it. While this introduction takes the photographic apparatus as its starting point, the same comparison can be extended to include much discourse around technical images. Consider, for example, the marginalising effect of art historian Rosalind Krauss' characterisation of the apparatus as an "appurtenance" in her discussion of early video art (1986, 184). The persistence of this view is reflected in Krauss' more recent characterisation of the 'heterogeneous apparatus' that confounds efforts to specify a singular material support for moving image artworks (2012, 416). Traditional art-historical conceptions of medium as 'material support' are inadequate for a consideration of the apparatus and the technical images that it produces. Such images are the product of diverse and distributed material supports and technologies, which often operate at some distance from the spectator's direct experience. The convention of medium specificity minimises the role of the apparatus, creating a partial view that reduces the complexity of practice.

In the context of photography, Roland Barthes' interpretive model of the *punctum* offers a paradigmatic example. Without wanting to revisit Barthes' thesis in detail, there are some key points to emphasise here. Barthes draws a key distinction between what he terms 'the Operator's photograph' and the 'Spectator's photograph,' with his own analysis restricted to the latter. In subsequent discourse, Barthes' highly influential formulation of the *punctum* as a small detail that forges a connection between viewer and image (1981, 27) makes that detail seemingly become the image's whole reason for being. This is despite Barthes' own emphasis on the subjective, shifting and inherently unintentional quality of the *punctum*. In this sense, Barthes' account of photography, like many semiotic or indexically oriented paradigms, shifts agency to the spectator/reader. While the spectator's photograph, centred around the *punctum,* takes precedence, the operator's photograph and the apparatus that produces it functions as a *punctum caecum*; a blind spot. Like the physiological blind spot—which forms at the point where the optic nerve meets the eye—the very connection that enables vision also creates a gap within it. The physical occurrence of the blind spot is, in this sense, mirrored in photographic discourse; the apparatus comes to function as a gap within theoretical considerations of the images that it produces.

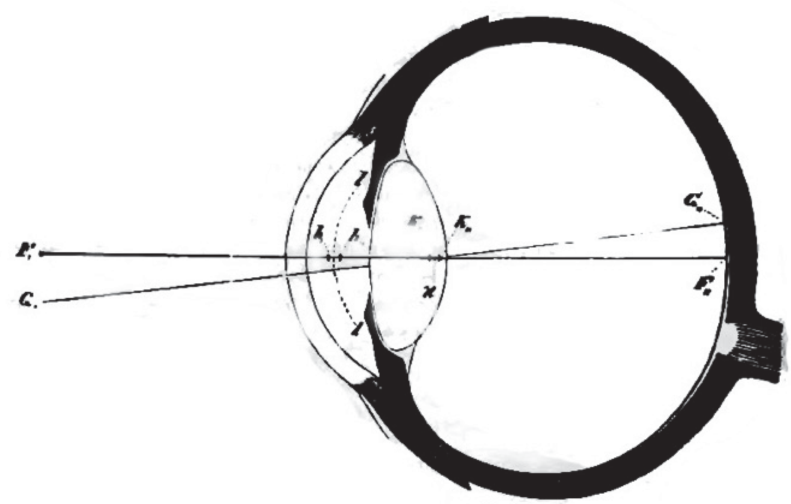


Figure 3: *Optics of the Eye,* showing the optic nerve that creates the blind spot. From Hermann von Helmholtz, 1896, *Handbuch der Physiologischen Optik*. Hamburg: Verlag von Leopold Voss, 90.

Pinpointing the Blind Spot

The late work of Maurice Merleau-Ponty considers the significance of the blind spot for a phenomenology of perception. In the notes for his unfinished book *Visible and Invisible* (1964), he describes the *punctum caecum* as 'the untouchable of the touch, the invisible of vision, the unconscious of consciousness' (1964, 255). The blind spot is not a flaw in vision but its pre-condition; according to Merleau-Ponty, 'every visible is invisible, that perception is imperception, that consciousness has a "*punctum caecum*," that to see is always to see more than one sees' (1964, 247). He goes on to say, 'one has to understand that it is the visibility itself that involves a non-visibility' (1964, 247). In this way, Merleau-Ponty's account of the blind spot foreshadows Barthes' presentation of the punctum as 'what I add to the photograph and *what is nonetheless already there*' (Barthes 1981, 55). In Barthes' schema, the significance of a previously overlooked detail within the image is brought to light through reflection. My question in response is: how might the same be achieved for the apparatus?

How might we think of an image in which the apparatus is foregrounded? What might an image that revealed the blind spot look like? Examples from the familiar territory of photography might be illuminating here. The fledgling photographic industry is recorded in *The Reading Establishment* (1846), a panoramic photograph attributed to William Henry Fox Talbot and Nicholas Henneman. Produced to advertise the assembly-line image production made possible by Talbot's paper process, the image depicts a range of possible subjects (a portrait sitter, etching, and sculpture) and processes (sensitising paper, contact printing and focusing instrumentation). This composite image foregrounds the dual sense of apparatus, highlighted by the two possible French translations of the term employed in 1970's film theory (Baudry 1974). On the one hand, '*appareil*' suggests a physical object or device; on the other, the term '*dispositif*' instead resonates with a view of the apparatus as an arrangement of multiple interacting parts. *The Reading Establishment* therefore represents the developing *dispositif* of the emerging photographic industry, with the *appareil* of the camera at its centre.

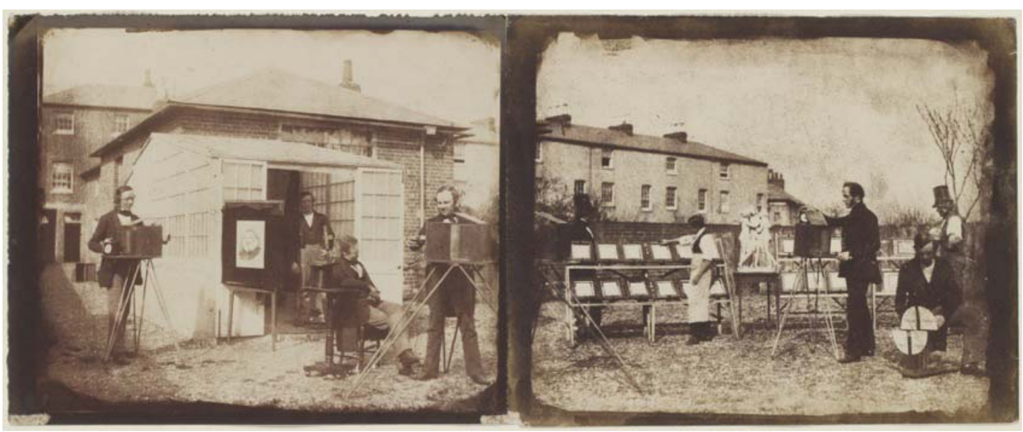


Figure 4: William Henry Fox Talbot and Nicholas Henneman, *The Reading Establishment,* 1846. Salted paper prints from paper negatives, Overall dimensions: 19.9 × 49.1 cm.

These two senses of apparatus come together in the works of Christopher Williams. His series of *Cutaway Models* document cross-sectioned cameras, literally dissecting the *appareil.* They also reveal the interior workings of the photographic 'black box' as an assemblage or *dispositif* of moving parts. Though his images specifically represent the physical interior of the photographic camera, in the context of Williams' practice they sit alongside a range of representations *of* and *by* photography. Together, these images develop a picture of photography as a network of promotional images, models for imitation, demonstrations of ideal conditions for imaging and, of course, equipment. This is a picture of the apparatus grounded within the broader visual culture that it produces.

Figure 5: Christopher Williams, *Cutaway model Zeiss Distagon T* 2.8/15 ZM Focal length: 15mm. Aperture range: 2.8-22. No. of elements/groups: 11/9. Focusing range: 0.3 m - infinity. Image ratio at close range: 1:18. Coverage at close range: 43 cm x 65 cm. Angular field, diag./horiz./vert.: 110/100/77º. Filter: M 72 x 0.75. Weight: 500 g. Length: 86 mm. Product no. black: 30 82016. Serial no.: 15555891. (Subject to change.) Manufactured by Carl Zeiss AG, Camera Lens Division, Oberkochen, Germany Studio Rhein Verlag, Düsseldorf, January 19th, 2013,* 2013. Selenium toned gelatin silver print 40.6 x 50.8 cm.
Figure 6: John Hilliard, *Camera Recording its Own Condition (7 Apertures, 10 Speeds, 2 Mirrors),* 1971.

An example that foregrounds the apparatus as *appareil* is John Hilliard's *Camera Recording its Own Condition (7 Apertures, 10 Speeds, 2 Mirrors)* (1971) — an image that literally turns the gaze of the apparatus on itself. The camera and operator's hand are photographed in a mirror as the apparatus cycles through the various combinations of aperture and shutter speed. However, this exercise in bracketing, in turn, 'brackets out' all but the functional operations of the apparatus. The relationship between apparatus and image becomes a closed circuit and the apparatus *becomes* image.

Steven Pippin's *Point Blank* (2010) consists of a series of photographs that mark the end of analogue photography with a bang. Pippin constructed an instrumental set-up that enabled analogue cameras to record their own destruction, at the moment a bullet breaks open the 'black box'. These are images that record their own creation by an apparatus that reflects its own destruction. Significantly, in this case the experimental destructive setup is exhibited alongside the images. The *appareil* is again situated within a *dispositif*, and both are ‘opened up’ for the inspection of an audience, to some extent avoiding the closed circuit of self-imaging indicated above.

Figure 7: Steven Pippin, *Non Event, 18th May 2010 at midday,* 2010. Install view.
Figure 8: Steven Pippin, *Point Blank,* 2010. Type C photograph.

Despite the fact that each of the above examples foreground the apparatus, they do so by *imaging* it. Instead, the approach I am pursuing is tied to the ambiguities between the apparatus and the images it produces. The later works of Merleau-Ponty again offer useful insights into this discussion. In particular, the dissolution of binary oppositions into intertwining parts is instructive; whether it is the titular *Visible* into *Invisible,* subject into object, eye into mind, or perception into consciousness. In assessing the traditional opposition between mind and body, Merleau-Ponty describes each as ‘the other side’ of the other, that which ‘overflows into it, … encroaches upon it, is hidden in it — and at the same time needs it, terminates in it, is anchored in it’ (1964, 259). It is this intertwining, entangled and co-constitutive character that is central to the relationship between blind spot and vision, and, I suggest, between apparatus and image.

Philosophy of the Black Box: Vilém Flusser

The philosophy of Vilém Flusser provides an important framework for considering the problematic place of the apparatus in relation to the images that it produces. Flusser provides what might be termed a relational model, which reciprocally defines the apparatus in terms of the images it produces and these ‘technical images’ in turn as images produced by means of an apparatus (2000, 85). Importantly for this research, the co-defining terms of apparatus and technical image incorporate a multitude of contemporary imaging practices, including analogue and digital photographs, computer synthesized or generated images, and ranging from snapshot photographs to complex scientific visualization. The apparatus-image correlation therefore cuts across disciplinary boundaries as well as discursive boundaries, such as medium specificity in the context of art. This potential is significant for this practice-led research, which employs a specific range of moving image media in order to consider multiple perspectives on the apparatus. In this sense, the value of Flusser's philosophy lies in its very incompatibility with traditional art historical models. Rather than focusing on individual images, bodies of work or a lineage of practitioners, he 'brackets out' such specific examples in favour of a wide-ranging view of the system in which they operate, and which he refers to as the 'Universe of Technical Images' (2011b). I argued earlier that in much art discourse the apparatus functions as a blind spot, whereas within Flusser's oeuvre the apparatus emerges as a central term.

For Flusser, the apparatus is not a blind spot, but a black box, whose key features are automation and impenetrability (2000; 2011b). Drawn from systems theory, a black box describes an element of a system whose operations are hidden from view, with only its inputs and outputs visible. The impenetrable 'black box' of the apparatus embodies the rational and calculating nature of science and technology. Its operations therefore simulate thought, as distinct from tools and machines, which simulate actions of the body (2000, 83). In the case of imaging apparatuses, which are the specific area of interest for this research, the apparently automatic transformation of phenomena into images by the apparatus constitutes the symbolic function of the apparatus; its purpose is 'not to change the world but to change the meaning of the world' (2011b, 36). By producing technical images, the apparatus 'does not discover meanings, but rather, it gives them' (Flusser 2002, 47). Via this apparently automatic transformation, a sense of autonomy is mistakenly attributed to the subject, which is consequently read as 'true.'

In turn, this model of the apparatus challenges the traditional view of photography as an indexical trace that is 'stencilled directly off the real' (Sontag 1977, 85). In Flusser's model, this focus on photographic indexicality is a case of mistaking symbols for symptoms, a condition that is itself symptomatic of the photographic ‘program’ (Flusser 2012, 195). Photographic and other ‘technical images’ are processed, whether by means of chemistry or computation, and translated from visual phenomena into symbols. Rather than indexical traces, technical images are projections of reality; they ‘must be decoded not as representations of things out in the world but as signposts directed outward. It is their projector, their program, that is the object of criticism’ (Flusser 2011b, 49). Accordingly, an analysis of technical images must focus on their actual ‘production’ rather than on their projected meaning.

The operations of the apparatus are determined by its program; by engaging with apparatuses we become functionaries of that program, part of an ‘apparatus-operator complex’ (2000, 35). While Flusser’s formulation would seem to resonate with dystopian or determinist accounts of technology, this is not entirely the case. Rather, Flusser suggests that the effects of the apparatus are utopian, in both totalitarian and idealistic senses (2011b, 4). Similarly, his earliest writings oppose scientific and technological thought to philosophical reflection, with art occupying an uncomfortable middle ground (2005, 6). Yet, by the time the apparatus emerged as a key term in his thinking, Flusser described science as ‘a game played with symbols,’ perhaps ‘the most entertaining of all games’ (2013b, 42). Indeed, science can be thought of as ‘a special case of fiction’, whose creations are more fantastic than those normally classed as science fiction (2015, 1-2). This is not a complete reversal in Flusser’s thinking; as with his discussion of the apparatus, his position is neither wholly utopian nor determinist. In a late essay, he presents both views – on the one hand, the goal of science is to ‘do away with wonders’ by explaining them, and, conversely, science produces wonders in the face of a world without wonder (2017a, 145, 153).

This dual potentiality is related to Flusser’s distinction between discourse – the transmission of existing information – and dialogue – the production of new information (2011b, 83). The apparatus embodies potential for both the one-way transmission of discourse and the participatory exchange of dialogue. The dominance of the former tends towards control and the latter towards freedom. In Flusser's thinking these are inter-related, rather than purely oppositional terms; each is an aspect of the other (2016, 70). Ideally, 'dialogue nourishes discourse, and discourse provokes dialogue' (2011b, 83). In order to develop a dialogic relation with the apparatus, Flusser entreats us to resist its program, to 'play against [the apparatus] in order to bring to light the tricks within' (2000, 27). This last point resonates with my own practice-based approach to the apparatus. I materially deconstruct and reconstruct apparatuses in order to intervene in their workings. This operates as a form of 'playing against the apparatus,' thus marking the relevance of Flusser's thinking for this research.

In addition to this brief overview of Flusser's oeuvre, his thought is threaded throughout what follows. Although none of the other key theorists whose work I will be discussing directly engage with Flusser's work, there are a number of resonances that are important for this research. Flusser draws on a range of scientific languages, and at multiple levels: from the 'quantic' decision-making process of the photographer (2013b, 101; 2014, 80) and analogies between photographic grains, pixels and particles (2011b, 10), to speculations on the potential of the second law of thermodynamics as a model for art criticism (2002, 51-57). Significantly for this research, these reflections remain grounded in Flusser's phenomenology of the everyday. Quantum physics, for example, is not opposed to, but part of the phenomenological life-world (2002, 89), while the method that characterises modern science is rooted in the everyday gesture of searching (2014, 147-159). Flusser's thought therefore provides an important framework for connecting my own engagement with apparatuses to those explored in the philosophy of science and technology. As I orientate my own thinking through the apparatus, Flusser's interpolation of science as a kind of art ('an intersubjective fiction') and art as a kind of science ('an intersubjective source of knowledge') (1990, 399), provides a valuable framework.

The inter-relationship between the participatory information-producing practices of dialogue, and the authoritative information-transmissions of discourse are also significant for this practice-led research. This relationship is interactive rather than strictly oppositional. This is demonstrated in Flusser's characterisation of science as a discourse composed of dialogues, in contrast to parliamentary debate as a dialogue composed of discourse (2016, 70). I would suggest that art is closer to science in this regard, and that there is a contextual dimension to this. In this model, the artist's studio, like the scientific laboratory, is a space of dialogue - a space in which the artist participates in the production of new information. The art museum is primarily a space of discourse, presenting the dialogically produced work to new audiences. In this sense, the focus of this research is the movement between these modes – between existing conceptions of the apparatus in artistic and scientific discourse, and the dialogic relation to the apparatus within my own practice. Guided by the parameters of my own projects, and informed by the connections that Flusser himself makes to science and technology, this research draws on philosophies of science and technology to develop a hybrid model of the apparatus that better reflects practice-based engagement.

Objectives of the Program of Research

The gap that this research seeks to address is one that is highlighted through creative engagement with the apparatus, and the discord between this practice and much discourse that surrounds it. The parameters of this gap are therefore determined by the practice and in the practice. The research aims to develop a reflexive engagement with the apparatus, which counterbalances the invisibility of the apparatus, while also foregrounding its transformative operations. In many senses, this is therefore a methodological problem, which is addressed by bringing divergent discourses into dialogue with one another.

In drawing on philosophies of science and technology to address this blind spot, the research initiates a cross-disciplinary dialogue that produces new insights into creative practice. While in transit between discourses of science and art, this research also acknowledges its situatedness as an outsider's view of scientific practice. As Irit Rogoff proposes, practice-led research and other 'creative practices of knowledge' involve a process of '"unfitting" bodies of knowledge from their accepted frames, leaving their place within the chain of argumentation and drawing to themselves unexpected companions' (2010, 40). Importantly, for Rogoff this is not a process of colonisation or consumption, but 'a centripetal movement outwards' that involves 'reaching unexpected entities and then drawing them back, mapping them onto the field of perception' (2010, 42). Rather than making a claim on territory, the mapping developed in practice-led research offers a means of making connections between sites.

Rogoff's characterization of practice-led research as a form of 'undisciplining' has parallels in the discourses that this research draws upon. Sociological studies of science, for example, emphasise the productive value of such an outsider's perspective, which is represented by the figure of the 'stranger' in the phenomenological sociology of Alfred Schutz. The stranger does not share the 'ready-made' knowledge or assumptions of the social group under study; this lack of familiarity makes the very act of observation a questioning gesture (Schutz 1976, 95-96). Harry Collins argues to the contrary that sociologists studying science must attempt to gain a deep understanding of the content of scientists' work, and only then must they 'estrange themselves once more so that they can analyze the world from the peculiarly sociological perspective' (2001, 159). Steven Shapin and Simon Schaffer also argue the importance of a deeply engaged analysis, with the researcher *playing* the stranger without *being* the stranger (1985, 6). Bruno Latour's two-year case study of the Jonas Salk Institute offers a middle ground. Working as a part-time technician, while performing a full-time ethnographic study of the laboratory, Latour argues that his own 'deficiencies' highlighted the 'wealth of invisible skills' employed by the scientists he was studying (Latour and Woolgar 1986, 245).

This research does not attempt an ethnographically embedded perspective, but seeks to acknowledge its own situatedness (Haraway 1988) within the specific disciplinary base of visual arts, while also seeking an in-depth engagement with ideas drawn from another discipline. Such a perspective has a particular risk in the form of the indiscriminate borrowing or inappropriate appropriation of concepts. As Karen Barad points out, when scientific ideas are taken out of their practice context and applied as analogies or metaphors in other fields, their original significance is easily distorted (Barad 2007, 23-24). With this in mind, this research therefore seeks to rigorously examine ideas of the apparatus *in context,* as well as in relation to my practice. The research responds to conceptions of practice that engage with the apparatus and seeks to be attentive to the transformations that occur in this process. This response is performed both through the content of the work and through its methodological engagement with the apparatus. In this sense, the apparatus is simultaneously subject, material, and methodology.

Chapter One takes the form of a literature review that delineates the field of diverse philosophies of science and technology and outlining conceptions of the apparatus in relation to that field. In order to attempt to avoid the sorts of analogical distortions referred to above, as much as possible this chapter maintains a focus on discussing these diverse perspectives in their own terms, rather than assuming a privileged position for my own analysis. Given my practice-led focus on the nature of our relations to the material technologies of reproduction and experience, it is not surprising that relational, phenomenological, materialist and performative philosophies of science and technology have assumed prominence, and are given extensive analysis.

Building on this background, the discussion of Methodology in Chapter Two seeks to consider the nature of cross-disciplinary relations between Art, Science and Technology as well as exploring their shared frameworks, complimentary methods and strategies. Revisiting some of the approaches surveyed in the first chapter, Chapter Two considers the methodological implications of Andrew Pickering's conception of the 'mangle of practice' and Karen Barad's proposal for diffraction as a material-discursive methodology. Strategies of re-enactment and re-construction emerged as central within this practice-led research. Differing perspectives on these strategies are explored within the history and philosophy of science, as well as within media archaeology. This chapter concludes by outlining a trans-disciplinary model of the apparatus as a discursive methodology in the context of an experimental studio practice.

The historically engaged and interdisciplinary focus of this research is given form in the Contextual discussion of Chapter Three, which traces both historical and contemporary practices, across these disciplines. In addition, the research aims to chart a history of relevant practices at the intersection of art and science, and to analyse the connections and trajectories that these apparatuses embody. While focused upon and grounded in the interests of the practice in developing and articulating this history, the research will also contribute to the field through the development and dissemination of new historical research and original analysis.

The theoretical, methodological and contextual elements are brought together in the creative outcomes of the research, which will be discussed in Chapter Four. These creative works are the product of a performative engagement with the apparatus. They also operate as media archaeological explorations of our relationship to the apparatus, drawing on the shared histories of the apparatus across the disciplinary boundaries of art and science. These works provide multiple perspectives on the apparatus, connecting everyday engagements with technology to the specialised experiences afforded by scientific practice. Through detailed discussion and reflection on the multiple outcomes of the research, this chapter will also consider the implications of the creative work for practice-based engagements with the apparatus.

Chapter 1. Surveying The Apparatus in Philosophies of Science and Technology

1.1 Introduction: Defining the Apparatus

In order to develop a new definition of the apparatus in creative practice, this chapter offers an extensive survey of the rich and complex literature on the apparatus to be found in philosophies of science and technology. The changing relationship between conceptions of science and technology are of particular interest for this research. The discussions traverse the oppositions between theory and practice, history and philosophy, epistemology and sociology. In particular, the widely discussed ‘practice turn’ in studies of science and technology over the last fifty years is illuminating for a consideration of the apparatus within creative practice.

As in artistic discourse, there is a lack of focussed attention on notions of the apparatus. In most philosophies of science and technology, the properties and operations of the apparatus are considered stable and not in need of explanation. The terms apparatus and instrument are used interchangeably as a consequence, usually only differentiated in terms of scale, if at all. In today’s era of ‘big science,’ experimental practice is centred around the data produced by immense, industrial-scaled apparatuses. Despite their imposing and expensive materiality, these technologies are still considered instruments and within discourse often remain in a peripheral role.

This chapter, however, examines an extensive and rich history of discussion in the philosophy of science, which challenges these assumptions. It begins with a definition of science reliant on a strict demarcation of the oppositions mentioned above and ends with definitions of scientific practice that challenge these divisions. In the course of this survey, considerations of the apparatus equally go through a profound transformation from being considered a tool at the disposal of the scientist, to models that emphasize the agency of the apparatus, and eventually to approaches that seek to evade the resulting dichotomy between the agency of the scientist, on the one hand, and the agency of the apparatus, on the other.

This chapter therefore focuses on a number of key thinkers whose conceptions of scientific and technological practice indicate a more complex consideration of the apparatus. A key figure in this regard is Bruno Latour, whose sociological analyses of scientific practice place considerable emphasis on the role of instruments as 'nonhuman actors' within scientific practice. Latour's approach will then be contrasted with phenomenological discussions of apparatus and instrumentation as forms of embodiment, as outlined by Gaston Bachelard and Don Ihde. This chapter will conclude with a preliminary discussion of performative accounts of the apparatus as formulated by Andrew Pickering and Karen Barad. I suggest that the insights of these physicists-turned-theorists contribute to the development of a creative engagement with the apparatus, the details of which are set out in the second chapter, through with a discussion of practice-led methodology.

1.2 Entangled Roots: Defining Science and Technology

What I am broadly referring to as "philosophies of science and technology" encompass phenomenological, sociological, historical and constructivist approaches. Within this spectrum, various sub-disciplines, theoretical factions and specialisations can be identified. The scope of this research is not defined by these internal disciplinary boundaries, but by the conception of the apparatus that these discourses afford in relation to practice. Nevertheless, this conception emerges from the historical relations between theory and practice, and between philosophies of science and philosophies of technology. The parameters of these fields therefore need clarification.

The traditional distinction between science and technology equates with the delineation of different knowledge domains found in ancient Greek philosophy. Science is traditionally associated with the pure knowledge of *episteme,* which is concerned with the eternal, the universal and the unchanging. In contrast, the mere practical knowledge of *techne* concerns itself with that which is 'man-made' and therefore 'variable, generated and perishable' (Boon 2008, 78). This fundamental distinction continues to underpin many conceptions of science and technology, and to colour accounts of the relationship between the two.

The traditional privileging of theoretical knowledge also relates to the Aristotelian equivalence between *philosophia* and *episteme* (Waugh and Ariew 2008, 15-16). For much of its history, science existed as a subset of philosophy, most commonly referred to as 'natural philosophy' in contrast to 'the mechanical, practical or even the vulgar, arts' of technology (Channell 2017, 3). Throughout the scientific revolution of the sixteenth and seventeenth centuries, however, science came to increasingly employ these technical arts in the development of instruments and experimental apparatuses.

These developments were contemporaneous with, and connected to, the emergence of scientific sub-disciplines and specialisations. It was this 'separation and dismemberment' of science into diverse, disunited disciplines that prompted William Whewell to resolve by uniting diverse practitioners under the term 'scientist' at a meeting of Britain's Association for the Advancement of Science in 1833 (quoted in Yeo 1993, 110). In coining the term, Whewell sought to both unify science and to reinforce its separation from the arts. This latter category of 'arts' included the fine arts as well as the practical and mechanical arts of technology (Yeo 1993, 154; Knight 2002, 73), whose 'mere practical habit' he saw as dependent on the 'superior' theoretical and conceptual knowledge of science (Schwarz 2014, 49). It is therefore ironic that Whewell advocated for the neologism, scientist, explicitly pointing to the example of art, which served as his model. In 1840, he wrote: 'thus we might say, that as an Artist is a Musician, Painter, or Poet, a Scientist is a Mathematician, Physicist, or Naturalist' (quoted in Ione 2005, 10). In defining the domains of science, Whewell is also often credited as the first practitioner of the new specialisations of history and philosophy of science.

1.3 Essential Tensions in Philosophy of Science

There is a tradition in philosophy of science of attempting to discern and define, or construct, a system. This is not the purpose of this research project. While a full description of such scientific systems is not possible here, it is necessary to outline basic essentials of the relevant systems in order to position the apparatus. The focus rests on the various conceptions of experimental practice proposed within philosophy of science. This is the context for developing a wider picture of the apparatus. My aim here is not to separate out practice and theory, or to oppose them to one another. This historical survey of the apparatus reveals the entangled nature of practice and theory and in turn this acknowledgment informs the methodological, contextual and practice-based considerations of later chapters.

1.3.1 Philosophies of Early Modern Science: The Experimental Revolution

Vilém Flusser draws a distinction between the connotations of the English words 'experience,'—which he likens to 'what streams toward us'—and 'experiment,' which denotes 'what we seek out' (Flusser 2003, 68). For Flusser, the photographic camera symbolises the prevalence of the latter; 'a dance around a possibility to actualize it' (Flusser 2003, 68). This distinction echoes Francis Bacon's earlier formulation at the beginning of the scientific revolution between 'simple experience, which, if taken as it comes, is called accident, if sought for, experiment' (Bacon 1999, 257). Bacon's writings reflect the changing nature of scientific practice, and he is often cited as the first philosopher to argue for the necessity of a specific and systematic scientific method, which included experimental practice, over the speculative insights of earlier natural philosophy (see for example Hacking 1983, 149-165, 246-261).

The particular method advocated by Bacon was induction, which involved an ascent from particular instances to universal principles. These particular instances were furnished by observations, whether their sources were the aforementioned accidental experience, or the sought-after experiment. Bacon does however include a qualitative distinction between instruments, which assist the senses, and the interventional activity of experiments — he states that, even when assisted by instruments, 'sense only gives a judgement on the experiment, while the experiment gives a judgement on nature and the thing itself' (2000, 45). Like Whewell, Bacon turns to the example of art as a form of technical knowledge, arguing that 'the secrets of nature reveal themselves more readily under the vexations of art than when they go their own way' (1999, 276). Within Bacon's taxonomy of experimentation, this is the spirit of the 'artificial experiment,' which Lorraine Daston notes came to be the dominant form of experiment by 1660 (2011, 86). Despite this reliance on the skilful operations of art, the status of artisans and technicians was not raised in the course of further demarcations and sub-specialization. The founding of the Royal Society of London in 1662 and the French Academy of Sciences in 1666 marks the institutionalisation of these new technologically-inflected fields of scientific practice, and the splintering of 'natural' philosophy into 'speculative' and 'experimental' branches.

As Steven Shapin and Simon Schaffer observe, an important factor in the proliferation of scientific societies was the possibility of 'collective financing' for expensive and now-necessary instrumental apparatus (1985, 38; 2010, 93). Ironically, however, these same societies internalised and maintained the old hierarchies of scientific knowledge over technological practice, not least through their own internal divisions of labour between 'gentleman scientists' and the 'invisible' technicians who 'made the machines work, but they could not make knowledge' (Shapin 2010, 78; see also Shapin 1989). The taxonomy of this era's scientific practices distinguished between the experimental activities of 'trying,' 'showing' or demonstrating an experiment and the analytical performance of 'discoursing' upon its outcomes (Shapin 2010, 83). While experiments would usually be 'tried' in private, the scientific societies provided the quasi-public space required for both demonstration and discourse.

Shapin and Shaffer identify a complex set of technologies at play in the new official scientific societies. These include the *material* technology of apparatuses, such as the air-pump; a *literary* technology in the form of scientists' reportage on their experiments; and a *social* technology that encompassed the community of trustworthy witnesses and knowledgeable peers (Shapin and Shaffer 1985, 25; Shapin 2010, 91-92). The experimental results of these material technologies were to be collectively witnessed and socially verified as 'matters of fact,' which could then be disseminated and ‘virtually’ witnessed in published form. The distinction between experimental and interpretive activity was an important one, but the balance between the different forms of practice was equally crucial. This was reflected in Whewell’s nineteenth century characterization of chemistry as ‘an Art, both of the mind and of the hand,’ and his definition of a scientific fact as a ‘combination of our Thoughts with Things’ (quoted in Schwarz 2014, 40, 28). Although some strands of philosophy of science celebrated the influence of experimental method, for others the mind continued to dominate the hand.

If Francis Bacon can be thought of as the philosophical representative for the ‘practical reformers’ of the scientific revolution (Whewell 1860, 104), then it could be argued that Rene Descartes occupied the same position for the opposite tendency. With his privileging of mathematics, emphasis on the rational power of the solitary thinker, and scepticism regarding the evidence of perception, Descartes would seem to be the antithesis of the Baconian scientist. Certainly, his writings downplayed the significance of observation and experiment—despite the fact that he relied on these strategies for his own studies of optics. Whewell countered that Descartes’ notion of science was ‘inconsistent with his own professed method’ (1847, 422), and he dismissed the nature of Descartes’ solitary fireside meditations as thought experiments (1847, 424).

Descartes’ mechanical philosophy does, however, reflect the influence of technologies on scientific thought. In Descartes’ case, the notion of the automata inflected his characterisation of the body as ‘a statue, an earthen machine’ (quoted in Shapin 1996, 158) as well as impacting upon his reflections on consciousness. Further, the ‘spectacle machinery’ of artificial grottos and fountains influenced his idea of the reflex as an automatic mechanical reaction governing the unconscious operations of the body (Lazardzig 2008, 164-168). More than mere explanation by analogy, these are instances of technologies shaping emerging scientific conceptions.

Don Ihde further traces the influence of such technological models on Descartes’ conception of consciousness. Citing both Descartes and John Locke’s references to the *camera obscura* in their accounts of the thinking subject, Ihde posits the idea of the epistemology engine (2000; 2002; 2010a;

2016b). What he means by this is that the apparatus of the *camera obscura* drives the development of particular models of experiential knowledge as a sort of determining metaphor. For Locke and ‘the Sensational School’ that followed him (Whewell 1860, 202), this results in a representational model of perception whereby incoming sensory perceptions serve as the sole ground for knowledge. For Descartes, the *camera obscura’s* internal projection of an external world becomes the model for a dualist split between subject and object. As we shall see, this split will come to be seen as a defining moment in what Bruno Latour calls the ‘modern constitution’ (1993), and continues to recur as a contentious issue in philosophies of science and technology up to the present day.

Though undoubtedly informed by apparatuses and experiments, the philosophy of Descartes nevertheless opposes the unity of ‘Thoughts with Things’ celebrated by the Baconian tradition. Flusser summarises the results of this Cartesian revolution as the dominance of ‘numeric thought,’ which holds that ‘the environment is indescribable but calculable’ (2002, 128). Mathematical and experimental practices had been opposed to one another in the philosophies of Bacon (Kuhn 1977, 31-65) and his eighteenth century followers within the Royal Society of London (Heilbron 1993, 81-130). By the end of the nineteenth century, however, mathematics was celebrated as the epitome of logic and rationalism, playing a central role in philosophies of science.

1.3.2 Twentieth Century Philosophies of Science: The Practice Turn

With the rise of mathematical practices and the increasing association of science with logic, the significance of experimental practice, and the material technologies it relied on, was downgraded within early twentieth century philosophy of science. Don Ihde notes that this era was dominated by ‘mathematician-philosophers’ such as Pierre Duhem, Jules Henri Poincaré and Ernst Mach (Ihde 2008b, 54). The prominent role of mathematics in physics made this the primary science for these philosophers. Yet this mathematically-informed view also cast the scientific apparatus as less a material technology and more as a manifestation of theory; hence Duhem averred that the use of apparatus represented ‘an act of faith in a whole group of theories’ (2014, 203). Duhem suggested that in physics two different kinds of apparatus were housed within the mind of the scientist: one, ‘the concrete apparatus’ that is ‘manipulated’ in the course of experiments and, two, ‘the schematic and abstract apparatus which theory substitutes for the concrete apparatus and on which the physicist does his reasoning’ (2014, 202). With a dominant emphasis on logic, philosophies of science in the first half of the twentieth century concentrated almost exclusively on the ‘schematic and abstract’ theoretical apparatus.

One symptom of this emphasis was the conscious separation made by philosophers of science between what is known as the ‘context of justification,’ a space of logical argument; and the ‘context of discovery,’ the spaces of embodied observation and experimentation. Recalling Flusser’s description of science as a discourse comprised of dialogues (2016, 70), we might suggest that the context of discovery is a space of dialogue, and the context of justification is one of discourse. As Thomas Nickles summarises the situation, for both the positivists and those who came after, the context of discovery ‘was just noise, something external to philosophy of science’ (Nickles 2008, 449). Post- and anti-positivist philosophers maintained this traditional ‘context-free’ perspective on science by drawing a demarcation between the logic of science and the ‘situational logic’ in which it occurs. The context, discourse and even its instruments of experimentation were relegated to the province of sociology (Popper 1994, 166-168). This is a view of science that ‘brackets’ out practice.

The hypothetico-deductive model, exemplified by the work of Karl Popper, refuted Francis Bacon’s model of scientific method ‘that starts from observation and experiment and then proceeds to theories’ (1963, 279). Despite their opposition to induction, philosophers such as Popper preserved Bacon’s notion of the crucial experiment, or those ‘instances of the crossroads’ where an experiment prompts the adoption of one theory over another (Hacking 1983, 168). The significance of the experiment, however, is transformed into one of refutation rather than of proof, thus confirming the primacy of theory. For Popper, experiments were not means of generating knowledge in themselves, but only ways of helping to decide between competing theories (Popper 1963, 277). By implication, in Popper's view of science as a system of hypotheses, experimental practice can only refute or fail to refute; it cannot in itself generate new information or knowledge.

From the 1960s onwards, the 'new philosophy of science' placed a greater emphasis on historical accounts of practice. With Thomas Kuhn's highly influential *Structure of Scientific Revolutions* (1966) as its figurehead, this new philosophy of science was historically engaged, emphasising 'the sources of science, not the end products of research' (Galison 2016, 57). In particular, Kuhn and his contemporaries critiqued the representation of scientific progress as having a simple linear structure, which is embodied in the 'profoundly unhistorical source' of the educational science text (1977, 179), Kuhn termed this the linear view of simple accumulation the 'textbook picture of science' (Kuhn 1996, 2). In contrast, Kuhn emphasised the multidisciplinary, non-linear, disunified and historical nature of science itself (Hacking 1983, 6). This contrasted with the picture presented by many traditional philosophies of science.

For Kuhn, philosophers such as Popper characterised all scientific practice in terms of the rare revolutions it produces, overlooking the vast majority of scientific practice (Kuhn 1996, 271-2). This day-to-day work of the scientist Kuhn referred to as 'normal science.' Normal science, he argued, can be thought of as a cumulative activity, akin to puzzle solving (1996, 52) or the activity of 'mopping up' (1996, 24). The puzzles that 'normal science' sets out to solve, and the loose ends it seeks to mop up, are those that are set by an over-arching paradigm. The paradigm supplies a 'preformed and relatively inflexible box' into which normal science attempts to force nature (1996, 24). When a paradigm changes, the possibilities for 'normal science' change dramatically, creating an upheaval Kuhn likens to a political revolution (1996, 92-94). Kuhn's discussion of the role of artisanal crafts in the 'new sciences' of the 'Scientific Revolution' also highlighted the role of technologies and instruments (Kuhn 2014, 115). Though not his intention, this laid the groundwork for later developments in the history and philosophy of science.

At the same time, Kuhn also instituted a new hierarchy (revolutionary versus normal science) in place of the old demarcations entrenched within the traditional view of science.

Despite advocating and inspiring a closer focus on practice, Kuhn's framing of the scientific paradigm still reinforces theory as the primary driver of practice. Arguing for the significance of technologies and instruments, physicist Freeman Dyson asserts that tools rather than ideas drive the majority of 'revolutions' in science, because new technologies enable new processes and practices (1999). Historian Peter Galison similarly argues for the significance of 'experimental traditions,' which include particular laboratory practices that are focused on the apparatus. In terms of pedagogy, technical skills and demonstrative approach, such traditions endure scientific revolutions, providing continuity despite theory change (Galison 1997, 21-22). Galison broadly places the twentieth-century versions of experimental traditions within the categories of 'image' and 'logic'. Each category is defined in terms of its outputs; 'image' traditions aim to record single, significant instances, while 'logic' traditions accumulate data and statistics. Galison's account of experimental traditions is one that I will return to in the next chapter, but it also demonstrates the ways that Kuhn's work has been built on and extended in different directions.

The work of Thomas Kuhn both called for and motivated a more contextual, even sociological view of scientific practice (1977, 176). This view came into focus throughout the 1970s and 1980s with the development of the range of approaches collectively referred to as Science and Technology Studies (hereafter STS). Prominent among these, the Sociology of Scientific Knowledge or 'SSK', with its so-called 'Strong Program,' emphasised the influence of social interests on the development of scientific knowledge (Barnes 1974; Barnes, Bloor and Henry 1996). Related approaches such as ethnomethodology (Lynch 1993) and Actor-Network Theory or 'ANT' (Latour 2005b) employed sociological methods while eschewing any related claims to scientific rigour. All of these diverse camps emphasise the importance of a symmetrical view that treats science and non-science equally. More importantly for this research, they produced empirical studies of scientific practice that inform the approaches to be considered in more detail below.

Some have argued that the revised picture of scientific practice developed by sociologists fared little better than traditional historians and philosophers of science because they similarly neglected the significance of experimental practice. Thus, in 1983 Ian Hacking called for a ‘back-to-Bacon movement’ that recognised ‘experimentation has a life of its own’ (1983, 150). According to physicist Allan Franklin, when commentators engage with experimental practice at all it is in the traditional historiographic form of ‘an almost mythological treatment of a few standard exemplary experiments,’ with ‘actual experiments’ being ‘rarely discussed’ (1990, 1). In Kuhn’s terms, the focus on revolutionary science is preserved by over-emphasising the significance of well-known experiments, thus neglecting the everyday experimental work of ‘normal science.’ Despite emphasising the ‘complex feedback relationship between theoretical explanation and experimental observation’ (1986, 104), even Franklin’s account defines experiments almost exclusively in relation to theory. He advocates ‘the evidence model,’ in which ‘questions of theory choice, confirmation of theory, or refutation of theory are decided on the basis of valid experimental evidence’ (1990, 193). Experimental practice does not play a generative part in this sense, but remains restricted to the traditional roles of “crucial” or “convincing” experiment, intended to confirm or corroborate pre-existing theory. Even though in Franklin’s account the apparatus emerges as central to scientific practice, the key terms of apparatus, instrument, and even experiment are still taken for granted and their parameters remain undefined.

One account that does seek to define the terms apparatus, instrument, and experiment is that proposed by philosopher Rom Harré. Recalling Flusser’s discussion of the apparatus-operator complex, Harré proposes the term ‘apparatus-world complex’ as a counter to the traditional philosophical fixation on the relation between theory and experiment (2003, 20; see also Aronson, Harré and Wray 1995, 179-181). For Harré, this traditional approach loses sight of the material nature of experimental practice and its relation to the world (1998, 354). Harré argues for the ‘metaphysics of experiment’

(2003). He seeks to 'recover' the relationship between experiment and nature in the face of postmodern critiques of science (Harré 1998; Harré, Aronson and Wray 2000, 15). Hence, he argues that 'experiments are not just discursive representations of Nature in a material medium. They are natural phenomena' (Harré 1998, 368). Paradoxically, what lies at the heart of Harré's metaphysics appears to be realism. Like Franklin's 'evidence model' of experimentation, the pre-eminence of realism for Harré's discussion is outside the scope of this research. Nevertheless, the materialist dimensions of his account of the apparatus provide a valuable point of comparison.

Harré distinguishes between an instrument and apparatus. An instrument, according to Harré, 'registers an effect of some state of the material environment.' Whereas an "apparatus," on the other hand, operates as 'a model of some naturally occurring structure or process' (Harré 2003, 20); the apparatus functions as a closed 'model system' within the laboratory, while instruments 'link the equipment to the world' (2003, 26). In other words, for Harré, instruments are *causally* related to the world, while apparatuses are *conceptually* related to the world (Harré 2010, 31-34). These distinctions are further refined into the uses of instruments for detecting and measuring, which are further contrasted with applications of the apparatus in isolating and modelling phenomena (2010, 37). While this research does not adhere to Harré's distinction between instrument and apparatus, his account does point to important distinctions between different functions performed by technologies. Thus, while I do not share Harré's definition of the apparatus as a model of the world, or as a means of reasoning by analogy (2010, 36), his insights do encourage further consideration of the conceptual and theoretical dimensions of the apparatus.

Throughout the twentieth century, philosophies of science underwent a paradigm shift, turning from ahistorical questions of logic and epistemology to an understanding of scientific practice understood as situated within specific social, cultural and political contexts. One ancillary effect of this 'practice turn' has been to foreground the role of technology, including imaging apparatuses, within science. With this in mind, I turn now to consider the philosophy of technology as a field in its own right.

1.4 Questions Concerning Technology

More than a century after William Whewell co-opted the nomenclature of the arts to his philosophy of science, philosopher Gilbert Simondon urged greater awareness of technology, arguing that it ‘be placed on the same level as scientific education,’ due to the fact that ‘it is as disinterested as the practice of the arts, and it dominates practical applications as much as theoretical physics does’ (Simondon 2017, 19). Simondon called for a study of technology as broad as the humanities, thus calling for ‘the existence of a technologist or *mechanologist* alongside the psychologist and the sociologist’ (2017, 19).

Simondon was in part responding to the overwhelmingly dystopian perspectives on technology presented by philosophers such as Martin Heidegger (1996), Jacques Ellul (1964), Herbert Marcuse (1964) and Hans Jonas (1974). As Andrew Feenberg summarises, such accounts of technology often formed part of a wider critique of society or the modern world and prescribe a ‘retreat from the technical sphere into art, religion, or nature’ (Feenberg 1999, 152). Philosophical focus on technology as a specialist area was rare, with German philosopher Ernst Kapp’s *Grundlinien einer Philosophie der Technik* (1877) the earliest exception. In Kapp’s philosophy, technologies functioned as unconscious projections of bodily organs. Within his schema, Kapp specifically associated the terms ‘apparatus’ and ‘instrument’ with the organs of perception (2018, 61-79). By positioning the human body as an unconscious prototype for technology, Kapp argued that the study of technology produced a greater understanding of the self (2018, 24). Despite these early articulations, it was not until a century later that the philosophy of technology came to cohere into a discipline as such.

1.4.1 Disentangling Technology

One issue inherent to the philosophy of technology is that of defining its subject. Some have argued that ‘“technology” is not one “thing” but a complex of practices, methods, hopes, intentions, goals, needs and desires, besides all the actual technologies in hand' (Olsen, Pedersen and Hendricks 2008, 3). Other commentators see 'technologies as an environment rather than as a collection of tools' (Feenberg 2008, 148). Others regard technology as 'the pursuit of life by means other than life' (Stiegler 1998, 17), or, even more broadly, as 'humanity at work' (Pitt 2011, 74). The relationship between the overarching category of 'technology' and specific examples of 'technologies' is therefore a recurring theme.

The fluidity of these definitions is also linked to slippages within and between languages; the German '*technik'* can mean both 'technique' and 'technology,' a double meaning that is reflected in German philosopher of technology Friedrich Rapp's dualist definition of 'technology as *procedural knowledge* and as *actual execution'* (1981, 32). While the French '*technique*' and '*technologie*' are both employed to translate the English 'technology,' there is also a particularly French tradition in which the term 'technology' is taken to describe 'the philosophy, the reflection, or the science about techniques' (Latour 2007b, 125; Parrochia 2009, 54-55). This tradition is perhaps best exemplified by Michel Foucault's fourfold model of technologies of production, sign systems, power and the self (1988, 18). The dystopian thread of this tradition is well represented by Jacques Ellul's equation of *technique* with rationalist efficiency (1964). From a different perspective, the early work of American philosopher Don Ihde thematised 'technics' for its ability to connote both 'action' and 'artifact' while also balancing the 'abstract "technique," which can refer to any set action with or without a material object, and the sometimes too narrow sense of technology as a collection of tools or machinery' (1983, 1).

Despite the emergence of philosophy of technology, the aforementioned hierarchical opposition between science and technology persists. The contemporary version of this distinction is reflected in philosopher Mario Bunge's assertion that 'science is about truth, technology is about utility' (2007, 18). Paradoxically, the consequence of this formulation is a contingent essentialism in which the status of science seems dependent on intentionality or utility. This partition also renders science as a diminishing discipline. As Steven Shapin observes, in modern science the theory/practice hierarchy has been reversed; ‘the authority of science is increasingly based not on what scientists know but on what they can help make happen’ (2010, 390). In light of the pervasive utility of scientific knowledge, for philosophers such as Bunge the traditional opposition is internalized to an opposition between ‘pure’ science as a ‘morally and ideologically neutral’ discipline (Bunge 2007, 22) and technology as ‘applied science,’ its ‘morally compromised’ other (2007 23; Bunge 1974). The implication is that the knowledge of ‘pure’ science is *inherently* neutral, regardless of its effects, while the application of that same knowledge through technology is fundamentally compromised, by its *potential* for ill.

The model of technology as a form of applied (and therefore lesser) science undertakes a reversal in the late thinking of Martin Heidegger. In his much-discussed essay *The Question Concerning Technology,* Heidegger seems to accept the model of modern (large scale and industrial) technology as applied science, which he refers to it as historically following modern science (Heidegger 1977, 22). However, he argues, though historically antecedent, the essence of modern technology is ‘primally early’ and lies ‘concealed’ within modern science, over which it ‘holds sway’ (1977, 22). This is because modern science depends on a technological way of seeing the world. For Heidegger, technology, as a ‘contrivance’ or *instrumentum* (1977, 5) is no ‘mere means’ but is instead ‘a way of revealing’ (1977, 12). What distinguishes *modern* technology is not its derivation from modern science, but its ‘putting exact science to use’ in this project of revealing (1977, 14). The essence of modern technology for Heidegger, also involves a different mode of revealing – it operates as a framework or apparatus (*Gestell*) that comes to ‘Enframe’ (*Ge-stell*) nature (1977, 20-21). By means of modern science, modern technology ‘sets upon’ (*Stellen*) nature (1977, 16), Enframing the world as ‘standing reserve’ (*Bestand*) - raw material, ready and awaiting exploitation (1977, 17-19). Paradoxically, however, the ‘sphere of technological activity,’ which includes the material components and assemblies of technology, ‘merely responds to the challenge of Enframing’ (1977, 20-21). Enframing therefore lies outside the technological sphere. Yet the essence of technology ‘is itself nothing technological’ (1977, 20).

Heidegger's emphasis on hidden essences, which control from without, renders his account of technology both dematerialising and determinist.

As in my introductory discussion of the apparatus as a blind spot, the question of visibility is crucial in Heidegger's account. But in his analysis what is revealed is not technology itself, but a dominating will. The concepts of technology as Enframing and revealing contrast, however, with his earlier discussion of technology. In his earlier work *Being and Time,* simple or traditional tools such as the hammer were valued for their transparency; they merely refer to the project for which they are used, and into which they are absorbed (1996, 64, 70). When broken or not fit for the task, they become conspicuous, obtrusive or obstinate – 'objectively present' - objects (1996, 68-69). Therefore the ideal tool is one that is ready but not present, rather than present but not ready.

It is also important to emphasise that Heidegger's influential discussion of technology remains at the level of tool and machine analysis in Flusser's sense of the terms, rather than approaching a conception of the apparatus. As Don Ihde also indicates, Heidegger's 'energy metaphors' are at odds with the 'information metaphors' that characterise much contemporary technology, and which connote qualities such as 'exchange, interaction, communication' rather than 'standing reserve' (2004, 105; see also 2010b, 120). The distance between Heidegger and the contemporary context highlights a number of paradoxes in his discussion of technology. Though seen only in terms of its usefulness, the 'handiness' of the hammer operates as a form of 'disclosing' rather than concealing or 'Enframing,' which stands in contrast with his view of large-scale industrial sites such as the power station. The 'conspicuousness' of the unusable hammer paradoxically frustrates this activity of disclosing, rather than operating as a mode of revealing. It would seem that the difference is that between traditional and modern science – and this difference is the intertwining of science and technology in large-scale projects.

The entanglement and expansion of science and technology through the twentieth century saw the emergence of 'Big Science,' characterised by complexes of high levels of funding, large-scale instrumentation, extensive industry linkages, government patronage and large organizational structures

(Shapin 2010, 166). From the perspective of scientists, the high level of funding was matched by accompanying bureaucratic processes, new organizational hierarchies with internal interdependences and ‘a relative lack of flexibility in its response to individual initiatives’ (Pickering 1995, 43). It is this implication of science in industrial complexes, and the attendant collapsing of distinctions between science and technology, that are captured in the term *technoscience*.

1.4.2 Seeing Science and Technology Together

The term technoscience was popularised through the work of Bruno Latour, who initially framed the term as a convenience to avoid constant repetition of the phrase 'science and technology’ (Latour 1987, 29). At the same time, he suggested that the term was valuable for the study of science in the making, because it encompassed those ‘dirty, unexpected or foreign’ elements that are part of the *production* of science and technology that are usually forgotten when considering its products (1987, 174). This latter sedimented knowledge ‘is only a sub-set’ of technoscience ‘which seems to take precedence only because of an optical illusion’ (1987, 175). More recently, however, for Latour the term ‘technoscience’ has been ‘tainted’ (Latour 1999, 178). This is due to its widespread equation with ‘applied science’ (Latour 2007b, 125-126), an equivalence that too readily extends dystopian critiques of technology (as discussed above) into the sphere of science. Similarly, Isabelle Stengers identifies the term ‘technoscience’ with a reductive view of science as ‘technical domination’ that ‘denies any possibility of distinguishing between scientific, technical, and technological productions’ (Stengers 2000, 10).

In addition to collapsing the opposition of science and technology, the notion of technoscience is also employed to break down related hierarchies of practice and theory, local and universal, nature and culture. This is the case for Donna Haraway, who suggests that the value of the term lies in its resistance to traditional category separations, not only between science and technology, but also between science, politics, society and culture. Such ‘category fusions’ highlight that ‘one such category cannot be used to explain the other, and neither can be reduced to the status of context for the other’ (Haraway 1996, 62-63). In this sense, the value of the term lies in, to paraphrase Latour, its ability to generate proliferating hybrids.

The focus of this research rests on the essential role of the apparatus for creative practice. This concern resonates with multiple philosophical perspectives on the role of technology within science, as well as discussions of technology as a phenomenon in its own right. For the purposes of this research, science and technology are treated as entangled entities—sometimes intertwined, sometimes coextensive, but always operating in relation. In this sense, the relationship sketched out echoes that described by Georges Canguilhem:

> Science and Technique must be considered not as two types of activity, one of which is grafted onto the other, but as two types of activity, each of which borrows from the other sometimes its solutions, sometimes its problems (Canguilhem 2008, 95).

Though not adopting the term ‘technoscience’ completely, the term is of central importance for many of the approaches that productively inform this exegesis. In these approaches, the term ‘technoscience’ draws together the historically opposed categories of science and technology, theory and practice. This continuum ranges from everyday engagements with technological artefacts to specialised scientific practices. In this sense, the apparatus operates as a focal point for material-praxis engagements within philosophies of science and technology.

The remainder of this chapter will examine how the apparatus is treated in such approaches. First, I will consider Bruno Latour’s description of the role of instruments in the production of scientific knowledge. Second, I examine the significance of specialised technology for scientific practice found in the work of Gaston Bachelard as well as the embodied dimensions of this relation developed in the work of Don Ihde. Finally, performative accounts of practice developed by Andrew Pickering and Karen Barad will be considered for their significance in exemplifying creative engagements with the apparatus.

1.5 Bruno Latour: The Black Box and its Networks

The particular significance of Bruno Latour for this research rests with his sustained focus on the importance of scientific instrumentation, and technology more generally, within science. Latour's work played an influential role for the 'practice turn' that took place within sociological studies of science, throughout the 1970s and 1980s. In the same period, Latour was also central in the development of Actor Network Theory (ANT). The aim of this approach was to adopt the empirical, 'case-studies' model of sociological studies without reducing the object of every analysis to an effect of the social. While not adapting the framework of ANT, this research does draw on the insights and approach of Latour, and his particular articulation of the role of apparatuses and instruments within scientific practice.

Despite the name, proponents suggest that ANT is not a theory at all, but is a 'theoretical repertoire' or 'adaptable, open repository' of terms (Mol 2010, 261, 265). Others argue it is more a sensibility or approach that is better described as a form of 'material semiotics' that performs an analysis of 'meaning' in social terms (Law 2009, 142). This entails an expanded definition of semiotics as 'the study of order building or path building,' which 'may be applied to settings, machines, bodies, and programming languages as well as texts' (Akrich & Latour 1992, 259). As should be clear from this brief sketch, it is important to emphasise that Latour's work is itself situated within a network of peers, co-authors and interlocutors. Therefore, although I focus on Latour here, he is but one actor within this network of ideas.

Informed by fieldwork (conducted by Latour and others) and historical case studies, Latour asserts that his own approach supplies the 'empirical grounding' lacking in the philosophy of science (Latour 1999, 24). Without this grounding, philosophical analysis can only reveal one half of the scientific enterprise. Like the mythological figure of Janus, who simultaneously looks forward and back, Latour describes science as comprising two faces: 'ready-made science' and 'science-in-the-making' (1987, 174–5). According to Latour, only the Actor-Network approach, with its empirical grounding, can reveal both faces. More recently, Latour has declared his earlier work 'mistaken' in directing attention away from the ontology of 'matters of fact' and '*toward* the conditions that made them possible' (Latour 2004a, 231). However, it is this very focus on scientific *practice*, or 'science-in-the-making,' that makes his earlier work significant for this practice-led research project's emphasis on the apparatus. It is therefore worth offering a brief outline of the picture of scientific practice that emerged from this approach, before delineating the specific role of the apparatus found within it.

1.5.1 Made to Order: Writing About the Laboratory

In Latour's account, scientific practice is a 'material operation of creating order' in the face of 'a seething mass of alternative interpretations' and 'utter confusion' (Latour and Woolgar 1986, 129, 245, 36). This resonates with Flusser's conceptualisation of science as one means of attempting to order chaos into cosmos (2017b, 2). For Latour, scientists aim not to discover pre-existing 'universal truths' but to make science universal by extending and stabilizing its network (Latour 1993, 24). This network view counters the traditional epistemological isolation of knowledge. Rather than treating knowledge as an object or inherent quality, it must be thought of as 'a cycle of accumulation that allows a point to become a *centre* by acting at a distance on many other points' (Latour 1987, 222). Although much of what is distinctive about Latour's analyses is captured in this 'network' view, it is the emphasis on practice within these networks that is of special relevance for a consideration of the apparatus.

Latour places practice at the heart of science, stating that: 'crafts hold the key to knowledge. They make it possible to return "science" to the networks from which it came' (Latour 1988, 218). Despite assertions that the material implements and infrastructure of science 'are only *ways and means* of bringing the truth to light,' they are constructed 'in order to create a focal point for the potency of truth' (Latour 1988, 214). Latour attributes the minimization of both practice in general and its material manifestations to a confusion of 'products with processes' (Latour 1993, 115). In Latour's early work, this confusion is enshrined in 'the most important and the least studied of all rhetorical vehicles: the scientific article' (Latour 1987, 31). Reporting on his conversations with scientists, Latour recounts a prevailing attitude that sharply distinguishes between the scientific papers and the facts and arguments that they presented (Latour and Woolgar 1986, 75-76). This separation renders the papers themselves immaterial, in both senses of the word. Within the 'paper world' created by the scientific article, the physical space of the laboratory, along with the scientists, materials and instruments it houses, appear as 'a set of semiotic actors presented in the text but not present in the flesh' (Latour 1987, 64). Latour's strategy in redressing this suppression of practices, materials and instruments is to trace a path back 'through the looking glass of the paper' from text to practice (1987, 67). In this regard, scientific apparatuses and instruments assume a central role.

Due to the central role of the scientific paper in Latour's analysis, his attention is focused on the relation between 'inscriptions' and 'instruments.' Though I suggest that the term 'apparatus' can be considered synonymous with Latour's use of the terms 'instrument' and 'inscription device,' in his work these latter terms predominate and are used interchangeably. Latour defines instruments in terms of their production of 'inscriptions' in the form of 'texts or visual displays' (1987, 67). Such instruments are the source of the multitude of 'maps, diagrams, columns, photographs, spectrographs' that populate scientific papers. According to Latour, 'these are the materials that are forgotten, the materials that are used to make "thought" intangible' (Latour 1988, 218). For him, this forgetting of materiality enables the construction of scientific knowledge; in order to be universal, timeless and transcendent, it must be de-localised, de-historicised and de-materialised. In this regard, 'scientific and technical work is made invisible by its own success' (Latour 1999, 304). Recalling my foundational analogy of the apparatus as a blind spot, the instruments that render phenomena visible similarly become invisible in science, by disappearing 'beneath the surface' of the inscriptions that they produce (Latour 1987, 69).

In keeping with his focus on the construction of scientific facts, Latour's definition of the instrument is itself an instrumental one; only those technologies whose inscriptions are present in 'the final layer' of a scientific paper are considered worthy of the name (Latour 1987, 68). 'Instrument' is therefore a contingent and relative term for him, shifting its referent from experiment to experiment. An instrument is defined in terms of its use value, its ability to 'facilitate a swift transition from craft work to ideas' rather than its material form (Latour and Woolgar 1986. 69, 89). Thus, what I would refer to as an apparatus might be termed an instrument for Latour in the context of one scientific paper where its inscriptions are featured, but not in another where its readings are considered 'intermediary' rather than conclusive (Latour and Woolgar 1986, 68).

As Latour notes, this contingent quality allows the instrument to take many forms from 'hardware', such as a telescope or bioassay to an institutional apparatus like a team of statisticians (Latour 1987, 68). At first glance, Latour's definition of 'instrument' seems a broad and all-encompassing one because it includes 'any set-up, no matter what its size, nature and cost, that provides a visual display of any sort in a scientific text' (Latour 1987, 68). While Latour's stipulation of 'visual display' clearly incorporates images, overall he emphasizes diagrams (such as those that populate his own texts), graphs and similar visualisations of data. The figure or image that forms the starting point of the text and the end point of instrumental practice is '*extracted* from the instruments,' to be '*cleaned*, *redrawn*, and *displayed*' (Latour 1987, 65). Thus, even photographic images are likely to be subject to this process, being rendered graph-like.

Flusser's discussion of the history of writing is illuminating in this regard. Noting the etymology of inscription in the Latin, *scriber,* and the Greek, *graphein,* meaning to scratch and to dig, respectively, he emphasises the slow and considered process of informing meaning into matter through carving (Flusser 2011a, 11, 12, 18). Similarly, for Latour the inscription device represents a 'prolonged and costly process' that aims to 'transform a material substance into a figure or diagram' (Latour and Woolgar 1986, 50-51). No matter the scale or cost of the apparatus, its 'end product is no more than a curve, a diagram, or a table of figures written on a frail sheet of paper,' which despite the contrast assumes central importance as "evidence" for the claims of the scientific paper (Latour and Woolgar 1986, 50). This figure, the end *product* of material transformation, becomes the starting point for the article (Latour and Woolgar 1986, 63). In other words, the *process* that led to its construction is effaced.

In the case of scientific 'craft work,' the invisibility of process is not only a result of the writing of articles, according to this conception, it is the actual aim of much of the labour involved. The process of writing a scientific article is 'not so much a method of transferring information as a material operation of creating order' through the application of a 'wealth of invisible skills [that] underpin material inscription' (Latour and Woolgar 1986, 245). The "controlled conditions" of the laboratory enable the staging of 'these empty forms' that 'are set up *behind* the phenomena, *before* the phenomena manifest themselves, *in order* for them to be manifested' (Latour 1999, 49). The purpose of the laboratory is to create order as a background against which phenomena can be observed in relative isolation.

1.5.2 Opening the Black Box

The models of information theory, inscription device and invisible operations are brought together in the motif of the 'black box,' which is central to the thought of both Flusser and Latour. As in Flusser's account of the apparatus discussed above, Latour characterises the black box in terms of its illusory autonomy and imposed impenetrability. Latour writes:

> When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become (1999, 304).

In accordance with Latour's view of science, the black box is another means of imposing order on chaos. 'Beautiful boxes are drawn, joined by nicely pointed arrows' that conceal the true picture, he asserts, which is far more messier: 'boxes overlap; arrows get twisted and torn; the law seeps into biology which diffuses into society' (Latour 1988, 206). In Flusser's etymology of writing, he distinguishes between the laboriousness of early inscription processes and the sort of circuit diagrams that Latour describes here. Both words, sketch and schematic, share the Greek root *sche,* which means to 'seize' (2011a, 19). Thus, the implication is that the schematic diagram *seems* to enable the viewer to 'seize' an understanding of the workings concealed within the black box, but this is illusory. Such diagrams present the technical artifact 'as if it were open to inspection and mastery'. Yet they conceal their nature as inscrutable black boxes: 'parts hide one another; and when the artifact is completed the activity that fit them together disappears entirely' (Latour 2007a, 141). The black box renders the system conceivable and apparently graspable, but it does so by effacing that which it orders.

When transferred to the sciences, the black box model reduces complex operations to inputs and outputs. Once black boxes are constituted, Latour argues, 'no matter how controversial their history, how complex their inner workings, how large the commercial or academic networks that hold them in place, only their input and output count' (Latour 1987, 2-3). In the context of laboratory practice, these inputs not only include data, energy, animals and chemicals, but even the scientists and technicians who work in the laboratory (Latour and Woolgar 1986, 52). For Latour, this network of inputs forms part of the stabilization mechanism of the black box. In order to challenge scientists' findings, one would have to rebuild the black box, plus a laboratory to house it, and then muster the same inputs in order to compare outputs. It is fully constituted when its functioning is taken as a given, not to be questioned. For earlier philosophers of science, this impenetrability was a measure of science's success. Pierre Duhem contended that 'physics is not a machine which lets itself be taken apart.' Instead it 'is a system that must be taken as a whole; it is an organism in which one part cannot be made to function except when the parts that are most remote from it are called into play' (Duhem 2014, 207). Following the approach of sociology of science, for Latour the only viable ways to uncover the constitution of a black box are either to study its destabilisation in the midst of controversy, or to 'follow scientists' in the course of its making.

Latour's emphasis on the making of scientific knowledge is often rebuked as promoting a form of relativism. In response, he warns that the very equivalence of fabrication and falsehood, on which that accusation is based, needs to be reconsidered (Latour 1999, 115). In reference to the isolation and synthesis of a hormone known as thyrotropin-releasing factor (TRF), the development of which Latour studied intensively, he and Woolgar argue: 'to say that TRF is constructed is not to deny its solidity as a fact. Rather, it is to emphasise how, where, and why it was created' (1986, 127). Insisting on the simultaneous artificiality of the laboratory and the autonomy of its products (Latour 1999, 127), Latour compares scientific objects to simultaneously 'fabricated' and 'real' objects, such as houses, cars and mugs: 'it is precisely *because* they have been artificially made up that they gain a complete autonomy from any sort of production, construction, or fabrication' (Latour 1999, 127). While these quotidian technologies serve an illustrative purpose in his thinking, it is worth considering further the role of technology within Latour's thinking.

1.5.3 From Instrumental Inscriptions to Technical Objects

As Latour points out, in Greek mythology 'science is represented by a straight line and technology by a detour' (1992, 177 n10). As we have seen, his description of scientific practice unsettles this traditional perception, showing instead the intertwining of *episteme* with 'the clever and crooked path of technical-know-how, *metis'* (Latour 1999, 174). But as previously discussed, Latour also belongs to the French tradition that emphasizes technology as 'technique.' Thus, while in the context of science Latour critiques the forgetting of materiality, he suggests that the word "technology" proves 'unsatisfactory because it has been limited for too long to the study of those lines of force that take the form of nuts and bolts' (Latour 1988, 191; 199). The issue here is not purely one of translation, but rather grammar; in short, he argues that both "technology" and "technique" make 'lousy nouns' (Latour 1999, 190). This is because they denote 'a *modus operandi*, a chain of gestures and know-how' rather than any one object (Latour 1999, 192). The noun form appears to break this chain of association in a way that the adjectival (technical), adverb (technically/technologically) or even verb (technologise) forms do not. In semiotic terms, the words technique and technology therefore tend to function as modifiers rather than denoting autonomous entities.

The 'technical object' rather than 'technology' proves to be the key feature of ANT analysis. Like technical images in Flusser's philosophy, such objects are considered to be the product of 'a self-effacing apparatus' (Akrich 1992, 222), and are themselves rendered as black boxes in this process of effacement (Akrich 1992, 221). Madeleine Akrich argues such objects present a challenge to traditional sociological approaches, which are unable to account for the 'long chain of people, products, tools, machines, money, and so forth' that make up these apparatuses. Akrich remarks that 'even the most mundane objects appear to be the product of a set of diverse forces' (Akrich 1992, 205). As with Latour's account of scientific practice, these processes of effacement and stabilisation follow 'a process of reciprocal definition in which objects are defined by subjects and subjects by objects' (Akrich 1992, 222). In a phrasing analogous to Flusser's notion of the program, Akrich and Latour describe this as the production and performance of a *script.*

This leads to an important consideration of the apparatus and of technology in general. As in Flusser's conception of the program, the script of a technology both enables and constrains performance; it determines what are 'prescribed and proscribed' uses (Akrich & Latour 1992, 261). Similarly, for Flusser the script is a form of text that operates under a pretext; it appears to embody a 'dramatic orientation' and 'show actions,' while really adopting a 'programmatic orientation' by delivering 'instructions about how to behave' (2011a, 135). Though potentially determinist, the script in ANT (like Flusser's program) is open to reciprocal rewriting. That is, the prescriptive 'in-scription' of the designer can be accepted through 'sub-scription,' but it is also open to 'de-scription' by analysis, 're-inscription' through modification, or may be entirely negated by the contrary intentions or 'antiprogram' of the user (Akrich & Latour 1992, 259-262). As in the accounts of Flusser and Heidegger, these inner workings are also made visible by 'the collapse of the relationship between a piece of apparatus and its use' (Akrich 1992, 224 n12).

While the preceding discussion of technical objects focuses upon the inscription relationship between designers and users (see Akrich 1992), it also reflects the way that over time, insights developed from Latour's observations of laboratory practice have been extended to technical objects and eventually to objects in general. In his early work, the laboratory figures as a site where 'traps are set to make the things that are talked about write' (Latour 1988, 219). More recently, Latour has advised prospective ANT analysts that when confronting ordinary everyday objects, 'specific tricks have to be invented to *make them talk*, that is, to offer descriptions of themselves, to produce *scripts* of what they are making others—humans or non-humans—do' (Latour 2005b, 79). The traps of the scientist become the tricks of the analyst.

The role of objects in writing scripts about themselves highlights the reciprocal nature of relations between technology and its users. Latour describes this relationship as a form of "delegation." For Latour, delegation implies collaboration rather than dominance or mastery; it does not mean 'an all-powerful human agent imposing his will on shapeless matter' (Latour 1999, 186-7). Instead, delegation implies that an object '*stands in* for an actor,' thus 'representing' them in their absence (Latour 1999, 189). Flusser characterises a similar position as an 'optimistic' view of technology, in which human beings free themselves by shifting 'the burden of instruction' onto programmed, 'inanimate objects' (Flusser 2011a, 58). However, Latour's favoured examples of delegation undercut this sense of optimism. Instead, he highlights techniques directed towards the assertion of authority or obtaining compliance. Examples include the hotelier's bulky key-ring, which is used as a means of ensuring room keys are left at the front desk (Akrich and Latour 1992, 259-260, 263-264); speed bumps as a means of enforcing speed limits (Latour 1999, 186-187); or cars designed to ensure that drivers wear seat belts (Latour 1992, 225-226). In these examples, technologies do not operate by facilitating action, but constrain human agency in order to prevent unwanted actions. Latour and other ANT theorists reframe this situation in order to underscore how humans enlist nonhumans as allies in the service of a program.

For Latour, the notion of delegation demonstrates the fact that 'nonhumans also act, displace goals, and contribute to their definition' (Latour 1999, 186-7). Such a view is central to Actor-Network Theory's version of 'symmetry.' This principle means that the materials and objects that scientists work with, and even those that we encounter in everyday life, must be considered as actors 'and not simply the hapless bearers of symbolic projection' (Latour 2005b, 10). Latour argues that the principle of symmetry does not only aim to counter Cartesian dualism, but to erase it. His stated aim is 'not to extend subjectivity to things, to treat humans like objects, to take machines for social actors, but *to avoid using* the subject-object distinction *at all*' (Latour 1999, 193-194). Importantly, this is figured as a corrective for a mistaken perception of difference, attributed to the modernist (and modern scientific) measure of progress as a widening gap between subjectivity and objectivity (Latour 2004b, 235), nature and culture (Latour 1987, 94), past and future (Latour 1993, 71). What is required is a realisation that the Cartesian categories of objectivity and subjectivity 'are not opposed, they grow together, and they do so irreversibly' (Latour 1999, 214). In emphasising attachments between human and nonhuman actors, the notion of the network plays an important role in fostering this realisation.

1.5.4 Knots in the Network: Problems and Limitations

In the context of this research, the network view adopted by Latour functions as a limitation. Though framed in terms of multiplying attachments, in other ways Latour's notion of the network operates as a neutralising discourse. The symmetry between human and non-human actors neutralises the sense of human agency but also diffuses difference. What comes to matter is the network, not the specificities of location, materiality or individual agency. Karen Barad points out that in the Latourean study of 'science-in-the-making,' practices of 'gender-in-the-making' remain a blind spot (Barad 2007, 87-88). In this way, the network operates as a paradoxically ahistorical, universalist and anti-materialist model.

Further, as Andrew Pickering also argues, the relations described by ANT are semiotically, but not practically, symmetrical (Pickering 1995, 15). In an important regard, the notion of delegation is itself asymmetrical, in the sense that it operates as one-way traffic. In Flusser's terms it represents a discursive rather than dialogic relation. From Pickering's perspective, ANT's recourse to semiotics is cast as a retreat into the world of texts and representations in the face of critique (Pickering 1995, 13). Though operating in a different framework, Rom Harré makes the comparable criticism that Latour's model of the instrument as inscription device incorporates 'material things into discourse,' replacing the "world/apparatus/inscription" relation with the binary relation "apparatus/inscription" (2003, 23). In this sense, Latour re-inscribes the textual/theoretical model of science that he would seem to critique.

Many of these issues are most clearly highlighted in Latour's relationship to phenomenology. Latour's version of ANT and phenomenology would seem to have much in common, not least of all, a shared target of critique in the form of the subject/object dichotomy. Similarly, Husserl's call to attend 'to the things themselves!' would seem to resonate with Latour's proposed 'object-oriented democracy' or *Dingpolitik,* with the slogan: 'Back to things' (Latour 2005a, 23). Annemarie Mol suggests that ANT allows analysts 'to attune themselves to the world, to learn to be affected by it' (Mol 2010, 261). Although this characterisation could equally be applied to phenomenology, it follows a caricature of phenomenology as a practice 'that elevates a single person's self-ethnography to grandiose proportions' (Mol 2010, 254). While advocates of ANT emphasise attachment in practice, when it comes to positioning their own approach, such points of crossover and commonality with potential allies are overlooked.

Despite the obvious affinities, Latour suggests that the value of phenomenology is limited to providing what we might—following Donna Haraway (1988)—describe as *situatedness*. Latour acknowledges that phenomenology enables an account of 'how we never distance ourselves from what we see, how we never gaze at a distant spectacle, how we are always immersed in the world's rich and lived texture' (Latour 1999, 9). While Latour endorses 'the rich descriptive vocabulary of phenomenology' (Latour 2005b, 61), ultimately he suggests that phenomenology is too bounded by 'the narrow focus of human intentionality,' which is always his target. For this reason, Latour dismisses phenomenology as ‘of no use in accounting for *how things really are*’ (Latour 1999, 9, emphasis added).

In this appeal to how things really are, Latour reveals a latent transcendentalism. When Latour characterizes the network as ‘all boundary without inside and outside’ (Latour 1996, 372), this bears more than a passing resemblance to the privileged position of the analyst in Descartes’ dualist schema. In adopting the position of ‘an analyst who describes configurations equally from the perspective of humans and nonhumans’ (Verbeek 2005, 168), the network enables what Haraway describes as the ‘god trick of seeing everything from nowhere’ (Haraway 1988, 581). Paradoxically, in attaining a perspective outside of divisions between subject and object, nature and culture, and beyond historical consciousness, the network becomes akin to everything that Latour has critiqued—an ‘immutable mobile,’ universal and timeless. While there is an inherent opposition in his work, between the open system of the network and the closed one of the black box, for Latour phenomenology hovers somewhere in between.

Latour himself contrasts the potential of the network for ‘exploring the ways we can shift from standpoint to standpoint,’ to that of phenomenology in which ‘we will always be fixed in the human one’ (Latour 1999, 9). In this sense, he argues that the very situatedness of phenomenology is incommensurable with the network perspective. For Vilém Flusser, however, the network view is entirely compatible with what he terms ‘phenomenological vision.’ This is a vision of society ‘as a net composed of intersubjective intentional relations,’ which reveals that the categories of Latour’s critique—including society and the individual, subject and object—disappear if the net is unknotted (Flusser 2011c, 237). This is a view that positions phenomenology as a relational field rather than as a subjectivist humanism.

Further, Flusser contends that the photographic camera is a tool for such a relational “phenomenological vision”. This is because, according to Flusser, cameras are ‘tools for assuming points of view as they surround objects.’ The camera, like phenomenological method, ‘reveals ever-new aspects’ of that which it depicts (Flusser 2017a, 244). The apparatus in this case parallels a relational, less subjectivist phenomenology. In Flusser’s view, both enable the movement 'from standpoint to standpoint' that Latour claims is lacking in phenomenology. The potential of such phenomenological perspectives for developing a new conception of the apparatus drawn from the analysis of science and technology forms the focus of the next section.

1.6 Phenomenology and Beyond

Alongside the view of phenomenology as human-centered and solipsistic, a dominant critique of phenomenology is its perceived anti-scientific stance. Bruno Latour describes this as a 'dramatic split' enacted between 'a world of science left entirely to itself, entirely cold, absolutely inhuman; and a rich lived world of intentional stances entirely limited to humans, absolutely divorced from what things are in and for themselves' (Latour 1999, 9). Much of this perspective is based upon Edmund Husserl's formulations of phenomenology.

It is worth noting, however, that Husserl is quite specific in the forms of scientific practice that are the target of phenomenological critique. Specifically, 'positive science,' which Husserl associates with Cartesian rationality, is described as 'a science lost in the world' (Husserl 1999, 157). It therefore becomes necessary to 'lose the world by epoché, in order to regain it by a universal self-examination' (1999, 157). Against the Cartesian 'all-embracing system of deductive theory,' with the self as its stable centre, Husserl offers phenomenology as a corrective '*all-embracing self-investigation*' (Husserl 1999, 154).

In his later work Husserl's critique is focused upon the specific aspect of modern science that he refers to as 'technization' (Husserl 1970, 46). This term does not, however, equate with technology per se, but specifically refers to the mathematical techniques of science, conceived as a 'mere art of achieving' (Husserl 1970, 47). The dominance of such technization leads to 'merely fact-minded sciences' (1970, 6), emptied of meaning (1970, 47). The impetus of this crisis comes from what Husserl refers to as Galileo's 'mathematization of nature' (1970, 23). By means of this mathematization, reality comes to be not what is perceived, but that which is measured (Ricoeur

1973, 90) as an ‘ideal praxis of "pure thinking"’ takes the place of ‘real praxis’ (Husserl 1970, 26). A ‘real praxis’ would be grounded within experiences of the life-world for Husserl, whereas the coherence of science and its theoretical system (defined in terms of universal mathematics) takes on the ‘the character of a single work or edifice’ apparently independent of the life-world, which is in turn forgotten (Husserl 1970, 380, 295). Anticipating both Kuhn and Latour, Husserl suggests that this situation is revealed in geometry textbooks, which present ‘ready-made concepts’ (1970, 366) akin to the black-boxed facts that make up the textbook picture of science.

While Husserl attributes the forgetting of the life-world to Galileo, some argue that he himself forgets Galileo’s instrumental praxis. Don Ihde contends that Husserl too readily accepts a positivist account of scientific practice, which privileges the role of mathematics. As a result, Husserl's version of Galileo ‘is not the lens grinder, the user of telescopes, the fiddler with inclined planes, the dropper of weights from the Pisa Tower’, in other words, ‘Husserl’s Galileo lacks the very mediating technologies that made his new world possible’ (Ihde 2016b, 52). Husserl’s Galileo ‘*is not a telescope user*, but a mathematizer’ (Ihde 1998, 43). On this view, it is Husserl’s account that forgets Galileo’s ‘*material* relation with the "things themselves"’ via instrumentation’ (Ihde 1998, 53). It is this material relation that I consider next, by examining attempts to extend the phenomenological model through analyses of science as a set of practices that are embodied in technology. The examples are the phenomeno-technics of Gaston Bachelard and the post-phenomenology of Don Ihde.

1.6.1 Phenomeno-technics

Bachelard’s approach to scientific practice differs considerably from Husserl’s. In place of Husserl’s view of modern science as a monumental ‘single work or edifice’ (1970, 380), Bachelard proposes a view of science that is discontinuous and diverse (Gutting 1989, 21). Science is discontinuous because progress occurs through a series of ‘epistemological breaks’ rather than smooth linear progression, and diverse because science consists of varying ‘regions of rationality’ (Gutting 1989, 14). Although operating within the epistemological tradition, the work of Bachelard is distinguished from traditional accounts by an increased emphasis on the significance of practice, in foregrounding the role of *techne* in generating knowledge, and not merely applying it. Accordingly, a defining character of modern science is that it ‘*realises* its objects without ever just finding them ready-made.’ Rather, ‘[a] concept becomes scientific in so far as it becomes a technique, and is accompanied by a technique that realises’ its objects (Bachelard 2002, 70). Understood this way, scientific apparatuses and instruments make modern science ‘a discipline of active empiricism’ that ‘actively seeks its complex truths by artificial means’ (Bachelard 1984, 171). Instrumental practice therefore plays a central, not supporting, role in the production of scientific knowledge.

Rather than phenomenology providing a Husserlian corrective to modern science’s ‘technization’ or ‘mathematization’ of the world, for Bachelard it is the technologically engaged nature of modern science that ‘*extends* phenomenology’ (2002, 70). That is, by ‘devaluing’ the obvious or apparent (Tiles 1984, 120), modern science operates in line with the phenomenological emphasis on seeing beyond the naïveté of the everyday and attentiveness to things themselves. On a related note, Bachelard suggests that the interplay between mathematics and material plays a productive role in modern science (Pravica 2012, 164-165). The result is a ‘truly scientific phenomenology’ whose ‘purpose is to amplify what is revealed beyond appearance’ (1984, 13). Bachelard refers to this extended field of phenomenological enquiry as *phenomeno-technique,* variously translated as phenomeno-technology or phenomeno-technics.

Bachelard’s phenomeno-technics brings theory and practice together in the apparatus, but for him the particular duality of apparatus and theory is not ‘oppositional but reciprocal’ (Bachelard 2002, 240). Like earlier philosophers of science, such as Pierre Duhem, Bachelard suggests that ‘instruments are nothing but theories materialized. The phenomena they produce bear the stamp of theory throughout’ (Bachelard 1984, 13). In the process of instrumental materialization, a reversal is effected. While the science of the past aimed to 'create reason in the image of the world; modern science has moved on to the project of constructing a world in the image of reason' (Bachelard 1984, 13). At the same time, this is neither the totalizing reason that was celebrated by positivism, nor the disconnected rationality that was critiqued by phenomenologists such as Husserl and Heidegger.

Husserl's critique suggests that science pursues 'the idea of absolute or scientifically genuine truth,' but it also suggests that this pursuit 'is obliged to modify its "truths" again and again' such that 'it reconciles itself to an infinite horizon of approximations' (Husserl 1999, 12). This 'approximate knowledge' takes on a different cadence in Bachelard's philosophy of science (Bachelard 2005, 176-184), where it is linked to the very instrumental nature of modern science. In contrast to the Husserlian critique of mathematization, Bachelard proposes that the history of laboratory practice 'is very precisely that of its measurement' in all its temporal, material, spatial forms (Bachelard 2000, 77). In contemporary science, the object is *constituted* through the method of measurement, such that the 'measured object is little more than a particular degree of approximation in the method of measurement' (Bachelard 2002, 213), or 'a center of convergence for technical methods' (Bachelard quoted in Smith 2016, 52). One source of this approximation is the relation between theory and practice, or as Mary Tiles puts it, 'between the idealized conceptual schema and its practical application' (Tiles 2005, 170). Another is the way that the object of scientific study can change with new or improved technologies or techniques (Tiles 1984, 134-135); our knowledge is therefore both technically approximate and temporally provisional.

In creating ideal conditions for observation and measurement, the conditions of the laboratory create another form of approximation. Phenomena are 'selected, filtered, purified, shaped' or even wholly produced by instruments (Bachelard 1984, 13). In this way, the apparatus is defined by what it excludes as much as by the observations it enables. Bachelard thus defines an apparatus in terms of:

> the perturbations it guards against, the technique isolating it, the assurance it gives that clearly defined influences can be neglected, in short in terms of the fact that it comprises *a closed system*. There is a

> whole complex of shields, casing, and immobilisers that fences in the phenomenon' (Bachelard 2002, 221).

In this case, the gap between the 'closed system' of the laboratory and the open one of the external world is no longer a source of criticism, as it was for Husserl. Rather, the substitution of the 'realism' of measurement (2002, 213) for the 'reality' of the object reflects the way that 'instrumentalized science' improves upon 'the science of natural observation' (1968, 9).

Though Bachelard celebrates the technological character of modern science, beyond the scientific context the implication of technology as applied science remains. Summing up the distinction between science and technology, he writes, '[o]ne searches for the rational, the other imposes it' (Bachelard 2005, 179). For all its benefits, the ultimate conservatism of Bachelard's position regarding technology is linked to his humanist emphasis on rationality and his association of scientific knowledge with 'mastery over objectivity' (2000, 77). In seeking to extend the sensory knowledge of phenomenology by means of the scientific knowledge of phenomeno-technics, Bachelard opens up a view of scientific practice as it engages with technology. In doing so, however, he also extends the perceived human-centeredness of phenomenology (as critiqued by Latour, for example) in a triumphalist direction. As Babbette Babich states in regard to Bachelard's position, 'a subversive humanism remains a humanism' (Babich 1994, 163). By the same token, we might say that Bachelard's non-cartesian epistemology (1984, 135-177) remains an epistemology. I will next consider a more recent attempt to extend the relational aspects of phenomenology, in the form of postphenomenology.

1.6.2 Postphenomenology

The developing sub-discipline of postphenomenology emerges from Don Ihde's earlier phenomenological exploration of technology (1979). Central to this is a relational view of technologies as forming part of a 'symbiotic,' 'human-technology' pairing rather than existing as 'objects-in-themselves' (Ihde 1991, 74). Donna Haraway underlines the phenomenological implications of this relational analysis, when she states: ‘technologies are not mediations—that is, something in between us and another bit of the world—rather, technologies are organs, full partners, in what Merleau-Ponty called “infoldings of the flesh”’ (Haraway 2006, 175-6). Ihde’s phenomenological analyses of technologies thus reflect the importance of technologies for everyday life. But this also extends to Ihde’s view of scientific practice as both technologically *embodied* (mediated by technologies) and technologically *embedded* (dependent on technology) (Ihde 1991, 141).

Ihde’s analysis of technoscience both extends and modifies the phenomenological tradition. Within this tradition, Ihde extends the emphasis on praxis within the thought of Husserl, Martin Heidegger and Maurice Merleau-Ponty, by moving the phenomenological analysis of perception beyond a ‘passive empiricist stance into the realm of action and sensibility’ (Ihde 1983, 4). This active perceptualist emphasis contradicts the conservative critique of science and technology put forward by Husserl. Against this conservative view, Ihde counters that: ‘in addition to mathematizing, modelling, and formalizing a world, science also *perceives* its worlds, albeit through instruments’ (Ihde 2002, xv). From this perspective, a consideration of contemporary technoscience requires ‘a praxis-perception model’ of scientific knowledge (Ihde 2002, 52). Such a model is provided by what Ihde has termed postphenomenology.

Postphenomenology has been variously referred to by Ihde as a nonfoundational and nontranscendental (Ihde 1993, 7), materialist and pragmatic form of phenomenology (Ihde 2016b, 106). Ihde emphasises, however that it is neither a ‘reductive’ or ‘mechanized materialism,’ but one that entails a ‘phenomenological and multi-dimensioned sense of body’ (Ihde 2010a, iv). Postphenomenology considers technology as part of the lifeworld rather than as a dominating or enframing that is imposed externally; as Ihde stresses, ours is a ‘technologically textured life-world’ (Ihde 1993, 13). While Husserl’s phenomenology is centred around consciousness and subjectivity (Ihde 2016b, 93), postphenomenology instead emphasises embodied action (Ihde 2016b, 129-130). This emphasis on technology is combined with the ‘anti-essentialism and anti-foundationalism’ of post-modern and pragmatist philosophy (Ihde 2016a, 115). In the discussion that follows, I will consider Ihde's phenomenology of technics, which lies at the centre of postphenomenology, before considering the further implications of this burgeoning field.

Ihde's work defines technology as a 'material artifact employed in a praxis which transforms a situation' (Ihde 1986, 105). In Ihde's view, if technologies were 'merely objects totally divorced from human praxis, they would be so much "junk" lying about' (Ihde 1993, 34). Ihde's praxical emphasis manifests itself through empirical—including historical and first-person—accounts of technologies-in-use. From such accounts, he developed a four-fold categorization of relations to technology, which include: embodiment, hermeneutic, alterity and background relations. My discussion will focus on the first two categories, which are the most relevant for this research.

Broadly speaking, the distinction between embodiment and hermeneutic relations echoes that drawn by Flusser between machines and tools. Embodiment relations 'extend or mimic sensory-bodily capacities,' while hermeneutic relations do the same for 'linguistic and interpretive capacities' (Ihde 1991, 75). Embodiment relations involve the 'incorporation' of technology into our experience of the world, while in hermeneutic relations the technology is both 'read' and 'read through' (2009, 43). In the context of scientific practice, the distinction can be thought of as between two trajectories, one toward and the other away from the perceptual (Ihde 1979, 36), or between '*instrumentally enhanced* and *instrumentally translational perception*' (Ihde 2016a, 37). The transformative dimension of both trajectories forms a significant consideration for this research. It is worth considering the nature of these transformations.

Like Flusser, Ihde views technologies as neither determining nor neutral. They can, however, *incline* their users in particular directions by virtue of the particular 'framework for action' that they embody (Ihde 1990, 144). Contrary to a Heideggerean 'enframing,' such inclinations are not inherent to technology but arise in our relations with technology. As Peter-Paul Verbeek puts it, this aspect of the post-phenomenological approach treats subjects and objects ‘not as pregiven entities that assume relations with each other, but as entities that are constituted in their mutual relation’ (Verbeek 2005, 163). Technologies transform our experience of the world, both in term of *what* we experience and *how* we experience it (Ihde 1998, 47). Such transformation is not neutral, but nor is its form wholly determined.

The term embodiment relations therefore indicates those particular human-technology pairings that extend sensory-perceptual abilities. They do so in ways that the technology becomes *incorporated* into its users’ experience of the world. Embodiment relations include the sorts of experiences described by earlier phenomenologists such as Martin Heidegger and Maurice Merleau-Ponty. Perhaps most famous of these examples is Heidegger’s discussion of the hammer, as we have seen, which when used is the *means,* not the *object* of experience, and only becomes ‘conspicuous’ if broken or unsuited for the task (Ihde 1990, 33). Heidegger’s account is simultaneously instrumental and ineffable; the tool withdraws from experience into the project for which it is used.

In Merleau-Ponty’s phenomenology of perception, such tools do not withdraw from experience but are appropriated. In his discussion of bodily motility, Merleau-Ponty cites the examples of a cane *enabling* bodily extension for a blind man and a woman’s feathered hat requiring *accommodation.* Merleau-Ponty’s terminology suggests that through habitual use such ‘instruments’ are appropriated. We become ‘transplanted into them’ or ‘incorporate them into the bulk of our own body’ (Merleau-Ponty 2002, 166). For Ihde, these everyday examples provide ‘a basis for perception at a distance, mediated through an artifact, a technology’ and therefore ‘a latent phenomenology of instrumentation’ (Ihde 1990, 40). If latency characterizes the relation between traditional phenomenology and technology, in postphenomenology it becomes a central concern, especially as developed in relation to scientific instruments.

Ihde’s key category of embodiment relations includes those technologies that are incorporated into our experience of the world just as described by Merleau-Ponty. In terms of scientific instruments, embodiment relations are most clearly exemplified by optical technologies, such as the telescope. The telescope amplifies and extends sensory perception, but it also highlights the transformational nature of technologies, which Ihde denotes as a key aspect of all human-technology relations. The transformation of experience through technologies takes the form of what Ihde describes as an amplification-reduction structure (Ihde 1979, 21-22). In every relation with technology, some aspects of experience are amplified and some reduced.

In the case of the telescope, what is amplified is the reach of visual perception across space. But the object of the telescopic gaze (the moon, for example) is also removed from its relation to the field of the night sky. This expansive field is reduced down to the 'limited instrumental "field"' of the telescope, in turn exaggerating the bodily movement of the user (Ihde 1993, 46). By means of this amplification/reduction, 'both body and moon are thus magnified' and therefore both become 'part of the now technologically transformed observational context' (1993, 46). With habitual use these processes of technological transformation, as with Merleau-Ponty's examples, are themselves transformed, incorporated and accommodated into bodily experience. Karen Barad points out that this 'incorporation' of tools and technologies into our experience of the world serves to blur the distinction between inside and outside, self and world, body and matter in productive ways (Barad 2007, 157). In embodiment relations, this quality of transparency relates to the fact that the technology is a means *through which* the world is experienced. Ihde's model of hermeneutic relations embody a different relation.

Embodiment relations means that we experience the world through technology, whereas in hermeneutic relations the experience occurs *with* technology. Technology is not incorporated in the same way, but remains in a more clearly distinguishable mediating position. Hermeneutic relations are not transparent as the term 'hermeneutic' implies because they involve a 'specialized interpretive act' that is analogous to language (Ihde 1991, 75). Everyday examples include the thermostat, or vehicle dashboard instruments, which give 'readings' at a perceptual remove from their referent. More significant, however, are a range of examples relevant to scientific practice.

Recalling Latour’s inscription devices, these include ‘digital, numerical, or graphed results which are nonisomorphic with the items themselves referred to’ (Ihde 1998, 58). This move ‘away from perceptual isomorphism’ is central to Ihde’s distinction between embodiment and hermeneutic relations, and thus a defining character of the latter’s analogy to texts, the traditional subject of hermeneutics (Ihde 2016a, 38-39).

Ihde’s use of the term hermeneutics builds upon its historical significance as the interpretation of texts. Although the term has its roots in ancient Greek, for most of its history it has been associated with the study of scripture. In the late nineteenth century, the domain of science was divided in two, separating the natural sciences, whereby phenomena are explained in terms of causes, from the human sciences, which interpret phenomena by determining their meaning (Flusser 2002, 4). As a consequence of this disciplinary divide, hermeneutics came to be considered a specifically human science. According to this view, it was therefore possible to perform a ‘*hermeneutic history of science,*’ but not a ‘*hermeneutics of science*’ itself (Ihde 1998, 40). Challenging this traditional distinction, Ihde argues that the specifically technological texture of the contemporary lifeworld, with its new and multiple forms of "texts," therefore requires ‘new types of hermeneutics’ (1998, 23). Ihde’s expanded conception of hermeneutics as ‘interpretive activity’ thereby encompasses not only its traditional domain of text and language, but also the perceptual phenomena of ‘sensory interpretive activity’ (Ihde 1998, 7-8). It not only enables a hermeneutics of scientific practice, but also casts scientific practice itself as a form of hermeneutics.

Building upon his conception of specific types of engagement with technologies, Ihde therefore characterises contemporary science as a form of ‘material hermeneutics’ that ‘constitutes meanings from material’ (Ihde 2016b, 84). He describes this as ‘a "hermeneutics of things," not merely of languages and texts’ (Ihde 1998, 59). Drawing on Paul Ricoeur’s model of hermeneutics as ‘the art of deciphering indirect meanings’ (quoted in Ihde 1986, 172), scientific apparatuses and instruments can be thought of as ‘the means by which unspoken things “speak,” and unseen things become “visible”’ (Ihde 2003a, 20). In this view, the hermeneutic dimension of contemporary science is embodied in the apparatuses that make otherwise unknowable phenomena available to perception.

Practices of instrumental perception are central to this model of science as material hermeneutics. These include what Latour would describe as inscriptions: ‘analogues of texts’ including ‘charts, graphs, models, and the whole range of “readable” inscriptions which remain visual, but which are no longer isomorphic with the referent objects or “things themselves”’ (Ihde 1998, 167). But they also extend to what might be described as visual analogues, including radio telescopes, MRI, computer tomography, false colour, infrared imaging, thermal imaging and magnetometry. As Ihde indicates, such images are ‘always less than and more than a “picture,”’ relying on translation or interpretation (Ihde 2016b, 118). As with my introductory discussion of indexicality—conceived of as a trace stenciled directly off the real—Ihde cautions that such images should not be thought of as isomorphic ‘copies,’ as in earlier representational epistemologies, but as constructions (Ihde 1998, 92).

Methods of image construction include a range of transformations including enlargements, enhancements, contrasts, and even the practice of assigned or ‘false’ colour. Such imaging practices are therefore far from passive observation (Ihde 1998, 59). Each individual image can be the product of decades of data collection, and synthesized from multiple classes, iterations and upgrades of apparatus. The resulting images are not indexical, or even representational, in the traditional sense; they are ‘instrumentally translated’ distillations of data into a form that are designed to be taken in ‘at a glance’ (Ihde 2002, 135). In sum, ‘images don’t just occur. They are made’ (Ihde 1998, 180). As in Latour’s discussion of scientific practice, the constructed nature of such images does not negate their effectiveness, for ‘once made […] they may then be taken as “proofs” within the visual hermeneutics of a scientific “visual reading”’ (Ihde 1998, 180).

For Ihde, the combination of methods employed in contemporary science resonates with phenomenological praxis. Specifically, the combination of instruments and techniques in scientific practice is likened to Edmund Husserl’s use of variational analysis (Ihde 2016b, 84-86). Husserl employed such variations as a means of progressing phenomenological analysis from its grounding in perception, towards identifying the invariant, essential and universal qualities of phenomena (Husserl 1999, 70). For Ihde, by contrast, the 'instrumental phenomenological variations' of contemporary science are a material and embodied equivalent, but with the result that 'with each variation a richer and more complex set of phenomena emerge' (Ihde 1998, 59). The specific use of variational analysis marks an important point of difference between postphenomenology and its classical counterpart. Through variational praxis the contemporary discipline identifies 'multiple ways of seeing, of multiple arrangements, and variants on themes' (Ihde 2016b, 84-86) in place of invariants or essences. Ihde refers to these variations as 'multistabilities.'

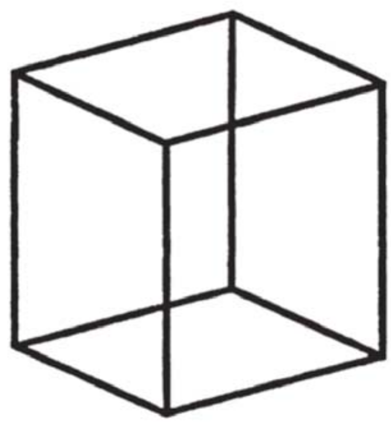


Figure 9: Necker Cube illusion

The notion of multistability comes from the study of optical illusions (Attneave 1971). The term describes the various interpretations possible in illusions such as the Necker Cube, in which a single figure can be seen to represent multiple, incommensurable objects (fig. 9). Ihde argues that postphenomenology highlights such multistabilities, rather than bracketing them out in favour of invariant phenomena as Husserl does (Ihde 2012, 22-25). Similarly, the multifaceted and changing performances of technology as analysed within postphenomenology exemplify muiltstability. Given the open nature of engagements with technologies, and the diverse uses to which they can be directed, Ihde argues that they consequently 'display a range of indeterminancy of meaning' that has implications for the hermeneutic model of technology relations (Ihde 2008a, 182). By foregrounding the 'context-dependent and materially-situated relationality' of technology (Rosenberger and Verbeek 2015, 28), postphenomenological analysis opens up an avenue of political analysis. In postphenomenological thought, the multistability of technology incorporates not only the multiple potential uses of any given technology, but also its 'cultural embeddedness' and operation within different cultural and political contexts (Ihde 2002, 106). Flusser makes a similar point when he states that we see both with our own sense of visual perception and through the 'common sense' of our culture (Flusser 2013a, 66). While Husserl's critique of modern science hinged on the incommensurability of material and theoretical praxis, postphenomenology reframes this complex in terms of different ways of seeing. This is a distinction between the physical, bodily nature of sensory experience, termed *microperception*, and 'cultural perceptions,' termed *macroperception* (Ihde 1993, 7).

Both forms of perception are inter-related and inter-dependent in a figure-ground relation. Ihde asserts that there is 'no perception without embodiment; but all embodiment is culturally and praxically situated and saturated' (1998, 170-171). Together, micro and macro forms of perception constitute a 'situated seeing that is both a seeing *as* ____ and a seeing *from* ____' (Ihde 1990, 42). This mirrors the different conceptions of embodiment within and without the phenomenological tradition. For example, there is the contrast between 'the active body, filled with actional experience,' as conceived by Merleau-Ponty, and 'the culturally fixed and acted upon body' described by Michel Foucault (Ihde 2002, 26). Framed in terms of my introductory discussion of the apparatus, we might say that microperception incorporates the interaction with the apparatus as physical device or *appareil,* while macroperception locates this physical engagement within the social, political and cultural apparatus of the *dispositif.*

Taken together, the modified phenomenologies of Bachelard's phenomeno-technics and Ihde's postphenomenology offer a valuable perspective on modern science as technologically engaged and instrumentally embodied. In contrast to the traditional disembodied perspective of epistemology, they offer a picture of situated knowledge and a model of relational engagement that is illuminating for considering my own creative engagement with the apparatus—and for considering technical apparatuses in creative practice in general. In order to evaluate this relevance to contemporary art, the final sections of discussion will explore the performative models of the apparatus discussed by Andrew Pickering and Karen Barad.

1.7 Performing the Apparatus in Science

Andrew Pickering and Karen Barad take different perspectives on scientific practices, though sharing a background in physics and an emphasis on performative and materialist accounts of scientific practice. It is important to distinguish the broad significance of performativity from narrower conceptions of theatrical performance. Performative approaches decentre the human from the position of prime mover, and instead acknowledge the performative potential of all matter (Barad 2007, 49, 60). Pickering's analysis foregrounds a model of performativity as action, articulated in relation to the material agency of both apparatuses and objects of scientific study. Barad builds upon a tradition of feminist and queer theories of performativity, to emphasise the discursive dimension of the apparatus. Both aspects of this performative emphasis are potentially productive for creative practice, and I will consider both thinkers in more depth in relation to creative practice methodology in the next chapter. In what follows I will briefly introduce the conceptions of scientific practice articulated by Pickering and Barad, and situate these in relation to the broader theoretical context outlined above.

1.7.1 The Mangle of Practice: Andrew Pickering

Combining his own experience as a physicist with a sociological framework, the work of Andrew Pickering seeks to develop what he describes as 'a post-humanist social theory: one that recognizes from the start that the contours of material and human agency reciprocally constitute one another' (2001, 173). His account of scientific practice sheds light on the material and performative aspects of engagement with the apparatus.

The starting point for Pickering's analysis is a conception of scientific practice as 'cultural extension' (1995, 3). The culture of scientific practice, according to Pickering's expanded conception, is 'made up of all sorts of bits and pieces—material, social, conceptual—that stand in no necessary unitary relation to one another' (Pickering 1992, 8). This suggests a diversity of practices through which scientists seek to attain various 'material grips' on the world (Pickering 2012b, 468). In turn, these material grips on the world are primarily achieved 'through the use of machines and instruments and all sorts of contrived setups' rather than 'unaided senses' (Pickering 2015, 120). Even though this implies that scientists gain an indirect access through apparatuses and the data that they produce (Pickering 2012a, 318), this does not to imply remoteness from the object of study, or a Husserlian critique of distance from the lifeworld. Instead it is an acknowledgment of the multiple ways and means through which scientists seek to engage with the world.

For Pickering, the importance of recognising practice as a starting point is the acknowledgement of the symmetry of human and nonhuman actors. The focus on practice focus has a levelling effect, according to Pickering, because it suggests that 'at the level of performance, we are the same as everything else'—scientists are performative agents, but so are 'rocks and stones, cats and TV sets, stars and machine tools' (2013a, 226). In other words, scientists may intervene in the world, but the constituent 'bits and pieces' of the world also intervene in return. The resulting material engagements are situated within and operate alongside social and conceptual elements of practice. It is in the movement *between* the 'machinic' and the 'epistemic' that practice develops. Through this movement, in Pickering's own words, 'articulated knowledge is built in the creation of alignments between machinic performances and conceptual structures' (Pickering 2015, 126). His term for the mapping of these multiple movements and alignments is 'the Mangle of Practice.'

Modeled on the antiquated domestic technology of the hand-cranked washing machine, Pickering contends that the 'mangle' provides 'a *performative* image of science, in which science is regarded as a field of powers, capacities, and performances, situated in machinic captures of material agency' (1995, 7). Importantly, this is not a dominating relation of mastery over inert matter. The products of science are not the result of pure rationality, but are better thought of as 'decentered joint products of the human and the non-human'; both the apparatus and the operator are 'tuned' and transformed (2017, 143). The practices of scientists therefore constitute a 'dance of agency' between human and nonhuman participants (1995, 21), a back and forth movement between scientists, apparatuses and matter.

While emerging from the field of science and technology studies (STS), Pickering's conception of the 'mangle' differs from the kind of social determinism that seeks to identify singular causes, such as social interests or programmatic models of practice, in which analyses might take the form of matching specific instances to predetermined categories (Pickering 1995, 63-66). Yet, it is similar to Actor Network Theory, on the other hand, because the mangle highlights that practice is a complex system of engagements, featuring a multitude of moving parts. The mangle underscores the particularly temporal and emergent nature of practice, which contrasts with the sociological view according to which 'enduring' causes or interests give rise to ephemeral practices. Each element of the mangle, by contrast, is in a constant state of emergent and inter-related becoming.

The mangle, according to Pickering's outline, suggests a responsive exchange between human, material, conceptual and disciplinary agencies. Pickering suggests that scientists might approach the apparatus with theoretical models or goals in mind, but that these are necessarily open-ended in practice. Any pre-conceived model is transformed, or 'mangled', through an engagement with the apparatus (Pickering 1995, 146). Rather than a deterministic descriptive system, the mangle offers a deeply materialist vocabulary to account for scientific practice that contrasts with the traditional emphasis on theory in the philosophy of science. Pickering characterizes the traditional positioning of theory as 'a kind of labor-saving device' that 'tells us what there is in the world, so one doesn't have to look very carefully' (Pickering 2003, 91). The mangle, on the contrary, affords a perspective that is grounded in the messy material specifics of practice and takes us 'into the thick of things—unlike traditional theory, which takes us away' (Pickering

2003, 91). There is no implied hierarchy or opposition between theory and practice; rather to use a Merelau-Pontean phrase, theory and practice are each only revealed in their intertwining.

The mangle is characterized by an open-ended relation to a multiplicity of actors and actions. This includes conceptual frameworks and disciplinary conventions, which are considered as agencies at play within the mangle. These diverse material and immaterial agencies 'interactively stabilise' one another through a process that Pickering describes as a 'dialectic of resistance and accommodation' (Pickering 1995, 23). It is in terms of these diverse relations between human and nonhuman that Pickering emphasizes the 'posthumanism' of the mangle. Posthumanism is therefore defined in terms of its *decentring* of the human rather than its displacement or negation (Pickering 1995, 92). This decentring is an important rejoinder to a perspective that Pickering terms 'human exceptionalism,' a privileging of the human perspective that is shared by the otherwise opposed positions taken by neo-positivism – man as the measure of all things – and social constructivism – in which the human realm of social interests play a determining role.

Pickering's posthumanism reframes the concept of the human as 'malleable, mangle-able, always liable to become something new in interaction with each other as well as with things' (Pickering 2013a, 37). On the one hand, the scientific apparatus is perceived as 'standing apart' from its makers as a relatively autonomous '*free-standing machine',* which ultimately results in 'a sort of *practical duality* of the human and the nonhuman' (Pickering 2012a, 319). On the other, the 'machinic field' of scientific practice remains 'enveloped by the human realm' (Pickering 1995, 16). This conception of posthumanism does not set the human or the material against one another, but views them as always inter-related and co-constituted.

The mangle positions the apparatus as 'the balance point, liminal between the human and nonhuman worlds (and liminal, too, between the worlds of science, technology and society)' (Pickering 1995, 7). The work of Karen Barad seeks to extend this exploration of liminality further through a consideration of 'boundary-making practices'. Though the picture of practice presented by the mangle emphasises the inter-related nature of human and nonhuman, scientists and the ‘nature’ that they study, for Barad the distinction between these categories is not troubled enough in Pickering’s account (Barad 2007, 414 n 47). Barad’s analysis instead develops the posthumanist and performative aspects of the material-discursive apparatus.

1.7.2 The Material-Discursive Apparatus: Karen Barad

Karen Barad brings her own experience as a former experimental physicist to what she characterizes as an experimental metaphysics (Barad 2007, 35) that brings together poststructuralist theory, science studies, and scientific practice. Like Pickering, Barad seeks to avoid the traditional oppositions of constructivism versus realism. Barad’s approach is to ‘read our best understandings of social and natural phenomena through one another in a way that clarifies the relationship between them’ (2007, 25). This project has been described as an ‘onto-epistemology in which being and knowing become indistinguishable’ (Dolphijn and der Tuin 2012, 110). In tracing the entanglement of being and knowing, Barad draws on insights from Quantum physics, in which the role of the apparatus in experiment and observation is shown into sharp relief.

Barad’s model of the apparatus extrapolates the relation of apparatus, phenomena and observer in the work of physicist Niels Bohr. Bohr’s theory of complementarity emphasises that ‘*we are a part of that nature that we seek to understand’* (Barad 2007, 26). Accordingly, Barad’s performative model of scientific practice underscores ‘that knowing does not come from standing at a distance and representing but rather from a direct material engagement with the world’ (2007, 49). Apparatuses are not, Barad contends, ‘passive observing instruments. On the contrary, they are productive of (and part of) phenomena’ (2007, 199). As Barad explains, Bohr defines the concept of ‘phenomena’ as ‘particular instances of wholeness’ (2007, 119) in which the ‘object of observation’ and the ‘agencies of observation’ (2007, 114) are entangled in the form of the apparatus.

In order to convey this sense of entanglement, Barad proposes the term *intra-action*. By intra-action, Barad is looking for a term that goes beyond the usual connotations of ‘interaction,’ which implies autonomous agents that temporarily relate to one another. Intra-action, by contrast, is intended to recognize that ‘distinct agencies do not precede, but rather emerge through, their intra-action’ (Barad 2007, 33). Just as with Andrew Pickering’s account of disciplinary agency, the entangled agencies envisaged by Barad ‘intra-actively’ emerge from scientific practice and have both physical and conceptual dimensions. Thus, for Barad, ‘theorizing and experimenting are not about *intervening* (from outside) but about *intra-acting* from within, and as part of, the phenomena produced’ (2007, 56). However, her account goes beyond the primarily machinic materialism of the mangle in order to consider concepts *as* material practices (Hinton 2013, 180) and as ‘*specific physical arrangements*’ in which ‘measurement and description (the material and the discursive) entail each other’ (Barad 2007, 109). As Donna Haraway points out, the ‘material and semiotic apparatuses’ that figure in the notion of intra-action ‘cannot be separated’ (Haraway 1996, 116). In this way, the discursive qualities of performance and the performative aspects of discourse are entangled.

Citing Bohr, Barad argues against any simple opposition between theory and practice. Instead, she asserts ‘theorizing must be understood as an embodied practice, rather than as a spectator sport of matching linguistic representations to preexisting things’ (Barad 2007, 54). Haraway’s discussion of biological science also supports this point. She asserts that discourses ‘are not just "words"; they are material-semiotic practices through which objects of attention and knowing subjects are both constituted’ (Haraway 1996, 218). Similarly, Barad argues:

> it is not merely the case that human concepts are embodied in apparatuses, but rather that apparatuses *are* discursive practices where the latter are understood as specific material reconfigurings through which “objects” and “subjects” are produced (Barad 2007, 148).

This suggests that the traditional Cartesian dualism of subject and object are not to be viewed as pre-existing, independent entities, but material-discursive productions of the apparatus.

Barad's philosophy considers the role of the apparatus in making these material-discursive properties determinate. Just as in Bohr's discussion of 'measurement interactions' between apparatus and object, 'certain properties *become determinate*, while others are specifically excluded' (Barad 2007, 12). Which are made determinate and which excluded is dependent on the specificities of the apparatus in each case. Analysis therefore requires attentiveness to these differences as they emerge through intra-action. Such a methodology sheds light on 'how different differences get made, what gets excluded, and how those exclusions matter' (2007, 29-30). Barad identifies what she terms a 'diffractive methodology', which means a method that is sufficiently 'attuned to the entanglement of the apparatuses of production' that it enables an attentive analysis (Barad 2007, 29-30).

In physics, the principles of diffraction foreground the wave structure of light. Diffraction gratings are apparatuses that generate interference patterns within waves for analytical and experimental purposes. As a methodology, Barad asserts, diffraction 'enables genealogical analyses of how boundaries are produced rather than presuming sets of well-worn binaries in advance' (2007, 30). The wave-particle duality exposed by diffraction it provides both a model and a means for considering the material-discursive duality of the apparatus. These ideas lay the platform for the discussion that follows in the next chapter, where I consider their value for a creative practice-led methodology.

1.8 Conclusion: Re-Defining the Apparatus

In light of the philosophical perspectives on the apparatus surveyed in this chapter, we can refine the parameters of the apparatus taking into account the debates surveyed in this literature. The broad foundations of this revised concept of the apparatus are provided by Vilém Flusser's definition that spans diverse disciplines and media, encompassing analogue, digital, artistic as well as scientific variations. My studio-based practice pursues an experimental engagement with the apparatus that accords with Flusser's encouragement to 'play against the apparatus in order to bring to light the tricks within' (Flusser 2000, 27). This approach enables me to explore the productive potential of many approaches discussed in this chapter, such as technical breakdown (Akrich 1992, 224), 're-inscription' (Akrich & Latour 1992, 259-262) or interventionist 'intra-action' (Barad 2007, 56). These experimental engagements with the apparatus are 'tricks' that can be employed to make the apparatus itself talk (Latour 2005b, 79); to highlight the operations that are often concealed by its nature when it is considered a 'black box' (Flusser 2000; Latour and Woolgar 1986; Latour 1987; 1999, 304; Latour 2007a, 141); or to expose what is overlooked by virtue of its habitual incorporation (Merleau-Ponty 2002, 166). In this sense, the apparatus figures both as a means and as an object of reimagination.

This approach also acknowledges the productive and performative agency of the apparatus (Barad 2007, 199). This agency is simultaneously material and discursive in nature (Barad 2007, 148). The ontologies of both apparatus and operator are redefined through a dialectic of resistance and accommodation (Pickering 1995, 23). The experimental approach enables a redirection or redistribution of the inclinations, amplifications and reductions embodied in particular apparatuses (Ihde 1979, 21-22; Ihde 1990, 144). More broadly, this permits an experimental approach that highlights the way that the apparatus, like technology in general, inevitably transforms the experiences that it mediates and facilitates. Of course, this challenges the idea that the apparatus functions as a neutral medium (Ihde 1998, 47). At the same time, such an approach must remain aware that the transformations produced by the apparatus are neither inherently negative or determinist, nor positive or utopian (Flusser 2011b, 4).

Apparatuses form part of an attempt to order and interpret the world in which they operate. Experimental interventions in these processes of transformation and translation can extend these activities in new directions, exploring the multistable potentialities of apparatuses (Ihde 2002, 135; Ihde 2016b, 84-86) and advancing new means of being in the world beyond familiar perception. By isolating and re-contextualising phenomena (Bachelard 1984, 171; Bachelard 2002, 70), apparatuses offer a means of *multiplying perspectives* that has parallels to the variational analysis of phenomenology (Flusser 2017a, 244; Ihde 1998, 59) and ANT analysis. My own creative practice also seeks to acknowledge both the 'microperceptual,' embodied dimensions of the apparatus and the 'macroperceptual' cultural and social contexts in which this engagement takes place (Ihde 2002, 26).

The research therefore is informed by the productive interplay between Actor-Network Theory and Postphenomenology; both claim an anti-essentialist and nonfoundational approach that 'introduces variations, sets up contrasts, and, time and again, proposes shifts' (Mol 2010, 256). The value of ANT for this research is the same as that ascribed to semiotics and phenomenology by ANT theorists. It offers a source of rich vocabulary and accounts of practice that offer illuminating insights into human-technology relations. Because this research focuses upon the material, perceptual and embodied relations of the apparatus, the insights of postphenomenology and the performative accounts offered by Andrew Pickering and Karen Barad have a particular resonance. The following chapter will extend these insights into practice by considering crossovers (and interactions) between art and science within the context of my research methodology.

Chapter 2. Working Through the Apparatus: Methodology

2.1 Introduction

This practice-led research emerges directly from the concerns of my visual arts practice. In this context, material and conceptual generative activities are interrelated and each informs the other, making reflective practice essential in both studio and theoretical research. This echoes Mika Hannula's formulation of artistic research as 'that interaction, where the two sides of practice and theory shape and shake each other' (2004, 76). This chapter will extend and develop perspectives on the apparatus that were discussed in the previous chapter, to consider their specific import within the particular context of a practice-led research methodology.

This chapter outlines the grounding of practice-led research and its specific potential for a hybrid methodology with philosophies of science and technology. The performative models of scientific practice proposed by Andrew Pickering and Karen Barad are of particular relevance here, and their specific cogency for practice-led research will be discussed. Finally, I discuss methods of re-creation and re-enactment as tools for a performative analysis, as they feature in both science and technology studies and the emerging subdiscipline of media archaeology. These methods establish connections between present and past practices and therefore contextualise the historically engaged focus of this research project.

2.2 Dialogue Between Discourses: Practice-led Research and Philosophies of Science and Technology

This research reflects on my own practice-based, dialogic engagement with the apparatus, through reference to conceptions of the apparatus in discourses surrounding science and technology. In this sense, the research relates to a history of interactions between the disciplinary categories of the 'sciences' and the 'humanities.' C.P. Snow's 1959 lecture *The Two Cultures* remains a key reference point for such discussions. However, it is worth emphasising that Snow's real target is the integration of scientific education within other academic disciplines (1993, 99). His incredulity at 'how very little of twentieth-century science has been assimilated by twentieth-century art' (Snow 1993, 16) and critique of the lack of communication between the opposing cultural elites of 'literary intellectuals' and 'alpha plus scientists' (Snow 1993, 4; 37-38), are only a foundation for his advocacy of science.

More recent work that seeks to bridge this cultural gap, such as that of James Elkins, is similarly structured along disciplinary lines already established within academia (see especially 2007, 2009). Elkins' survey of interactions between the humanities and sciences identifies four methodological approaches, all centred around the notion of explanation. These comprise: 'texts in which art explains science;' 'where science explains art;' where 'a third discipline, normally philosophy,' explains both art and science; or finally an approach 'where various disciplines are put in ambiguous conjunction' (2008,11; 14). To this list Elkins adds what is, by implication, his own unique methodological approach, a 'noncausal' approach that does not seek explanation (2008, 14). In eschewing explanation, this research project's approach is similarly noncausal. But unlike Elkin's account, this research does not start from the entrenched disciplinary divisions of the sciences and the humanities. Instead, the research emerges from the relationship of multiple practices centred around the apparatus. Like Elkins' third category, it could be said to adopt an ambiguous conjunction of disciplinary approaches, many of them consciously drawn from outside of science itself, including histories and philosophies of science and technology.

In one very important sense, however, this research also operates outside of the parameters of Elkin's proposed methodological categories. While overlapping with Elkin's academic discipline of art history, the practice-led nature of this research further precludes the notions of explanation, or cause and effect, inherent to his account. Instead, it echoes a strain of discourse that runs throughout the development of practice-led or artistic research – although with a very different emphasis. Such comparisons have historically attempted to align artistic discourse with the established criteria of scientific research, or to ally artistic and scientific research via rhetorics of innovation (e.g. Charyton 2015; Bast, Carayannis and Campbell 2015). As noted in the previous chapter, the emergence of ‘natural’ sciences such as physics, chemistry and biology, as objects of study for ‘human sciences’ such as sociology and psychology, was a contentious issue within twentieth-century philosophy of science. Ironically, confrontations between these ‘hard’ and ‘soft’ sciences (Latour 2003b, 30) have been highly productive for the even softer, nebulous science of practice-led research. One example is Michael Polanyi’s reframing of scientific knowledge as grounded in routines of practice, which sought to emphasise the personal and social dimensions of scientific practice. His notion of ‘tacit knowledge,’ with its suggestion that practitioners ‘know more than they can tell’ (Polanyi 1967, 4) is particularly relevant for conceptions of creative practice (see, for example, Jarvis 2007).

Similarly, Donald Schön’s quest for an ‘epistemology of practice’ positioned itself in opposition to the technical rationality that he equated with Positivist epistemology (1983, 31-34). To some extent this quest was motivated by a perceived privileging of the academic researcher’s role over that of the practitioner (1983, 26). In order to foster new insights into the ‘professions’ of architecture, engineering, management, planning and psychotherapy, Schön adopted a strategy shared by contemporaneous social studies of ‘science in the making’, concentrating on ‘situations of uncertainty, instability, uniqueness, and value conflict’ (1983, 49). At the same time, he was concerned to ‘increase the legitimacy of reflection-in-action’ by linking ‘the art of practice in uncertainty and uniqueness to the scientist’s art of research’ (1983, 69). This concern for legitimacy is shared by many who have applied Schön’s model of reflective practice to discussions of practice-led research, where his combined explication of reflection-in-action and reflection-on-action has been highly influential (e.g. Gray and Malins 2004, 22-24). But while Schön’s analysis sought to discern the artistry within the practices of scientific and technical rationality (1983, 34), in the practice-led context it also enables the opposite trajectory; phrased in Actor Network terms, reflective practice becomes a means for the arts to enlist the sciences as allies.

The significance of reflection for practice is further extended within science and technology studies (STS), through the related idea of reflexivity, which Latour and Woolgar define as an acknowledgment *within* STS accounts ‘that observers of scientific activity are engaged in methods which are essentially similar to those of the practitioners which they study’ (1986, 30). Despite sociologists’ emphases on symmetry, Woolgar argued that sociological accounts of scientific practice can easily assume an objective stance within their own practice, while affirming the relativism and fallibility of the disciplines under analysis (1982, 486). In contrast to such ‘instrumental accounts,’ he advocates a reflexive approach that ‘would seek ways of retaining and highlighting’ its own fallibility, arguing: ‘the fact that all our analyses are essentially flawed is better celebrated than concealed’ (Woolgar 1982, 494).

In refusing to play the part of impartial observer, the reflexive approach mirrors Donna Haraway’s urge for an acknowledgement of the ‘partial perspectives’ that inform analysis, and the role of the analyst as a ‘split and contradictory self’ (Haraway 1988, 586). In Woolgar’s work this involves the conscious foregrounding of the analyst as a character within a narrative whose subject is ‘the construction of fictions about fiction construction’ (Latour and Woolgar 1986, 282). Citing the influence of Haraway and other feminist writers, the work of Don Ihde similarly seeks to situate its author through the inclusion of autobiographical and anecdotal asides (2016b, xvi-xvii). While these approaches emphasise the necessity for acknowledging the situated and constructed nature of one’s own account, in the case of practice-led research it would seem that the practitioner is always already situated at the centre of any practice-led research. In comparison to research approaches modeled on the impersonal scientific ideal, the personal involvement of the researcher is viewed as a limitation (Griffiths 2011, 179-180). This is a question I will return to below.

As Bruno Latour ventures, the arts would seem to be an ideal candidate for constructivist analysis, given that ‘the constructivist character is built into the arts in a different way than in to a scientific fact’; specifically, while constructivist accounts of practice are often taken as attacks on scientific knowledge, Latour suggests that this perspective ‘flatters some essential feature of the arts’ and ‘adds to the pleasure' of an artwork (Latour 1998, 423). Despite these assertions, this research addresses a certain ‘black boxing' of the apparatus that is common to both scientific and artistic discourse. The research therefore draws upon recent traditions within philosophy of science and technology that seek to reveal the previously obscured practices and technologies that are central to the production of scientific knowledge.

The 'disciplinary looseness' of STS (Jensen 2004, 230) and the 'nomadic traversing' of academic disciplines enacted in new materialist philosophy (Dolphijn and der Tuin 2012, 100-101), provide a fitting compliment to the previously noted 'undisciplining' performed by practice-led research (Rogoff 2010, 40). Like practices such as Actor Network Theory, practice-led research multiplies connections between sites and ideas, and offers mobility between diverse perspectives. In contrast to the traditional view of scientific method as developing general laws or principles, Irit Rogoff posits practice-led research as a means of *singularising* knowledge (2010). Indeed, Dolphijn and der Tuin go so far as to suggest a reciprocal modelling of art and philosophy within new materialist philosophy, in that 'the experience of a piece of art is made up of matter *and* meaning. The material dimension creates and gives form to the discursive, *and* vice versa' (Dolphijn and der Tuin 2012, 91). This relationship between the material and the discursive is central to the work of Karen Barad, which will be discussed below.

The outcomes of these attempts to present a less detached, more situated and reflexive vision of scientific knowledge and its development, often map easily onto the already situated and reflexive practices of the artist. This research seeks to extend this relationship, foregrounding cross-disciplinary dialogue and rigorously examining ideas of the apparatus *in context,* as well as in relation to my practice. The research responds to conceptions of practice that engage with the apparatus and seeks to be attentive to the transformations that occur in this process. This response is performed both through the content of the work and through its methodological engagement with the apparatus. In this sense, the apparatus is simultaneously subject, material, and methodology. In what follows I will consider the relevance of specific methodological frameworks offered by the work of Andrew Pickering and Karen Barad, before turning to consider the specific methods employed within this research.

2.3 Hybrid Methodologies of the Apparatus

In the context of contemporary art, writers such as Dorothea von Hantelmann have emphasised the performativity of the art object. Cautioning against the simple equation of performativity to 'performance-like,' Hantelmann instead defines the performativity of artworks in terms of their capacity to provoke change in the world (Hantelmann 2010, 17-20). Similarly, both Andrew Pickering and Karen Barad develop accounts of scientific practice that specifically explore performativity in relation to the apparatus. Pickering's characterisation of the flows and interactions involved in working with apparatuses resonates strongly with my own material methods. Barad's modelling of the apparatus as simultaneously material and discursive highlights the interactions between practice and theory that are essential to my own creative engagement with the apparatus. In this section I will consider the particular potential of these ideas for creative practice-led research, and outline the ways that this research project draws on the specifically material and machinic model of practice that results.

2.3.1 The Mangle of Creative Practice

As introduced in the previous chapter, the work of Andrew Pickering attempts to develop a 'performative' image of science as practice, rather than as epistemology. In contrast to traditional models of epistemology, Pickering states that in his own experience: 'if there is a sun around which all else revolves, it is performance, not knowledge' (2010, 381). The name given to this particular model, 'the Mangle of Practice,' comes from the domestic sphere, in the form of a washing ringer, also known as a mangle – although Pickering freely acknowledges that the metaphor does not bear too much scrutiny (1995, 23). For Pickering's purpose the irreverence of the metaphor for scientific practice is significant; as a technology this sort of mangle is mundane; it does not run smoothly, but requires laborious and thoroughly embodied input in order to operate. In these senses, it marks Pickering's opposition to what might be called a classical view of science as epistemology, in which scientists figure as 'disembodied intellects' (1995, 6). More significant is the fact that, like practice itself, 'mangle' is both a noun and a verb. It therefore conveys a sense of practice as both a system and a process.

In contrast to theory-centric, classical models, the mangle emphasises open-endedness and foregrounds the responsiveness of practice in a way that would seem to be productive for creative practice. Despite this, engagements with the mangle in relation to practice-led research have been scarce, and largely indirect (see, for example, Bolt 2013, 6). More recently, Pickering himself has turned his attention to discussions of artistic practice, but with an emphasis on questions of emergence and becoming that connects cybernetics to Eastern spirituality. The mangle's focus on performativity shifts to what Pickering calls 'ontological theatre,' a means of modelling and acclimatising viewers to 'processes of unpredictable emergence' that constitute being in the world (2016, 3-4). Ironically, this conception of creative practice implicitly relegates it to a rehearsal ground for a 'real' becoming, a representationalist mode like that so heavily critiqued within STS.

Despite Pickering's recent interest in creative practices, the mangle remains most closely linked to other accounts of practice in STS. As discussed above, in science contexts such accounts serve to destabilise the fixity of scientific knowledge, while in the context of creative practice their scientific credentials simultaneously stabilise conceptions of creative practice. Indeed, the model of the mangle has considerable similarities with an array of creative practice models. These include developments based on Donald Schön's 'enquiry cycle,' which famously incorporates the modalities of reflection-in-action and reflection-on-action (Haseman 2007, 152-153). Further developments of reflective practice are especially congruent with the mangle, such as the fusion with rhizomatic thinking in the "iterative cyclic web" of practice-led research and research-led practice, posited by Hazel Smith and Roger Dean (2009, 19-25). Similarly, Elias Carayannis and David Campbell posit 'Quadruple and Quintuple Helix Innovation Systems' as means of capturing the 'non-linear' innovation that characterizes artistic research (2015, 46) for potential export to other disciplines. However, in emphasizing the open-endedness of practice, the mangle also highlights the non-linear nature of all innovation. While this research draws upon the general commensurability of these disciplinary models of practice, the specific model provided by the mangle resonates with my own practice experience.

As discussed earlier, from the perspective of the mangle, scientists' engagements with technology constitute a 'dance of agency' between human and material participants (1995, 21). While scientists might approach the apparatus with theoretical models or goals in mind, these are inherently open-ended in practice. They are transformed, or 'mangled', through an engagement with the material agencies of the subject of their study, as well as the material agencies of the apparatus(es) through which this study is performed (1995, 146). For Pickering, practice is a 'dialectic of resistance and accommodation' (1995, 23) in which:

> resistance denotes the failure to achieve an intended capture of agency in practice, and accommodation an active human strategy of response to resistance, which can include revisions to goals and intentions as well as to the material form of the machine in question and to the human frame of gestures and social relations that surround it (1995, 22).

Practice unfolds through the back and forth of 'free and forced moves', as well as false starts, the re-tuning of apparatuses and revision of goals. As a result, Pickering emphasizes that 'goals should be seen as in the plane of practice […] rather than as controlling practice from without' (1995, 20). Thus, the human, material, conceptual and disciplinary agencies that make up the mangle are 'interactively stabilized' and 'constitutively intertwined' within it (1995, 17). This is significant for both creative and scientific practice, in the unsettling of traditional narratives of mastery.

As in Actor Network Theory, the symmetry of human and material agencies are emphasised in the mangle. As noted earlier, this is a de-centring of the human, not a total displacement; in Pickering's words: 'the human actors are still there but now inextricably entangled with the nonhuman, no longer at the centre of the action and calling the shots' (1995, 26). While this would seem to be compatible with Karen Barad's version of posthumanism as ‘not calibrated to the human’ (2007, 136), she suggests that the mangle remains too centred on the human. For Pickering, the practice of science remains ‘enveloped by the human realm’ (1995, 16).

In the remainder of this section I will consider some important points on which the disciplinary agencies of the mangle and practice-led methodology might fail to interactively stabilise. The first of these relates to the emphasis on symmetry between human and material agencies within the ‘mangle’ of practice. This symmetry is cast in such a way as to suggest that human and material agency cannot be in operation at the same time, creating an alternating on/off binary. The result is that a range of activities that are central to practice-led research – namely activities such as observation, recording and reflection - are explicitly defined as passive (Pickering 1995, 51). There is, in this sense, no ‘reflection-in-action’ in the mangle, only retrospective ‘reflection-on-action.’

The notion of passivity connoted by the mangle reflects the schism between ‘image’ and ‘logic’ traditions, as recounted in Peter Galison’s history of twentieth-century physics. One of the key critiques directed at ‘image’ practitioners by those in the ‘logic’ camp was the perceived passivity of their methods, in particular their reliance on photographic recording (Galison 1997, 25; 434). The bubble chamber, which features as a key subject in Pickering’s account of the mangle (Pickering 1995, 37-67), was a prime target for this allegation of passivity (Galison 1997, 497). For Galison, the antipathy between image and logic traditions was largely resolved with the emergence of digital imaging, which effectively combined knowledges drawn from the differing methods of ‘the passive registration of the eye’ and ‘manipulation’ (1997, 810). While in this sense the model of passivity is seen as historical and contingent, associated with particular material arrangements of apparatus, in the mangle it remains an implicit feature of all engagements with the apparatus.

Another key limitation posed by the mangle in relation to practice-led methodology is its grounding in sociological approaches. While Pickering characterises the mangle as a potential ‘theory of everything’, its application tends towards similar retrospective narratives that describe the evolution of practices, techniques and technologies. For example, in his original formulation of the mangle, he narrates the conception, construction, implementation and modification of various scientific apparatuses such as the bubble-chamber, an apparatus developed to render the trajectory of otherwise imperceptible particles visible and recordable; he traces its evolution into ever larger and more complex assemblages of technologies and people (1995, 37-67). A similar approach characterises the work of those that have subsequently taken up the mangle as a means of performing sociological analyses on a variety of disciplines, a representative sample of which includes archaeology (Huvila 2016), pig-farming (Coppin 2008), environmental management (Asplen 2008) and Chinese medicine (Scheid 2008). While the mangle provides a descriptive vocabulary that vividly articulates many aspects of my own practice-based engagement with the apparatus, its potential as a generative methodology is not complete. The integration of the mangle into the strategies of practice-led research, as an *active* form of reflection-in-action, is one methodological challenge undertaken by this research.

Andrew Pickering's formulation of the mangle offers a means of articulating practice as an intertwining of human and material agencies. As such, it also provides a means of productively conceiving of an artistic engagement with the apparatus. This model foregrounds the open-endedness of goals in scientific practice, and traces their stabilization through human and material performances of agency. In this, it counters static or sedimented conceptions of knowledge. In the context of creative practice this quality of open-endedness persists, with meaning remaining open to interpretation rather than being fixed in or through the artefact. Nevertheless, this research draws upon the mangle as a vocabulary for articulating an engagement with the apparatus, and model that reflects (and reflects on) the intricacies of this process.

2.3.2 The Diffractive Practitioner

The work of Karen Barad, like that of Andrew Pickering, seeks to articulate a performative account of practice, distinct from traditional conceptions of both epistemology and ontology. Both writers emphasise the posthumanist nature of performativity, and the necessity of accounting for qualities of emergence and becoming. While Pickering's model of the mangle accentuates the material—and more specifically machinic—character of scientific practice, for Barad it is the entanglement of the material and the discursive that is of interest. This emphasis on the generative performativity of material-discursive intra-actions resonates with many aspects of practice-led research. Drawing on insights from quantum physics, Barad defines the apparatus in terms of 'differences that matter' within the intra-active production of phenomena (2007, 208). On one level, this expands the scope of what counts as an apparatus, in both its material and discursive dimensions. The resulting potential for generalization, however, makes it even more important that the specificity of the apparatus is highlighted in each instance. The expanded scope afforded by Barad's model of the apparatus makes it amenable to an engagement with practice-led research. In this regard, it parallels the transition of reflective practice across disciplinary boundaries, which has been discussed above. At the same time, Barad critiques discourses of representation and reflection that are also foundational for practice-led research. I will first appraise the notion of the material-discursive in the context of practice-led research, before surveying the grounds of her critique of reflection and the implications of the diffractive methodology proposed in response. Given my inter-disciplinary focus on the performativity of the apparatus, I suggest that this methodology has particular significance for this particular practice-led research.

As in the work of Andrew Pickering, Karen Barad emphasizes the potential of performative frameworks for collapsing the oppositions that traditional epistemologies rely upon. While for both thinkers, performative accounts ground accounts of practice 'in the thick of things,' for Pickering it is the objective distance implied by theory, and opposed to practice, that is at issue. The object of critique for Karen Barad, however, is the representational framework that establishes this picture of distanced theory. Thus, she argues:

> *Performative* approaches call into question representationalism's claim that there are representations, on the one hand, and ontologically separate entities awaiting representation, on the other, and focus inquiry on the practices or performances of representing, as well as the productive effects of those practices and the conditions for their

> efficacy. A performative understanding of scientific practices, for example, takes account of the fact that knowing does not come from standing at a distance and representing but rather from *a direct material engagement with the world* (Barad 2007, 49).

Rather than a reframed opposition between theory and practice, in Barad's thinking it is the conception of theory *as* practice, and more especially as *material* practice, that is at stake (2007, 54-55). Performativity thus entails not merely a different opposition, but an entirely different perspective, which recognizes that the 'entangled practices of knowing and being are material practices' (2007, 379). Thus it is not theory 'which positions us above or outside the world we allegedly merely reflect on,' but a *representationalist conception of theory*, in contrast to which 'a performative account insists on understanding thinking, observing, and theorizing as practices of engagement with, and as part of, the world in which we have our being' (2007, 133). This material dimension of theory and the critique of representation both have potential significance for practice-led research methodologies.

Barad's employment of the material-discursive builds upon the conception of the apparatus figured in Niels Bohr's Quantum physics. Thus Bohr's observation that measurement and description entail each other comes to reflect the fundamental relationship between the material and discursive (Barad 2007, 109); neither is prior to the other (2007, 177), both are mutually implicated and entailed (2007, 152, 184), to the extent that Barad states: '"material" is always already material-discursive' (2007, 153). Hence, 'the point is not merely that there are important material factors in addition to discursive ones; rather, the issue is the conjoined material-discursive nature of constraints, conditions, and practices' (2007, 152). The material and the discursive are in this sense 'mutually implicated' (2007, 244); entangled, co-producing and productive.

An important aspect of Barad's philosophy-physics, which distinguishes it from much contemporary philosophy of science, is that traditional distinctions such as those between cause and effect (Barad 2007, 214), 'subject and object, nature and culture, fact and value, human and nonhuman, organic and inorganic, epistemology and ontology, materiality and discursivity' (2007, 381) are not refuted but re-imagined as effects of practice. For example, like accounts such as Latour's, Barad seeks to reveal the constructed nature of the subject-object distinction, arguing that: 'subjects and objects do not preexist as such but are constituted through, within, and as part of particular practices' (Barad 2007, 208). Unlike Latour, however, Barad does not equate this awareness with an complete erasure of the distinction. Rather, this is part of the nature of the apparatus; '*apparatuses are not mere observing instruments but boundary-drawing practices - specific material (re)configurings of the world-which come to matter*' (2007, 206). For Barad, the apparatus is not a discrete entity occupying the mediating position between subject and object – indeed, none of these categories are discrete, pre-existent or inherent, but are qualities 'made determinate' (2007, 19) by the boundaries that are produced through intra-action.

Barad argues that traditional philosophical models fail to account for the entangled nature of phenomena. In particular, traditional models of knowledge such as representationalism (Hacking 1983) assume an inherent 'ontological distinction' between 'two distinct and independent kinds of entities - representations and entities to be represented' (Barad 2007, 46). Moreover, she suggests that more recent rejoinders to these traditions serve to reinforce the representationalist picture, for example by re-centering the human as ultimate cause in sociological or relativist accounts. Similarly, for Barad the reflexive approach advocated by some in STS (Woolgar 1982, 494; Latour and Woolgar 1986, 30) only serves to re-confirm a series of problematic assumptions. Phrased in representationalist terms, reflexivity positions the knower in relation to representations and objects of knowledge (Barad 2007, 86), but without troubling the distinction between these terms. From this perspective, reflexivity mirrors representation; it 'still holds the world at a distance' and 'does nothing more than mirror mirroring' (2007, 87, 88). Writing of a similar sense that 'reflexivity, like reflection, only displaces the same elsewhere,' Donna Haraway proposed diffraction as 'an optical metaphor for the effort to make a difference in the world' (Haraway 1996, 16). The work of Karen Barad seeks to develop diffraction from an imagined semantic category (Haraway 1996, 16) to a material-discursive methodology.

Diffraction patterns are created by the interaction (or in Barad's terms, intra-action) of waves with each other or with other objects (Barad 2007, 28). Observations of the diffractive properties of light led to the formulation of the wave-particle duality, a cornerstone for the foundation of Quantum physics. As discussed previously, the wave-particle duality was a central concern in Niels Bohr's 'proto-performative' philosophy-physics – that is, in Barad's reformulation, light *performs* as particle or wave depending on the apparatus with/in which it intra-acts (Barad 2014, 180). Significantly, diffraction troubles the traditional conception of the behaviour of light. In particular, it reveals the linear, ray-based model of light in geometrical optics - on which metaphors of reflection are based - as an approximation schema that represents only certain aspects of this behaviour (Barad 2007, 81). Hence the significance for both Haraway and Barad of diffraction as an alternative optical metaphor that highlights, rather than excludes, patterns of difference.

In Haraway's formulation, the rhetoric of reflection involves the replication, reproduction and displacement of sameness, while in contrast diffraction is an *interference* phenomenon that 'does not map where differences appear, but rather maps where the *effects* of difference appear' (Haraway 2004, 70; see also 1996, 268). Beyond the registration of difference, Barad argues that diffraction apparatuses 'highlight, exhibit, and make evident the entangled structure of the changing and contingent ontology of the world, including the ontology of knowing' (2007, 73). The reflexive goal of putting the observer back in the picture does not take sufficient account of our part in the 'world's differential becoming' (Barad 2007, 91). More specifically, in bringing into focus '*the entangled nature of differences that matter*' (Barad 2007, 381) and enabling 'the processing of small but consequential differences' (Haraway 2004, 97), Barad suggests that 'a diffractive methodology is respectful of the entanglement of ideas and other materials in ways that reflexive methodologies are not' (Barad 2007, 29-30). Given the emphasis on reflective practice, what potential does such a diffractive methodology hold for practice-led research?

It is worth noting that, as a methodology, diffraction features most prominently as a means of comparative analysis. Physical diffraction effects are complex phenomena, and as such are studied in the laboratory by means of reductions – for example, projecting homogenous or monochromatic light (that is, of a single wavelength) through slits to control its amount and direction. The aim is not to eliminate complexity, but to produce the phenomena within perceptible limits. The most famous example of this is the two-slit experiment, which for physicist Richard Feynman 'has in it the heart of quantum mechanics. In reality, it contains the only mystery' (quoted in Barad 2007, 73). In its discursive form, those performing a diffractive reading often bring together the work of different thinkers in order to consider the overlaps and interferences between patterns of thought (e.g. Hoel and van der Tuin 2013; van der Tuin 2014; Geertz and van der Tuin 2016). In contrast to the simplified schematics of geometric optics, diffraction emerges as a means of both multiplying and mapping complexities.

Though less explicitly articulated *as* methodology, in Haraway's case diffraction can be seen as a further development of her earlier call for partial perspectives, an attempt to reformulate conceptions of scientific objectivity in terms amenable to feminist and postmodern frameworks. In place of a discrete and distinct knowing subject, Haraway proposed a partial, imperfectly 'constructed and stitched together' knowing self (Haraway 1988, 586). Her later development of diffraction can be thought of as a radical, fragmented version of post-phenomenology's variational practice, aimed less at identifying multistabilities than acknowledging instabilities and inconsistencies; a form of 'postmodern plurivision' (Ihde 1990, 174) that leads to a model of objectivity as 'comparative *knowledge*' (Haraway 1988, 597 note 5). In Haraway's work these plural and partial perspectives are afforded by scientific disciplines including primate studies, biology, anthropology and sociology, diffracted through semiotics, popular science reporting, science fiction novels and cinema, advertising, and personal narrative.

The comparative aspect of Haraway's work is accentuated in Karen Barad's methodology of 'diffractively reading the insights of poststructuralist theory, science studies, and physics through one another' (Barad 2007, 135) with an awareness 'for the patterns of resonance and dissonance they coproduce' (Barad 2007, 195). In this way, Barad suggests that diffractive methodology works against the traditional separation into distinct disciplinary domains (Barad 2014, 50). Although most often employed a methodology of reading, this aspect therefore suggests the interdisciplinary – or even anti-disciplinary (Pickering 2013b) – potential of diffractive methodology for practice.

2.3.3 Conclusions

The performative accounts of scientific practice put forward by Andrew Pickering and Karen Barad both hold potential for a consideration of creative practice-based engagements with the apparatus. Broadly speaking, Pickering's work foregrounds the material aspects of knowledge practices, while Barad rethinks discursive knowledge as material. Both emphasise the necessity for attentiveness to the nuances of open-endedness, emergence and becoming within practice.

Responding to the notion of 'becoming' modelled by the mangle, Casper Bruun Jensen and Randi Markussen have argued that 'the obligation to self-consciously locate oneself within the flow of becoming is paradoxical, as if one could choose to "enter becoming" through a process of deliberation' (Jensen and Markussen 2008, 155). Instead, they argue, it is necessary to bring to the mangle 'a willingness to stay attuned to the many-sided requirements of practices, as they learn to live with and in transformation' (Jensen and Markussen 2008, 155). Elsewhere, Pickering has seemingly acknowledged this limit, suggesting that 'an adequate social theory can amount, at most, to a set of sensitivities in our encounter with empirical phenomena' (Pickering 2001, 173). Likewise, the diffractive methodology outlined by Karen Barad requires (and enables) attentiveness to entanglements and an acknowledgment of differences that matter. While both potentially provide a vocabulary and framework for considering practice-led research, this research project explores the possibility of extending these sensitivities to a generative studio engagement with the apparatus.

In the intra-active processes of practice-led research, discursive and material strategies are entangled; the creative work is both the object and means of research; it co-creates and is co-created with/in its object of study.

In this particular practice-led investigation, historical research and critical analysis are diffractively mangled, combined and filtered through both my own creative practice and through critical theory. The next section will consider the specific material strategies that are made determinate within this intra-active process.

2.4 Material-Discursive Methods

2.4.1 Introduction

This research pursues a creative practice-led engagement with the apparatus and considers the significance for such an engagement with conceptions of the apparatus drawn from philosophies of science and technology. Key creative methods involve revisiting historical apparatuses and experiments, drawn from the histories of art and science. These are re-imagined using everyday materials and technologies, combined with “d.i.y.” practices of modification and construction. While notions of reconstruction and re-enactment are familiar from art discourse, I suggest that the dominant modes of postmodern appropriation or referentiality, or preservation of presence do not fully reflect the dimensions of my own practice-led engagement with the apparatus. This section will therefore contextualise these methods by considering replication and re-enactment in scientific practice itself, as well as in science and technology studies (STS) and the history and philosophy of science (HPS). The specific material methods employed in my own practice will then be considered in relation to the material-discursive practices of revisiting and reimagining histories of media that constitute media archaeology.

2.4.2 Reconstruction and Re-enactment

This section considers the methodological traditions relevant to practices of reconstruction and re-enactment in the domains of art and science. In particular, I seek to explore here whether insights drawn from the philosophy of science and technology can be developed in order to reframe methods of reconstruction and re-enactment in my art practice. To return to

Vilém Flusser's discourse/dialogue duality, this entails a shift away from a discursive model of referentiality or citationality, and towards dialogic practices of performativity.

The replication of experimental outcomes has been taken as a cornerstone of the scientific method since the scientific revolution. As discussed earlier, in the course of the seventeenth-century formalisation of scientific method, the discursive forms of experimental protocols and reports were important tools (Shapin and Schaffer 1985, 25-26). Employed as literary technologies, they extended opportunities for other scientists to become either 'distant but direct witnesses' who replicated the apparatus and repeated the experiments described (Shapin 2010, 96), or 'virtual witnesses' who clearly visualized them 'in the laboratory of the mind and the mind's eye' (Shapin 2010, 98). Here, material-discursive practices of reconstruction and re-enactment function as a form of 'action at a distance' (Latour 1987, 219) in the dissemination of scientific knowledge across a geographically dispersed network.

In the context of contemporary science, Bruno Latour argues that the capacity to repeat an experiment is less of a guarantee of the surety of a scientific fact, than it is an obstacle for those who would oppose it; in the age of Big Science, with its vast networks of black-boxed technologies, in order to question a scientific fact by repeating an experiment one requires a 'counter-laboratory' that is equipped than the original (Latour 1987, 80-81). Ian Hacking goes further, characterising the emphasis on repeatability of experiments as folklore. He argues that the purposes of repetition are rarely to test an outcome, and more often to use different techniques and technologies to improve upon a result, not to repeat it. Most often, he suggests, the repetition of experiments occurs in a teaching context, where the aim is not to test a theory but to test a fledgling experimenter against an already known experimental outcome (Hacking 1983, 231). It is also in this last category, which some have termed the instructional laboratory (Devons and Hartmann 1970), that the re-enactment of historical experiments takes place (see also Reiss 2007, Cavicchi 2008, Chang 2011, Heering 2007). The value of reconstruction and re-enactment in this context is educational rather than evidentiary.

Thomas Kuhn's analysis of the relationship between history and philosophy of science pinpoints a disjuncture between present and past that he suggests is unique to the sciences. Using the discipline of art as a point of comparison, he suggests that artists, 'whether in imitation or revolt, build from past art' (Kuhn 1977, 152). In sharp contrast, he suggests, 'science destroys its past' (Kuhn 1977, 345). In other words, the truths of science are ahistorical and timeless; what is today considered truth has always been true, but what is no longer considered true never was. This applies not only to facts, but also to practices; therefore the reconstruction of historical apparatus and repeating of historical experiments within the instructional laboratory is aligned to the teaching of fundamental skills, rather than to an exploration of historical practice. In what follows, I will consider accounts of historical re-enactment that offer other possible perspectives.

Within his account of the mangle, Andrew Pickering raises the possibility of what he terms a *performative historiography* of science (Pickering 1995, 230-234). A key example discussed by Pickering is historian of science Heinz Otto Sibum's attempts to reconstruct James Prescott Joule's apparatus and experiments of the mid 1800s (Pickering 1995, 104-109). Based on Joule's own 1850 reporting of his efforts to measure the mechanical equivalent of heat, Sibum sought to reconstruct the apparatus used and to replicate the original experiments. Despite Joule's 'detailed description of the mechanical construction of the experimental set-ups' and 'minute accounts of how to perform the experiment properly' (Sibum 1995, 73), Sibum's attempts were prolonged as a range of issues arose, none of which were discussed by Joule. These included the physically laborious nature of working the apparatus (Sibum 1995, 77), the specific spatial and delicate environmental conditions that the experiments required (Sibum 1995, 79), the resulting importance of carefully calibrating and placing the thermometers (Sibum 1995, 78-79), not to mention discrepancies between the remaining 'relics' of Joule's apparatus and his published description (Sibum 1995, 80). Of these issues, Pickering notes:

> None of these requirements could have been envisaged in their specifics in advance of Sibum's actual experimental work. They were the upshot of a temporally emergent dialectic of resistance and accommodation - of problems arising and being addressed in practice (Pickering 1995, 108).

Each of these resistances required accommodation, as the practitioner's 'gestural knowledge' (Sibum 1995, 76) interactively stabilised with/in the material, conceptual and environmental conditions of the apparatus.

As a means of historical research, Sibum's project 'opens dimensions of past practice' which may have been overlooked, forgotten, repressed or misunderstood (Sibum 1995, 74, 76). This especially includes what Sibum refers to as "gestural knowledge," but also dimensions of sensory experience (Fors, Principe and Sibum 2016, 90) and the previously referred to 'tacit knowledge' discussed by Michael Polanyi. In Sibum's case the embodied performativity of Joule's experiments connect to contemporaneous brewing practices, an industry in which Joule also played a part (Sibum 1995, 83-91).

The particular dance of agency developed in the course of re-enactment highlights the twin gestures of 'doing the work' of physically operating the apparatus, and 'reading temperatures' (Sibum 1995, 81), which required its own specific set of practices and performances (Sibum 1995, 77). To combine vocabularies, we might say that this particular dance of agency took the form of a dialectical movement between postphenomenological embodiment and hermeneutic relations to the apparatus. Balancing these dual requirements produced, in Sibum's words, 'an artistic mechanical performance' (Sibum 1995, 74, 99). Yet, as he repeatedly emphasises, the necessarily isolated environment of the laboratory also affected a divide between the private and public spaces of knowledge, making the experimenter 'a performer without audience' (Sibum 1995, 82, 101). Sibum's labours highlight the ways that practices of reconstruction and re-enactment themselves play out as a dialectic of resistance and accommodation, while also facilitating an acknowledgment of this dialectic within historical practices (Pickering 1995, 230-231). In this way, they inform historical analysis while also acknowledging the significance of performativity for scientific practice.

The projects of reconstruction and re-enactment just described is especially enlightening in highlighting dimensions of practice that are relevant to this research, including the embodied practices and hermeneutic labour that are part of engaging with the apparatus. But this example also belongs to a tradition of historical reconstructions of decisive experiments by significant figures from the history of science, including Galileo's inclined plane (Settle 1961) and freefall experiments (Drake 1970 and 1973; MacLachlan 1976 and 1998). It is worth noting that these earlier examples of experimental re-enactments reconfirm the privileging of the crucial experiment, and the notion of individual genius, rather than emphasising the significance of experiment for daily scientific practice (Franklin 1986, 1-2; 1999, 7-8). They are often aimed at proving or disproving historical conjecture, filling in blanks in the historical record, or clarifying descriptions of observations (Stuewer 1970). As such, these practices operate within a framework of historical accuracy that is not shared by this research.

Attempts to replicate historical experiments "as close to the original as possible" are characterised by Hasok Chang as *historical replications* (Chang 2011, 319). To this taxonomy he adds *physical replications,* which attempt to reproduce phenomena from historical experiments without replicating full material and contextual detail, and *extension,* where the phenomenon, once reproduced, is investigated further through additional experiments (Chang 2011, 319-321). For Chang, the recreation of historical experiments are more than simply a method for data gathering, it is a means of shifting the relationship between the history and philosophy of science and contemporary scientific practice. That is, rather than being '*about* science,' the work of historical recreation '*is* science, only not as we know it' (Chang 2012, 51): it is 'a continuation of science by other means' (Chang 1999). In particular, Chang suggests that his approach, which he terms 'complementary science,' modifies the Kuhnian observation, cited above, that 'science destroys its past' (Kuhn 1977, 345). Instead, he observes that 'science does leave some valuable things behind as it progresses' (Chang 2011, 333), and that such phenomena can be the object of a scientific 'recovery' rather than 'discovery' (Chang 2012, 44).

In contrast to Chang's terminology of historical or physical "replication," other commentators have pointed out the evidentiary and pedagogical connotations of that term in contemporary scientific practice. In place of replication or the potential synonyms "reconstruction," "re-enacting," "restaging," they argue that historians who 'rework or reproduce' experiments 'are not replicating in these scientific or pedagogical senses, but are instead seeking fresh historical information' (Fors, Principe and Sibum 2016, 93). Although not necessarily intended by the authors, the notion of reworking also suggests approaches of re-imagination and transformation being pursued in this research. The question arises, beyond reproducing experiments as a historical exercise, what is the creative potential for reworking historical experiments?

In completing the historical record and countering the 'rational reconstruction' tendency to edit out process in favour of outcomes, the benefits of re-enactment should be apparent for the history of science. But the above accounts by Sibum and Pickering go further - they reframe the original experiment and 'open dimensions of past practice' to analysis (Sibum 1995, 74). By bringing out different aspects of the original experiment, these examples come close to the ethnomethodological notion of 'respecifying' through re-enactment; for example, re-enacting Goethe's light and colour experiments, originally performed as counter-experiments to the work of Newton, in order to foreground 'the embodied work of a (scientific) demonstration' (Bjelic and Lynch 1992, 53). The notion of respecifying emerged from the work of Harold Garfinkel, in confronting precisely the tendencies of pedagogical replication described above towards 'discovering work that proceeds to a foregone conclusion' (Garfinkel 2002, 263). In contrast to the Galilean replications discussed above, Garfinkel and colleagues sought to *respecify* Galileo's inclined plane experiment as an ethnomethodological production, instead of a demonstration of a known law (Garfinkel 2002, 263-285). Rather than refutation or critique, the aim in this case is to produce an 'alternate' account of the experiment, full of specific ethnomethodological detail that is absent from the existing literature (Garfinkel 2002, 284-285). Although this research project does not engage directly with ethnomethodology, this approach of re-performing such experiments as if for 'yet another first time' (Garfinkel 2002, 272) provides an important example. But the potential of such material-discursive transformations are taken even further in Bruno Latour's discussions of re-enactment.

Latour suggests that the activity of re-enactment provides an opportunity to not only gain insights about the past, but to consider the implications of other potential outcomes. Latour's key example centres on the 1922 debate between Henri Bergson and Albert Einstein, which has been seen as a historical marker of the decline of Bergson's philosophical influence and the ascendancy of Einstein. The original debate was characterised by a lengthy exposition from Bergson, which only elicited a brief, cursory dismissal from Einstein. In 2011, philosopher Elie During wrote a 'philosophical fiction' based upon the transcript of the debate, which was performed by Latour and others. For Latour, the process or re-enactment does not result in a 'mere facsimile of the original,' but, curiously, a 'second version, or a *second print* of the first instance' (Latour 2011, 5). He suggests that During's revisions not only transform this uneven debate into a dialogue (Latour 2011, 5), but create a bifurcation within history (Latour and Eliasson 2011). In this sense, practices of creatively reworking the past are a means of representing *as* intervening, putting into practice the sociological mantra that 'it might have been otherwise.'

The complexities of Latour's notion of the 'second original' (Latour and Eliasson 2011) become intractable, however, when extended into the domain of art. When discussing the possibility of a 'migrating aura,' transferring originality from one object to another, (Latour and Lowe 2011), complications arise. Referring to Shakespearean theatre, Latour wonders why the aura of the original, so central to the traditions of visual art, is not a constraint in the world of theatre (Latour and Lowe 2011, 279). For one of Vilém Flusser's key interlocutors, information theorist Abraham Moles, this difference is easily explained. In attempting to apply information theory to aesthetics, Moles distinguishes between *semantic information*, which includes the linguistic and notational structures of script and score, and *aesthetic information*, comprising its material interpretation (Moles 1966, 129-169). The semantic information is fixed and translatable, the aesthetic information 'represents the *field of freedom'* exercised by the performer 'in relation to its operating notation (the score)' or script (Moles 1966, 168). Despite Latour's assertions to the contrary, there is a sense of the original in Shakespeare, and it is precisely in the semantic information of the text; the performance of a script is not a facsimile, but an interpretation. Similarly, in the re-enactment of the debate between Bergson and Einstein, the two versions take the form of the script, the transcript of the 'original' debate, and the revisions performed by During. As suggested by Flusser and the earlier Latour, these scripts function as programs to be performed.

Within Latour's argument, however, there is one insight that is highly relevant for my practice-based methods of reconstruction and re-enactment. He points out the relationship of the word "copy" to "copious", stating that the existence of a 'copy, then, is simply a proof of fecundity. […] to be original means necessarily to be the *origin* of a lineage' (Latour and Lowe 2011, 279). Flusser similarly points out that the Latin meaning of *copia* as 'superfluous' (Flusser 2011b, 96). For Flusser this does not describe the copy itself – rather, it is the myth of the author and the discursive authority of the original that are rendered superfluous by the act of copying (Flusser 2011b, 98). In the process, the reproducibility of technical images reveals the dialogic nature of information exchange (Flusser 2011b, 98). Moreover, for Flusser 'the entire history of the West can be seen as a series of variations on this theme' of copying, as an anti-entropic process of information production, transmission and storage; 'from the copying of manuscripts to print to automated memories and artificial intelligences (Flusser 2011a, 13-14). For both Flusser and Latour, the capacity to be copied and the ability to withstand the process of reproduction are twin measures of significance.

One aspect of this practice-led research and its engagement with the art and science of the past is therefore precisely to explore the relationship between past and present. By creatively and experimentally engaging with past practices centred around the apparatus, aspects of those practices become respecified in a material-discursive dialectic of resistance and accommodation. The fertile ground of the past is explored for its contemporary relevance, as old and new technologies are brought into productive dialogue with each other. New engagements and experiences are created, and potential new histories narrated. This brings this practice-led research into the apparatus into the territory of another key methodological framework, that of media archaeology.

2.4.3 Media Archaeology in Theory and Practice

This research explores connections between everyday media technologies and scientific instrumentation in order to reflect on the broader role of the apparatus in generating and mediating experience. As discussed, accounts of performativity and materiality in the philosophy of science and technology are significant in framing the research methodology. One point of intersection for these ideas can be seen in the praxis of media archaeology. The materialist dimension of media is accented by Jussi Parikka's observation:

> Media history is one big story of experimenting with different materials from glass plates to chemicals, from selenium to coltan, from dilute sulphuric acid to shellac silk and *gutta percha*, to processes such as crystallization, ionization, and so forth (2012b, 97).

As Michelle Henning observes, this 'broadly materialist' approach, with its focus on the 'hardware' of media technologies, contrasts with the conventional media studies model, which is centred on the 'the interpretations of specific media texts' (Henning 2014, n.p.). This contrast, between the analysis of hardware and the interpretation of texts, in some ways mirrors that between image and apparatus.

Influenced by Michel Foucault's *Archaeology of Knowledge* (1989) media archaeologists approach history as 'a multi-layered construct, a dynamic system of relationships' (Huhtamo 1997, 221) that is open to intervention and reimagination. In the context of cinema studies, Thomas Elsaesser sums up the three key propositions of this Foucauldian 'archaeological agenda' as: a questioning of the already-said; a rejection of the search for beginnings; and the description of discourse as practice

(Elsaesser 2006, 17). Media archaeology is a theoretical and practical approach that makes connections between purportedly 'new media' and their historical precursors. A key concern therefore is the historical inter-relations of art, science and technology (Zielinski 2006). However, media archaeological practices do not seek to construct master narratives but to explore traces of the past as embedded in culture of the present.

In its key strategies of exploring alternative or imaginary histories and obsolete technologies (Parikka 2012a, 138-141), media archaeology presents 'a challenge to linear media history as well as a foregrounding of the practices and uses connected to media rather than the effects of media' (Gansing 2013, 62). Although there have been numerous recent considerations of media archaeology from the perspective of museum studies (see for example Henning 2015; Hoskins and Holdsworth 2015), it should be emphasized that media archaeology is less an archival practice than a practice that intervenes in archives. It is the disunified, nonlinear aspects of technological development that are emphasised in its treatment of media, and the fragmentary nature of narrative practices in its relation to archaeology. It is precisely the 'omissions, undetected or masked ruptures, and dark corners' of the archive that inform media archaeological praxis (Huhtamo 2016, 70). This aspect of the discipline is highlighted in Siegfried Zielinski's characterization of media archaeology as a form of *anarchaeology.*

As a historical method that does not impose the linear trajectory of teleology, Zielinski's anarchaeology instead maintains the historical character of 'a collection of curiosities' (Zielinski 2006, 34). Instead of the "rational reconstruction" traditional to the philosophy of science, this is a 'mangle-ish' form of history, in which the discordant domains of magic, science and technology do not feature in a linear progression from primitivism to civilization, but instead 'combine at particular moments in time, collide with each other, provoke one another, and, in this way, maintain tension and movement within developing processes' (Zielinski 2006, 258). However, in adopting an admittedly 'romantic' 'spirit of praise and commendation' for 'people and their works' (2006, 34), Zielinski also preserves the heroising historiography of the progress narratives that he critiques (Parikka 2012a, 51-52; Goddard 2015, 1768-1769). Despite this aspect of media archaeology, in which textual practices conform to the conventions of linear history, the broader emphasis on anarchic practices of retrieval and reimagination are productive for the development of practice-led engagements with the apparatus.

As a critical practice media archaeology 'rummages textual, visual and auditory archives as well as collections of artefacts, emphasizing both the discursive and the material manifestations of culture' (Huhtamo and Parikka 2011, 3). This construal echoes the practice of the bricoleur, a figure whose improvisational 'tinkering' was framed by Claude Levi-Strauss in opposition to the methodical planning of the engineer and the scientist (1966, 19-20); the bricoleur works with their hands to transform 'whatever is at hand' (1966, 16-17). In this sense, practices of bricolage radically reframe Heidegger's notion of 'handiness' (1996, 64-70). As discussed earlier, Heidegger's early tool analysis, with its categories of ready-to-hand and present-at-hand, and his later critique of technology as enframing, are connected by an underlying rubric of essences. For Heidegger, we lose sight of the essence of a thing when it is subordinated to a project, viewing it as a "mere" ready-to-hand tool or a standing reserve of resources. According to Levi-Strauss however, the materials and means of the bricoleur *cannot* be defined in terms of a project, but only by their *potential use* – the fact that 'they may always come in handy' (Levi-Strauss 1966, 17-18).

While ANT theorists such as Latour define deconstruction negatively, as an attempt to 'destroy in slow motion,' (Latour 1999, 8), the shared material practices of bricolage and media archaeology emphasise the creative capacities of deconstruction and reassembly, conceived as a form of applied structuralism (Zielinski 2011, 299). Rather than a fetishisation of the apparatus, or a reduction of technology to 'those lines of force that take the form of nuts and bolts' (Latour 1988, 191; 199), it is the potential for reuse and transformation, not the project of domination, that is at the heart of these practices. As in postphenomenological analysis, the aim is not to define singular essences, but to explore multiple possibilities. Here, there is potential for the variations of postphenomenological method to interact productively with an attitude that Siegfried Zielinski has termed a variantology of the media; an approach that is less concerned with history as what 'allegedly' happened, than with what else *might* have happened (2013, 133). In media archaeology, this includes past possibilities not followed through, but ripe for revisitation.

In contemporary science, the figure of the bricoleur would seem to be most visible in the form of the citizen scientist. While this category includes non-scientists who contribute to scientific practice through voluntary data sharing and processing, of most relevance here is the culture of enthusiastic amateurs, constructing home-made scientific apparatus and experiments, often modelled on historical examples, but using domestic and at-hand materials. A number of commentators, however, also locate bricolage at the heart of science and technology studies. Bruno Latour refers to 'the invisibles of technology — deviations, labyrinths, workarounds, serendipitous discoveries' (2014, 220), and Lynch and Woolgar assert that a close examination of scientific practice reveals that 'bricolage is at the heart of the work of sustaining a plan and remedying its provisions in light of unanticipated contingencies' (1990, 8). In line with my own practice interests, media archaeology provides a methodology for animating these invisibles to help render the blind spot of the apparatus visible.

Parikka characterises media archaeology as an 'under-the-hood methodology' (2012a, 86) with both theoretical and practical dimensions. This resonates with my own practice-based interest in the intertwining of theory and practice, and strategies of both conceptual and material deconstruction and reinvention. The dual nature of media archaeology, as both theoretical framework and creative practice, therefore provides an important material-discursive methodology for my studio-based research. Furthermore, while textual accounts of media archaeology cannot entirely escape the linearity of historical narration, as creative practice media archaeology holds the potential for a truly nonlinear and user-determined experience, a true variantology of the media.

2.4.4 Methodological Conclusions

This practice-led research develops a creative engagement with the apparatus, through a consideration of the historical entanglements and intra-actions of art, science and technology. Throughout this endeavour, many resonances between practice-led research and philosophies of science and technology can be found. Forms of analysis that have in the past been applied to both soften the hard sciences and solidify the humanities come together in this research to provide a multiplicity of perspectives on the relation between these fields. The performative methodologies articulated by Andrew Pickering and Karen Barad have been particularly valuable in this regard. Pickering's formulation of practice as a dance of agency and a dialectic of resistance and accommodation creates a powerful vocabulary for articulating my practice-based engagements with the apparatus. Karen Barad's diffractive methodology provides a framework for thinking through the intra-action of diverse phenomena and their material-discursive implications. These ideas, developed in response to scientific practice, are fruitfully applied to a creative engagement with the apparatus.

In my creative practice, the material-discursive methods of bricolage, deconstruction and reassembly play a significant role. Within this research project, these methods are focused through practices of replication, reworking and re-enactment, conceptualised in relation to past and present scientific practice. These perspectives highlight the transformative material-discursive potential of these methods, beyond either narrowly discursive or material conventions of art history, epitomised by practices of referential appropriation and the material aura of presence. The methodological approach of media archaeology provides a further focus in this regard. Although this research extends beyond the conception of media as means and complete content, I suggest that creative practice provides a cogent means of achieving this discipline's stated aims of fostering a non-linear view of history and a dialogic engagement with past practices and apparatuses. This archaeological engagement will be further developed in the next chapter, which considers contextual practices at diverse historical and disciplinary intersections of art and science.

Chapter 3: Situating the Apparatus

3.1 Introduction

This research is framed by my own practice-based engagement with the apparatus. It investigates conceptions of the apparatus within various philosophies of science and technology in order to consider their potential for rethinking the apparatus as something more than 'mere means.' To this same end, the research also considers the historical entanglement of art, science and technology as manifested in the practices of artists, scientists, inventors, and cultural institutions. The approach taken in this particular chapter reflects the historical and interdisciplinary character of the discourses that inform this research. The material-discursive entanglements of theory, methodology and context have required a specific approach in this research. In line with a media-archaeological methodology, this is an approach that looks for traces of the past in the present, and especially examines the historical foreshadowing of purportedly 'new media.' The research also extends this concern for marginalised and forgotten technologies beyond 'media' in order to offer more expansive and varying perspectives on the apparatus. The histories examined here therefore inform both the context and content of the creative work. These connections will be further discussed in the final chapter, which focuses on the creative outcomes of the research.

As detailed in previous chapters, the entanglement I consider here was once literal because the terms art, science and philosophy were often largely interchangeable up until the nineteenth century (Ross 1991, 6). The terms 'art' and 'science' were used as qualitative characteristics of practice rather than as rigid disciplinary boundaries. Though modelled on the term "artist," William Whewell's formulation of the title "scientist" in the 1830s served to further distance scientific practice from both the broader speculations of philosophy and that era's association of the arts with practical knowledge. The timing of this shift in nomenclature is significant for this research project because it accompanies a number of significant shifts in the relationship between art and science. These include the emergence of 'technical images' through the independent scientific experiments of William Henry Fox Talbot and Louis-Jacques-Mande Daguerre, and the popularization of science and its emergence into public discourse through the performance of scientific demonstrations in newly established societies and institutions.

Throughout the 1800s, numerous public institutions sought to promote scientific knowledge among the general public by presenting lectures and demonstrations. This constituted a culture of scientific spectacle that sought to educate by means of novelty and amusement. The starting point for this chapter is one such institution, the Royal Panopticon of Science and Art, which both in name and in practice highlighted some of the tensions within this relationship between art and science. I then consider the role of opticality and illusion in these scientific spectacles, as well as in the experimental practices of individual scientists, such as William Henry Fox Talbot, and modern artists such as Marcel Duchamp. This discussion of perception and phenomenal experience is extended to incorporate a consideration of attempts to view the invisible by means of apparatus. This section draws on examples from turn of the twentieth century and contemporary science and art. The final section in this chapter considers the performative light-based apparatuses of Thomas Wilfred. Positioned in between the conventions of medium as material support, I assert that Wilfred's 'lumia' experiments exemplify the potential of the model of the apparatus that has been developed in previous chapters of this exegesis.

For the moment, however, it should be noted that the approach taken here departs from other contemporary artistic engagements with scientific apparatus. The artist Steven Pippin, for example, spent ten years constructing a setup that would give physical form to physicists' hypothetical figure of a pencil balancing on its point (fig. 10). My aim is not to either emulate or ironize scientific practice in this way. Nor do I collaborate with scientists using cutting-edge technology, as is common practice in the field of bio-art (see Kac 2007).

Figure 10: Steven Pippin, *Ω = 1,* 2004/5–2014. Two optical lens system, infrared system, two LED lamps, carbon fiber cord, pulleys, metal stand launcher, aluminium framework, two DC electric motors, electronic control system, 12 volts car battery and 2B pencil

Figure 11: Conrad Shawcross, *Slow Arc Inside a Cube IV,* 2009. Wire mesh, light, motor.

Figure 12: teamLab, *Flowers and People - Gold,* 2015. eight channel computer generated interactive program, colour, sound, motion sensors. 120 x 548 x 5.5 cm

My work does not aim to celebrate the harmonic geometry of mathematics, as projected by artists such as Conrad Shawcross (Manchester 2013, 154; see fig. 11). The patterned projections generated by Shawcross' sculptures operate as ornamental analogues for the Cartesian computation of space described by Flusser (2017a, 206). In this sense, they invert the relation between the digital and the image that is presumed in much interactive work. In digital interactive works, such as those by self-described 'ultra-technologists' teamLab, the movement of spectators within space produces changes within screen-based imagery (see fig. 12). For Andrew Pickering, such works operate within the framework of cybernetics as a form of 'ontological theatre' that plays out themes of emergence and becoming (2016, 3-4). As noted in the previous chapter, this theatrical model carries with it representational overtones, suggesting the lesser status of a rehearsal ground that is secondary to a 'real' becoming to be enacted elsewhere. However, such contemporary digital interactive works also play out the 'programmatic ontology' that Flusser attributed to cybernetics (2013b, 33). Flusser defines cybernetics in terms of 'automatic guidance and control of complex systems' (2011b, 125). He emphasises the discipline's etymological derivation from the Greek verb *kybernein*, meaning "to steer" or to govern (2011b, 123). It might seem that the interactivity of cybernetics endows the spectator with this responsibility of governance. Yet, on the contrary, the image exerts control through a dialectic of 'acting and being acted on' (2011b, 128-129), through which the spectator is made subject to the programmatic ontology of the work. Transformed into an input source, the spectator becomes a functionary within an interlocking apparatus-operator complex (2000, 71). The performances of the program itself are blackboxed; that is, works such as those by teamLab mobilise — for the purposes of performance — what Don Ihde has described as an 'alterity relation' between the digital systems and their audience (Ihde 1990, 97-108). They invite uncritical play with/in the image, but without inviting consideration of the structure of the system or enabling the deconstructive unpacking of its performative capacities. Contrary to this position, this research instead considers the potential of playing against the apparatus as a means of fostering a critical, deconstructive but also a projective engagement with it. Within this endeavour, the specifically digital discourses of such works feature as a background concern. As stated at the outset, Flusser's model of the apparatus affords a wide-ranging view of the apparatus that is not limited to the digital. Rather, it encompasses considerations that range across digital and analogue forms of the apparatus.

As Flusser also suggests, the ways of life that have developed around technical images can only be understood 'if we delve into the very roots of our being-in-the-world' (2011b, 7). While the contemporary practices noted above do form part of the context for my practice, historical engagements with the apparatus across the boundaries of art and science both contextualise and directly inform this practice-led research. For this reason, the historical context is my primary focus here. This is aimed at fleshing out the understanding of the apparatus, by considering histories and philosophies of science. To extend Karen Barad's model of the apparatus as a boundary-making practice, my interest is in the potential of the apparatus as a boundary-*blurring* practice. The histories explored in this discussion register the diffraction effects created by the intra-play of spectacle, perception and performativity, all within the figure of the apparatus.

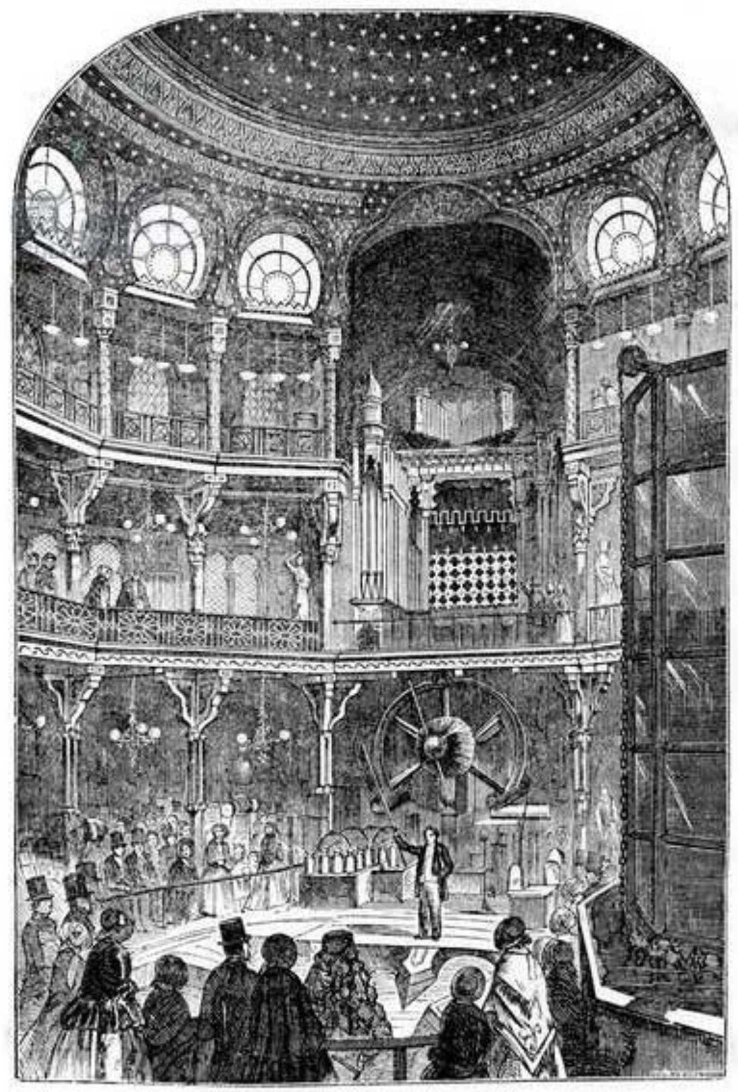
3.2 Spaces of Experience: Instructive and Amusing Uses of the Apparatus

This section examines a historical aspect of scientific practice in which the relations between science and art are brought into sharp relief. I argue that there is more to the performative practices of nineteenth century scientific demonstrations than just communicating scientific knowledge. In place of Bruno Latour's motif of the Janus-head, embodying the opposition between science-in-the-making and ready-made science (Latour 1987, 174–5), in this period the two faces presented by science were instruction and amusement (Altick 1978, 363). The demonstrative performances of this era highlight tensions between science and spectacle that are productive for a consideration of my own practice-led creative engagement with the apparatus.

As discussed previously, the establishment of scientific societies in the seventeenth and eighteenth centuries gave institutional form to a social technology, whose members were connected together by acts of actual and virtual witnessing (Shapin and Shaffer 1985, 60-63; Shapin 2010, 97-100). In the nineteenth century, there were numerous attempts to further expand the community of those engaged with science, through popular entertainments in the form of scientific demonstrations, which were presented at both public and privately run institutions. The peak venues for these scientific displays were primarily based in London and included educational institutions such as the Royal Polytechnic Institution; exhibition spaces such as the Royal Gallery of Practical Science (better known as the Adelaide Gallery); the nationalistic spectacles of the Universal Expositions; as well as a range from natural science museums to dioramas and panoramas. All were precursors to today's museological combinations of science and art. This culture of scientific spectacle is examined in this exegesis through the lens of a lesser-known institution, the Royal Panopticon of Science and Art (London, 1854-6). Granted a royal charter, this institution was run as a commercial venture and was driven by the instrument maker Edward Marmaduke Clarke, who in his own way traversed the disciplinary boundaries between art and science.

Institutions like the Royal Society relied on members to collectively witness the experiments performed under its aegis. The authority of the institution – and therefore the effectiveness of its experimental culture - was therefore allied with a form of social discipline. Performing experiments for an audience of witnesses thereby effected a move *towards* science as a form of publically shared knowledge, while preserving the closed networks of a scientific elite (Shapin 2010, 114). Conversely, the later institutions publicly shared scientific knowledge through popular demonstrations, but as a means of disciplining society. When the Royal Panopticon of Science and Art opened in London's Leicester Square in 1854, the address given to mark the occasion was suitably entitled: 'Literature, Art, and Science Considered As Means of Elevating The Popular Mind.' In that lecture, the mission of the Royal Panopticon was described as 'to aid in dispensing those treasured fruits of the mental life of universal mankind which are the common property of all' (Biber 1854, 23). In attempting to make science engaging for the broadest possible public, these types of institutions sought to present what one commentator described as 'amusement of the best kind' – an aim that came at the risk of the lecturer 'degenerating from a philosopher into a mere showman' (Zeta

1844, 230, 233). The tension between popular appeal and scientific rigour is a defining characteristic of the institutions under discussion in this chapter, and represent an issue that continues to shadow interactions between science and art.



INTERIOR OF ROYAL PANOPTICON.

Figure 13: Unknown artist, *The Royal Panopticon of Science and Art, London* c. 1854.

Largely modelled on the Royal Polytechnic, a key feature of the Panopticon was a program of talks and demonstrations, repeated twice daily. Although the published program suggests that the only difference between the two sessions was the addition of music in the evening, the Handbook to the Royal Panopticon implies a greater divide by advising that the morning session is ‘chiefly confined to scientific illustration, whilst that in the evening assumes a much more popular form, and constitutes an artistic entertainment, blending instruction with amusement' (White 1854, 11). Allied with these formal lectures and artistic presentations, the Royal Panopticon presented displays of scientific apparatus and industrial technologies. When it closed in 1856, its collection entailed 'numerous instruments for the illustration of modern scientific discoveries, including those connected with the microscope, chromatrope, kaleidoscope, dioramas, cosmoramas, &c' (Chinnock and Galsworthy 1856). This list demonstrates the blurring of boundaries between optical amusements and scientific instruments during this period.

Many of the scientific apparatus featured at the Panopticon were made by its first managing director Edward Marmaduke Clarke, who was credited as the institution's 'sole originator' as well as 'projector and promoter' (White 1854, 10-11). The coat of arms for the Royal Panopticon was reworked from a design that had previously been used to promote Clarke's own business, as a maker of 'mathematical, philosophical, optical and chemical instruments and apparatus' (Clarke c.1837). Both versions of featured the figures of a scholar and a mechanic, linked by a banner bearing the Latin phrase "*mente et manu,*" or 'mind and hand' (see fig.14). These figures would seem to embody William Whewell's contemporaneous promotion of science whose English equivalent was central to championing of science as 'an Art, both of the mind and of the hand' (quoted in Schwarz 2014, 49). Crossed between them are the tools of their respective trades: 'a pen to be directed by a cultivated mind, and a hammer to obey the guidance of an experienced craftsman' (White 1854, 7). The principal difference between the two designs is the crest at their centre. For the Royal Panopticon, the figures of Newton's apple, Columbus' egg and Galileo's lamp all connect the institution to histories of discovery and progress. In William Henry Fox Talbot's *English Etymologies,* he traces the root of 'the word *device* in the sense of *invention* or *contrivance*' to the skilful design of such shields for knights (1847, 316). In Clarke's earlier version, the symbolic device borne on the shield is a technological device that he claims as his own invention: a magnetic electrical machine, for use in a range of experiments including administering shocks, decomposing water, charging a Leyden battery, and heating metals (Clarke c.1837, 75-82).

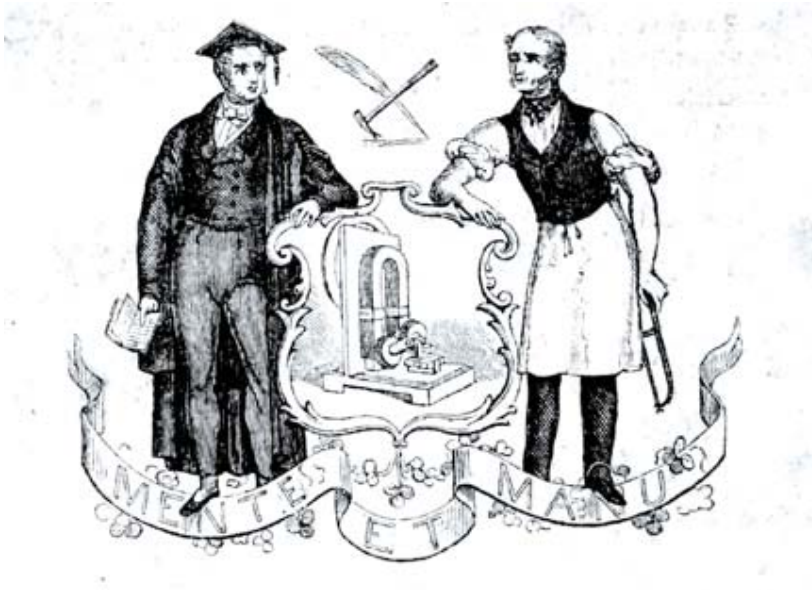


Figure 14: Cover illustration from Edward Marmaduke Clarke. c.1840. *Directions for Using Philosophical Apparatus in Private Research and Public Exhibitions*. London: E. M. Clarke.

As an instrument maker, Clarke produced and sold optical technologies to be used by both scientists (including microscopes, polariscopes, telescopes) and artists (such as camera obscura, camera lucida, Claude glasses), as well as photographic and magic lantern projection equipment. He also made and sold devices that formed part of the broader nineteenth century culture of optical amusements, including those designed by scientists such as David Brewster's kaleidoscope and Charles Wheatstone's stereoscope. Clarke claimed to have been the first to develop the popular magic lantern technique of dissolving views in 1840, and also sold phantasmagoria equipment, and mechanical magic lantern slides for purposes ranging from astronomical lectures to humorous farce. His own contributions to the Panopticon's displays tended towards 'improved' or oversized versions of existing apparatus such as an Electrical Machine, a Leyden Battery, a Magnetic Machine, and the Stereoscope. The most imposing of Clarke's creations was his 'colossal electrical machine,' which was described as 'producing the most stupendous results and demonstrations of scientific experiments' (Chinnock & Galsworthy 1856 n.p.). This example also reiterates the aforementioned tensions between art and science, with the Handbook to the Royal Panopticon expressing regret that the exhibition of this 'monster electrical machine,' though necessary 'to the prosecution of science,' also concealed ‘so much architectural and artistic beauty, behind a huge mass of experimental philosophy’ (White 1854, 26).

The architectural features of the Royal Panopticon were promoted as attractions in their own right. The building’s distinctive, ornate ‘Moorish’ styling was later said to have ‘diffused a gleam of sunshine over a shady place, and created a fairy oasis in a desert of bricks and mortar’ (White 1869, 1). Many of the larger apparatuses presented by the Panopticon did not conceal the architecture, but were themselves architectural in nature. These included a large ‘Crystal Cistern’ for experimentation and demonstration of underwater equipment including a subaqueous lantern, improved diving suit and subaqueous balloon for recovering ‘sunken property’ (White 1854, 39). Other architectural features included a circular railway in basement for testing improvements to railways (White 1854, 107), while an ‘ascending carriage’ transported spectators to the photography gallery on the upper levels (White 1854, 36). Perhaps the most spectacular of these architectural apparatuses was the organ, which was lit from within by ‘the optical diorama’ (White 1854, 32), and the luminous fountain. On a more utilitarian note, the building also incorporated many technical innovations that its proprietors were keen to promote, including a warming battery, a lockable entrance turnstile that recorded attendance numbers, and pneumatic blinds to control the lighting (White 1854, 26, 35-36). The architecture of the Royal Panopticon therefore demonstrated the combination of ingenuity and industry that the institution also espoused.

As an architectural apparatus directed towards the social discipline of its audience, the Royal Panopticon echoes its better-known disciplinary forebear. Objecting to the transportation of convicts to the recently established British colony of New South Wales in a series of writings produced from 1787 to 1791, Jeremy Bentham proposed a new type of institutional architecture especially suited to prisons (Bentham 1995). Bentham’s Panopticon delegated the authoritarian action of surveillance to architecture. While no prison was ever constructed to Bentham’s exact plans, their general principles of architecturally enabled surveillance did become incorporated into prison architecture.

Michel Foucault famously revisited and revived the motif of the Panopticon in 1977, arguing that it occupies a pivotal position in the transition away from spectacle (in the form of public displays of corporal punishment) and toward surveillance (of the isolated and removed subject) as a key strategy for enforcing discipline and order. Foucault viewed the methods of surveillance mobilised by the panopticon as 'minor techniques of multiple and intersecting observations, of eyes that must see without being seen,' mirroring 'the major technology of the telescope, the lens and the light beam' that were so central to observation in science (Foucault 1977, 171). Countering Foucault's opposition of spectacle and surveillance, however, the major technologies of scientific observation played a central role in the *spectacles* of the Royal Panopticon, which shared with its disciplinary namesake the aims of enculturation and internalisation of social discipline. By mobilising cultural edification in the service of discipline and order, such popular museums of the nineteenth century perform what Foucault terms the 'discipline-mechanism,' seeking to 'improve the exercise of power by making it lighter, more rapid, more effective, a design of subtle coercion for a society to come' (Foucault 1977, 209). Cultural theorist Tony Bennett characterises these cultural spaces as an 'exhibitionary complex' that combines principles of the panopticon 'together with those of the panorama, forming a technology of vision which served not to atomize and disperse the crowd but to regulate it, and to do so by rendering it visible to itself, by making the crowd itself the ultimate spectacle' (Bennett 1995, 68). As frameworks for the presentation of entertaining instruction, these institutions constitute an 'exhibitionary complex' that reframes the disciplinary panopticon as a site of seeing as well as being seen.

The Royal Panopticon of Science and Art provides a historical example of an institutional and architectural apparatus that melds many of the concerns of this research, including science, art, spectacle, opticality, performativity and practice. It is also an example that foregrounds some of the power relations at play within these historical examples. Though the creative components of this research are performed in a different context, and even though these historical political contexts are not specifically addressed in the research, it is important to acknowledge that they form part of the macroperceptual context in which these explorations take place. Institutions such as the Royal Panopticon sought to educate and elevate their audiences, acting upon them as an engaging but authoritative institutional apparatus. The specific crossovers and engagements between art and science under investigation in this research are distinct from those historical ends. The next section considers perceptually playful intra-actions with the apparatus across science and art.

3.3 The Persistence of Vision

This section focuses on questions of perception and mediation, with a particular focus on intra-actions incorporating apparatuses in both their perceptual and technological forms. The tension between art and science is made especially clear by the different disciplinary approaches to questions of visuality and representation, which have been a prominent target for criticism in the philosophy of science. In this section I clarify the significance of these questions for my own creative engagement with the apparatus. This is achieved by surveying instances from the histories of art and science that bring them into focus. Despite sustained critiques, vision persists as a central motif, metaphor and tool. In my own works, and in the examples discussed, I suggest that the potential for ocular-centricity is countered by the eccentricity of the viewing experience. That is, the works destabilize the primacy of vision and the smoothness of perception, emphasise the full-bodied nature of perception by creating physically immersive and interactive experiences, and foreground the mediating and transforming role of technology.

For Bruno Latour, the dominance of representational models within science results in a confusion between epistemology and art history (Latour 1999, 78). Like the effacement of brush stokes in a *trompe l'oeil* painting, he argues that the theoretical models and laboratory setups of science create 'a confusion of the senses,' by means of which 'we follow the dazzled gaze but forget the hands that write, combine, and mount' (Latour 1988, 228). By associating representation with theoretical detachment, however, this critique also overlooks the performative and embodied nature of perception itself. Ironically, these qualities are highlighted by one of Thomas Kuhn's recurring metaphors of the gestalt switch associated with paradigm change. Kuhn cites George Stratton's late nineteenth century experiments with inverting lenses, in which he wore lenses that inverted his view of the world (Stratton 1897). After around eight days, his perception adjusted and reverted the inversion. Kuhn writes:

> … after the subject has begun to learn to deal with his new world, his entire visual field flips over […] The assimilation of a previously anomalous visual field has reacted upon and changed the field itself. Literally as well as metaphorically, the man accustomed to inverting lenses has undergone a revolutionary transformation of vision (Kuhn 1996, 112, see also 122).

Even though Kuhn is using the inversion of vision as a metaphor for theoretical change, his example highlights the transformative potential for an embodied engagement with the apparatus of inverting lenses. This section considers the potential for a performative visuality, distinct from traditions of representationalism, and brought to light by engagements with the apparatus.

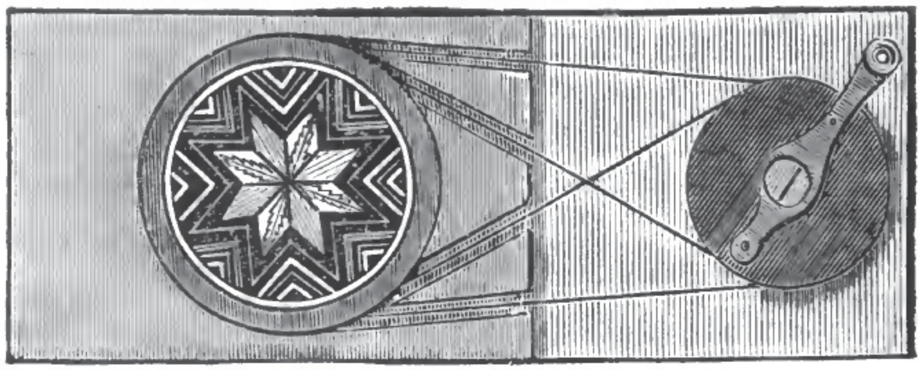
My starting point for this consideration is the chromatrope, a form of magic lantern slide, that played a prevalent role in the edifying spectacles discussed in the previous section, but which features only marginally within surrounding discourse. One reason for this marginal standing is a lack of clarity around the device itself. The term was both spelled differently and used in varying ways by different commentators and practitioners. Literally meaning 'turning colours,' the chromatrope is a mechanical rackwork slide featuring overlapping abstract patterns that create optical effects as they are turned. The alternate spellings "chromatrope" and "chromotrope" were sometimes used to refer to any form of rotating mechanical slide, including those featuring figurative imagery. In other instances, there is confusion between the abstract patterns of the chromatrope and those of the eidotrope, which featured two rotating metal plates, each pierced with patterns to create changing moiré or mirror ball effects. The application of such terms in the show culture of the Victorian era was often inexact. Attractions were routinely promoted as displays of whatever technical or spatial apparatus was thought most likely to attract a crowd at the time. As a result, the specific material practices and perceptual effects of dissolving views, chromatropes, dioramas, panoramas, and cosmoramas were rendered discursively fluid and malleable.

Figure 15: *Chromatrope Slide,* 1883. Collection: National Science and Media Museum, Bradford UK Accession 1990-5036.

Perhaps the clearest definition is one provided by a Magic Lantern manual from the 1890s, written by an anonymous author identified only as ‘a fellow of the chemical society’:

> The glasses are round, and on each one is painted a geometrical design. By moving a handle these two designs are caused to turn in opposite directions, giving a wonderful kaleidoscopic effect upon the screen. Most gorgeous effects can be produced by using these chromotropes in the double lantern, for while both are working one can be slowly dissolved into the other, and in this way endless changes are brought about. The chromotrope effect forms a very great relief to a lantern entertainment, and is often used to divide subjects from one another. Their exhibition serves, too, to give the reader a few minutes respite (Anonymous c.1890, n.p.).

This last point highlights the important but marginal nature of the chromatrope. Chromatropes were sometimes referred to as ‘artificial fireworks’ (see fig.16). Just like “the real thing,” their most frequently recurring role was as a means of bringing a magic lantern show to a close. Slides made especially for this purpose included a ‘good night’ slide, ringed by moving chromatrope border. In one sense, the chromatrope slide therefore featured as the climax of the entertainment. The advertising of magic lantern shows support the view of the chromatrope as a recognisable drawcard in its own right, on the same level as the dissolving views.



Class XII—Chromatropes, or Artificial Fire-Works, &c.

Figure 16: *Chromatropes, or Artificial fireworks,* from L.J. Marcy. 1877. *The Sciopticon Manual, Explaining Lantern Projections in General, Sciopticon Apparatus in Particular. Including Magic Lantern Attachments, Experiments, Novelties, Colored and Photo-Transparencies, Mechanical Movements, Etc.* 6th Ed. Philadelphia: James A. Moore. 30.

London institutions such as the Royal Polytechnic and the Royal Panopticon of Science and Art featured chromatropes prominently, bringing their twice-daily shows of Magic Lantern slides and Dissolving Views to a close. But the chromatrope also belonged to a particular class of slide that exemplified the “Vigorous Prosecution of Novelty” that the Royal Polytechnic claimed for itself. As Richard Altick notes, this prosecution entailed both ‘new inventions that could be adapted for entertainment purposes and new entertainments that could be disguised as inventions’ (Altick 1978, 385). The association of optical novelties, such as the chromatrope with such scientific spectacles, is evidenced by an 1848 advertisement for a magic lantern show in Australia, featuring the ‘new-discovered and wonderful optical instrument, the chromatrope’. This was accompanied by the promise that the display would be ‘a faithful repetition of the admired exhibitions which have received the patronage of every lover of science in the United Kingdom,’ even down to the inclusion of musical accompaniment, ‘as is usual on such occasions in

London.’ The promotion of chromatrope performances in these terms highlights their dual nature as a form of entertaining visual music and edifying scientific demonstration.

The effects of the chromatrope were often compared to those of the kaleidoscope, another device that was emblematic of nineteenth century intra-actions of amusement and education. As Jeremy Brooker has noted, the ‘randomized images’ generated by the kaleidoscope differ from the regular ‘geometric forms and endlessly repeated cycles’ of the chromatrope (Brooker 2018). Beyond this range of formal similarities and differences, the chromatrope and the kaleidoscope were united within the popular culture of scientific spectacle that is represented by the category of the ‘philosophical toy.’ This category of optical instruments both ‘provided popular amusement’ and enabled users ‘to examine phenomena experimentally, rather than by naturalistic observation alone’ (Wade 2004, 102). Such novelties playfully mimicked the exploratory empirical approach taken in the scientific research of David Brewster, inventor of the kaleidoscope. Brewster’s research into the refractive, reflective and polarising properties of crystals and the crystalline structure of insects’ compound vision directly informed his development of the kaleidoscope. Philosopher of science Ian Hacking argues that Brewster’s rigorous material and perceptual investigations were not aimed at ‘testing or comparing theories at all,’ but at ‘trying to find out how light behaves’ (Hacking 1983, 157). The practical and empirical basis of Victorian science required disciplined vision, and the illusions created by ‘philosophical toys’ such as the kaleidoscope were a means of exercising this faculty.

Fig. 52.

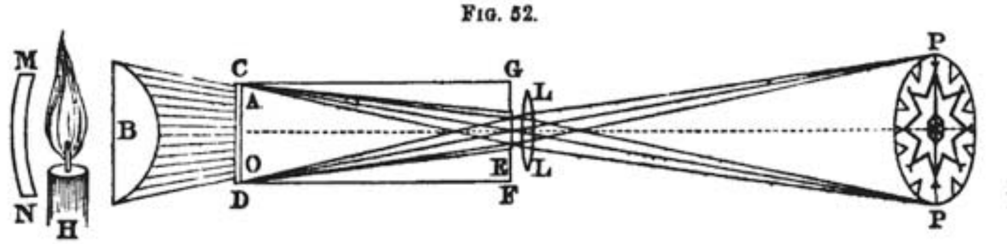


Figure 17: David Brewster, 1858. *The Kaleidoscope: Its History, Theory and Construction with its Application to the Fine and Useful Arts*. London: John Murray. 137.

Brewster argued that the eye was the ‘most important’ of the sensory organs, especially given its ‘boundless range of observation’, extended by scientific instrumentation such as the telescope (Brewster 1832, 8-9). By virtue of its importance and its susceptibility to illusion, Brewster asserted that the eye was a key source of the mistaken belief in the supernatural:

> … it is not only an amusing but an useful occupation to acquire a knowledge of those causes which are capable of producing so strange a belief, whether it arises from the delusions which the mind practices upon itself, or from the dexterity and science of others (Brewster 1832, 11).

Brewster’s arguments regarding the edifying nature of illusions were especially influential for the showcasing the dexterity of magic lantern shows at the Royal Polytechnic and similar institutions. As Iwan Rhys Morus has noted in relation to the “Dissolving Views” of the magic lantern, although operators ‘did not want their audiences to see all their secrets, they wanted them to see enough to recognize and applaud the skill and ingenuity that lay behind the successful show’ (Morus 2006, 105). By aligning their displays with the latest advances in science and technology, lanternists continued the tradition of ‘honest illusion’ in mechanical and natural magic discussed by Brewster. Yet the particular model of vision championed within these spectacles was a modern technoscientific one. Brewster advocated for the kaleidoscope as a potential tool for the ‘fine and useful arts,’ claiming ‘it will create in an hour, what a thousand artists could not invent in the course of a year’ (Brewster 1858, 137). In particular, he predicted its utility for the designers of fabric and wallpaper patterns, exactly the sorts of geometric designs that are so often reflected in the chromatrope. Although different in operation, accounts of the chromatrope also emphasised notions of automation and ‘endless change’ that were at odds with its hand-painted designs and ‘looped’ series of variations.

While the optical play of philosophical toys popularised elements of scientific vision, scientific instruments—such as the spectroscope and polariscope—were generating aesthetic effects. These devices revealed the chemical composition or material structure of specimens by creating diffracted or reflected abstract colour patterns. The polariscope was noted as being especially effective in scientific displays, for its ability to ‘create wonderfully abstract kaleidoscopic effects akin to the chromatrope lantern slide' (Plunkett and Sullivan 2012, 53). Before founding the Royal Panopticon of Science and Art, the apparatus sold by Edward M. Clarke included polariscope attachments for the magic lantern. These were advertised using a slide of his own design, in which thin sheets of selenite formed an image of shamrocks above the motto 'Erin-go-Bragh,' meaning "Ireland Forever". When projected through by the gas polariscope, two versions of the image were produced in green and orange, the respective colours of Irish Catholic and Protestant factions (see fig. 18). Other similarly produced slides included depictions of flowers, butterflies, dolphins and folk heroes such as Robin Hood (Clarke c.1837, 27-28). These examples emphasise the potential uses of scientific apparatus for entertainment purposes.

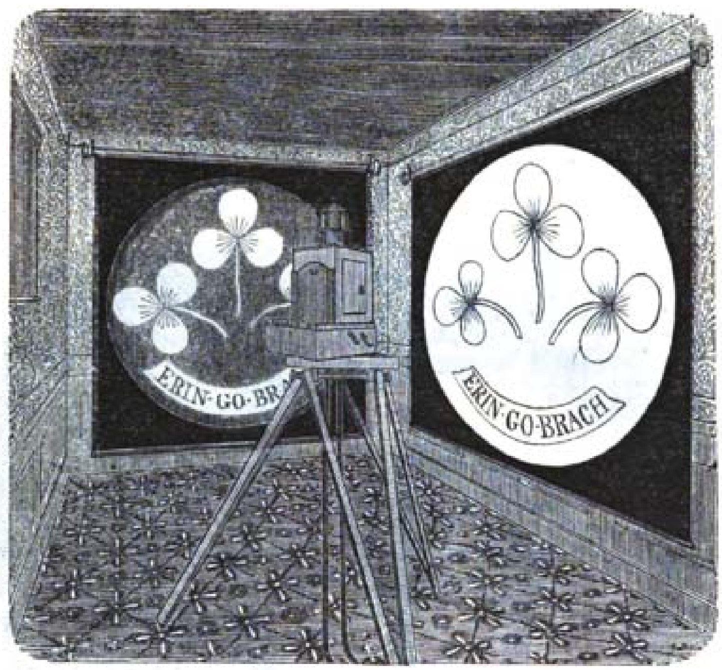


Figure 18: Illustration from Clarke, Edward Marmaduke. c.1837. *List of prices of mathematical, philosophical, optical, and chemical instruments and apparatus, manufactured by Edward M. Clarke.* London: Taylor and Walton.

In 1875 a version of the Chromatrope was created that made its scientific aspects explicit. Geared to rotate a single slide at great speed, this chromatrope was designed to *blend* colour, based on Isaac Newton's colour experiments. It included changeable slides that corresponded to the differing colour theories of Newton, Brewster and Thomas Young, and to the 'persistence of vision' experiments of Michael Faraday. It was designed by

American science lecturer Henry Morton, for whom its effects were evocative of ‘an ever-opening and changing morning glory, or of a fountain of light and color, from whose center wells out a succession of colored waves, chasing each other outwards until they are lost on the margin of the basin’ (Morton 1875, 344). Although Morton’s chromatrope exploited then-current scientific theories of persistence of vision to aesthetic effect, it also makes clear a connection to contemporaneous experiments in that area.

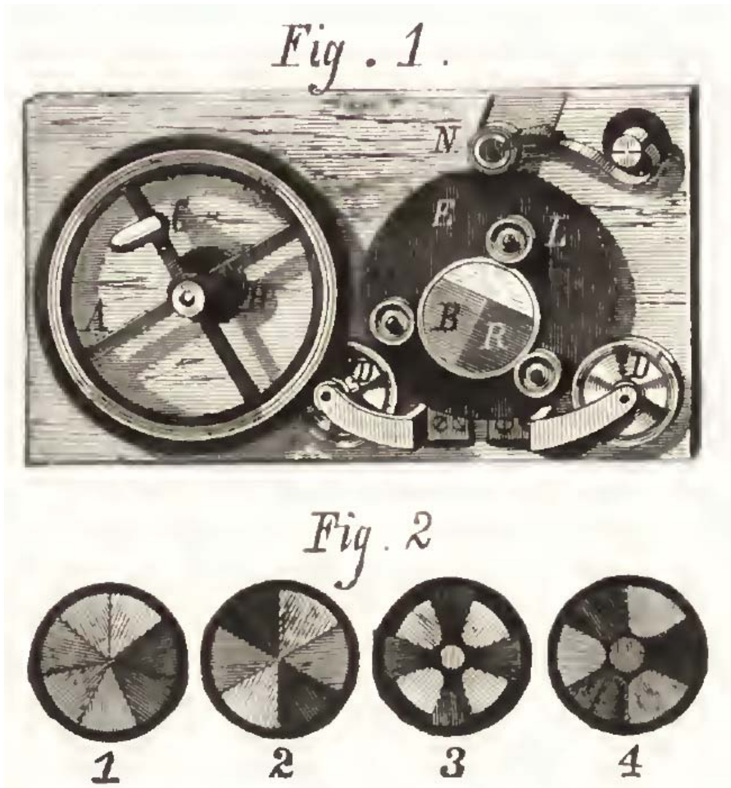


Figure 19: *Diagram of Henry Morton’s Chromatrope designs,* from Amos Dolbear 1888 *The Art of Projecting: A Manual of Experimentation in Physics, Chemistry and Natural History with the Porte Lumiere and Magic Lantern.* Boston: Lee and Shepard. 142.

British scientists Michael Faraday, Charles Wheatstone and William Henry Fox Talbot all investigated the perceptual phenomena known as persistence of vision. Along with the work of French scientist Joseph Plateau, their research informed a range of popular philosophical toys that produced the effect of animation, including the phenakistocope and zoetrope. Although these devices, like Morton’s chromatrope, sought to blend phenomena, the experiments of all three scientists were seeking to determine methods to counteract the persistence of vision. In order to dissemble fleeting phenomena into their constituent instants, they employed a range of mechanised optical devices that included spinning discs, rotating mirrors and flashing lights (Schuler 2016, 42-44). In Talbot's words, his private experiments sought to develop a means of "optically fixing moving bodies" (quoted in Ramalingam 2015, 345). Faraday and Wheatstone both regularly presented public lectures and scientific demonstrations demonstrating persistence of vision experiments. These performances fulfilled the desire for novel and engaging scientific phenomena, while also helping to develop and refine techniques of experimental observation (Ramalingam 2013, 249). The object of study for these scientists was the perceptual performances of their own optical apparatus, whereas the popular appeal of their public performances lay in the ability to stimulate this same performative visuality in their audiences.

Figure 20*: Optical photometer for the measurement of the intensity of light and colour, to the design of William Henry Fox Talbot, constructed by W. & S. Jones, London,* c. 1830. Collection of National Museums Scotland, ref. T.1995.31

The optical experiments of Faraday, Wheatstone and Talbot are echoed in a series of works made by Marcel Duchamp between 1920 and 1925, collectively known as *Precision Optics*. The first of this series, *Rotary Glass Plates (Precision Optics)* of 1920 operates directly within this lineage. Like Talbot's persistence of vision apparatus, the spinning propeller-like segments of this device optically merge at speed to form concentric circles. This group of works focus explicitly on retinal sensation despite Duchamp's (in)famous critique of 'retinal art' (Duchamp in Cabanne 1971, 43). Indeed, at the time of making the work *Rotary Demisphere* (1924), Duchamp stated that he would regret if the apparatus were seen as 'anything other than "optics"' (Duchamp 1975, 185). Nonetheless, art discourse references abound to the representational qualities of this work, and its 'obvious allusion to the part-object: the breast, the eye, the belly, the womb' (Krauss 1993, 81; see also Schwarz 1997, 58). Seen from this perspective, these works operate as representations of embodiment.

Figure 21: William Henry Fox Talbot, *Apparatus for persistence of vision experiments,* c.1850. Collection of the Fox Talbot Museum.

Figure 22: Marcel Duchamp*, Rotary Demisphere (Precision Optics),* 1925. Painted papier-mâché demisphere fitted on velvet-covered disk, copper collar with plexiglass dome, motor, pulley, and metal stand.

On one hand, Jean Clair argues that Duchamp's optical works move away from an 'excessive grounding in the sensory world,' and towards a 'purely conceptual space, without thickness or depth, of optical and linguistic games' (Clair 1978, 104; 112). On the other, for Rosalind Krauss the project of these optical works concerns 'corporealizing the visual,' and doing so 'against the disembodied opticality of modernist painting' (Krauss 1993, 216).

This discursive movement backwards and forwards, between the poles of the conceptual and the corporeal, echoes the dizzying movement of Duchamp's optical works; it is both perceptually and discursively destabilising. In Duchamp's own words, the significance of the effect lies in the fact that it is not produced by the apparatus, but 'in the eyes of the onlooker, by a psycho-physiological process' (quoted in Richter 1965, 99). The effect is therefore dependent on the perception of the individual viewer (Duchamp in Tomkins 2013, 79). In contrast to the 'obvious allusions' to the body surveyed by Krauss above, Duchamp's optical works do not represent but *activate* embodiment. By generating an experience of performative visuality, these works highlight that the spectator is intra-actively part of the phenomena that they perceive.

The optical amusements of the chromatrope, the kaleidoscope and the experimental apparatuses of Talbot and Duchamp are all united by their explorations of opticality. They suggest movement in two directions: on the one hand, towards the non-referential "universality" of abstract pattern; and, on the other, towards the performativity of projection technology itself, that is, to the specific situatedness of this performance and its incorporation of the spectator. These abstract and illusory apparatuses encourage a mode of engagement with the apparatus that is best described in Hacking's terms as intervention rather than representation. In other words, they seek to intervene in the perception of their spectators, to produce an optical effect, not to represent some state of affairs out in the world. Rather than either representing or intervening from outside, they provide a means of '*intra-acting* from within, and as part of, the phenomena produced' (Barad 2007, 56).

3.4 Viewing the Invisible

The previous section developed an account of performative visuality in relation to the apparatus. The focus of this section extends this further in order to consider the performativity of the apparatus when employed in an effort to visualize the invisible. This account concentrates on two historical instances, one from the last decade of the nineteenth century and one from the first decade of the twentieth century. One relates to an ‘epistemology of the eye,’ embodied by the expert perceptive faculties of the scientist and augmented by optical technologies; the other exemplifies the emerging role of photographic technology as a delegation of expertise to the ideal of ‘mechanical objectivity’ (Daston and Galison 2007). Both examples also complicate categorical divisions between objective and subjective modes of observation and reveal creative potential for an engagement with the apparatus.

Although it is common to equate photography with mechanical objectivity, Galison contends that photography realised an ideal already established by earlier uses of optical devices such as cameras lucida and obscura (Galison 1998, 354). These technologies of instrumentally augmented seeing conferred a sense of objectivity on the representations they were used to produce, in advance of the enhanced objectivity offered by the photographic apparatus. One mark of photography’s influence was its ability to produce a visual record of phenomena beyond human perception. In 1888, scientist Pierre Jules Cesar Janssen proclaimed: ‘sensitive photographic film is the true retina of the scientist,’ due in large part to the fact that ‘in the radiative spectrum it covers a range more than double that which the eye can perceive and soon perhaps will cover it all’ (quoted in Ihde 2003b, 255). For scientists such as Janssen, photography offered a means of translating non-visual phenomena into images, thereby bringing the imperceptible within the realm of observation.

The discovery of X-rays by Wilhelm Roentgen in 1895 is seen as the greatest fulfillment of that potential during the nineteenth century. Roentgen’s discovery of these rays, normally invisible to the eye, emerged from the study of another scientific apparatus, the Crookes tube. Roentgen observed that the discharge of concentrated rays from the Crookes tube exposed unopened photographic plates. As Don Ihde notes, ‘the phenomenon was produced by the apparatus’ and in this sense ‘became experienceable only in instrumentally mediated form’ (Ihde 2016a, 7-8). In intra-action with the ‘compound technology’ of Crookes tube and photographic emulsion, the normally invisible ‘Roentgen rays’ were found to render matter itself invisible, passing through some materials but not others. X-rays became a widespread object of research, but they also sparked a wave of new research into the science of the invisible, fuelled by the possibility that the next major discovery would be hiding in plain sight.

One of the scientists researching the “new” phenomena of X-rays was French physicist Rene Blondlot. In the course of a range of experiments designed to identify the velocity, wavelengths and possible polarization of X-rays, Blondlot identified another type of radiation. He named them ‘N Rays,’ after the city and university of Nancy, where he lived and worked. In a series of papers written from 1903 to 1906, Blondlot catalogued a wide range of material manipulations and experimental observations, which in turn resulted in an ever-expanding list of properties apparently possessed by N rays. Depending on the thickness of the material, these new rays were found to pass through aluminium, paper, wood, copper, brass, cardboard and glass, but could be blocked by lead, iron, and the smallest amount of water. Sources of N rays identified early on included sunlight, gas Auer Burners and incandescent Nernst lamps. Eventually this list grew to include materials subjected to force such as tempered steel, glass objects known as Rupert’s drops and compressed wood. The natural and industrial energies exerted upon these materials were thought to have been detectable as an emanation of N rays.

Blondlot stressed that N rays were not light rays, but a form of radiation that interacted with light. Their study therefore involved the detection of subtle changes in luminosity of different materials in darkened spaces. These observations were complicated by the fact that some materials were found to store and re-transmit the rays – including materials making up the instruments of observation, such as quartz lenses and prisms, even the human eye. N rays were therefore only perceptible to a trained observer, working to the most rigorous methods. These difficulties are reflected in Blondlot’s advice to experimenters. Potential observers were required to ‘play an absolutely passive part’ and to try to ‘see the source [of light] without looking at it’ (Blondlot 1905, 82). He likened the perceptual skill required to that of an Impressionist painter, and concluded: ‘this requires some practice, and is not an easy task. Some people, in fact, never succeed’ (Blondlot 1905, 83).

Many scientists seeking to repeat Blondlot's experiments never did succeed, although it should also be noted that many did. Between 1903 and 1906, more than 40 people reported observations of the N-rays, and around 100 scientists and medical doctors wrote articles on the topic (Nye 1980, 125 n6). Blondlot used many of the same observational techniques and instrumental supports that he had employed in his earlier successful X-ray experiments (Bauer 2002, 11). Eventually, however, a consensus developed that they were a purely subjective phenomenon, the product of faulty perception.

Two experimental episodes were taken as especially conclusive refutation of the phenomenon. Most famously, the American scientist Robert Wood visited Blondlot's laboratory and, in the darkened space, intervened in the experiments. The fact that the reported outcomes of these demonstrations did not change was taken by some as conclusive. In the retelling of this account, the details were embellished (see Ashmore 1993, 67-106). Wood and others claimed that his intervention put an immediate stop to belief in N-rays in 1904. However, almost a quarter of the research papers published on the topic of N-rays were published following this article (Baldi and Hargens 1995, 242). German scientists Otto Lummer and Heinrich Rubens also claimed to have replicated Blondlot's observations, not through the action of N-rays but through the well-known powers of peripheral vision in a darkened space (Nye 1996, 157). To paraphrase Vilém Flusser, what N-rays brought to light was 'the tricks within' one's own perceptual apparatus.

The perceptual peccadillos that were so damning in the case of N-rays are productively exploited in the work of contemporary artists such as James Turrell. Works such as *Hind Sight* (1984) require that their spectators optically acclimatize to a darkened space, which they approach through a double-blind corridor. This spatial *dispositif* operates as a controlled environment for a structured experience of predefined duration. Despite these structures, and the management of audience experience by gallery attendants, there is an ambiguity that is central to this work. Turrell's earliest such works employed a darkened anechoic chamber as part of the Art and Technology program at the Los Angeles County Museum of Art. In his 1969 notes for this project, Turrell stipulated that the light was ‘to border on its questionable existence’ and leave the spectator uncertain whether the phenomena were ‘real or retinal field induced’ (Turrell in Livingstone 1971, 134). This ambiguity encourages attentive observation. As the spectator’s eyes adjust to the darkness and search for something to focus on, it becomes possible to extrapolate a range of potential observations from the minimal stimulus available. Every potential form perceived in the darkness becomes significant.

In the cases of both Rene Blondlot’s N-ray experiments and the dark room installations of James Turrell, the combination of spatial and environmental *dispositif* with human perceptual apparatus (optical instruments in Blondlot’s case) require the perceptual interpretation of changes taking place in darkened spaces. This is a perceptual hermeneutics in which the experiential apparatus reveals more than is seen, in contrast to the psychoanalytical tradition (as framed by Ricoeur) as revealing more than is said. The next section will consider the material hermeneutics of photography, with its promise of removing the instrumental artefacts of perception from the observation of the invisible.

The negative verdict for N-rays can be at least partly attributed to the impossibility of photographing them, given the subtlety of the phenomena and the nature of their interactions with light. Blondlot, as author of the phenomenon, was unable to withdraw and allow the apparatus to make the case on his behalf (Stengers 2000, 84). A century earlier, William Herschel had discovered infrared light by sensing its heat, claiming to be able to identify the transmission of heat to a ratio of one part in a thousand (Hacking 1983, 177). In the age of mechanical objectivity, Blondlot’s dependence on claims of expert perception was, once again, found to be ‘irremediably subjective’ (Tiles 1984, 60). In response to such criticisms, Blondlot did attempt to photograph the effects of N-rays. His principal method was shielding one half of a photographic emulsion from the action of N-rays and repeatedly exposing both halves to sparks of light. The intention was that the multiple exposures would cumulatively reveal the greater luminosity of the emulsion that had also been exposed to N-rays. The diffuse halo registered in these images did not serve as conclusive proof.

Blondlot's multiple N-ray exposure photographs employ the technologies of photography as a measuring device rather than as a tool of representation per se. As a primitive form of technoconstruction, in which multiple events are combined into a single visual result, these images anticipate the complex variational imaging practice of contemporary science. As Don Ihde emphasises, such imaging practices are far from passive processes of observation (Ihde 1998, 59). Each individual image is the product of decades of data collection, synthesized from multiple classes, iterations and upgrades of apparatus. This sustained accumulation replaces the traditional indexical relation, disconnecting the resulting images from the traditional photographic sense of representation. While earlier scientific imaging often sought to instantaneously capture fleeting phenomena for later sustained analysis, much contemporary scientific imaging consists of 'instrumentally translated' and analysed data, distilled into a form able to be taken in instantaneously 'at a glance' (Ihde 2002, 135).

This approach has been epitomized in recent decades by the project to map Cosmic Microwave Background (CMB) radiation. Constructed through the decades-long collection of data, in turn generated by multiple iterations of radio telescopes and satellites, the CMB project seeks to map traces of invisible radiation leftover from the formation of the universe. The example of CMB imaging therefore foregrounds the highly constructed nature of contemporary imaging, as well as its hermeneutic aspect. As Ihde describes it, such instrumental complexes seek to allow the universe to 'speak' and 'to make what was invisible visible' (Ihde 2003a, 20). The material hermeneutics of CMB imaging might be productively compared to a much earlier attempt to materialise phenomena that lie beyond the scope of non-instrumental perception. In the remainder of this section I want to consider one final example. It represents what might be considered limit phenomena in relation to the ability of the apparatus to bring the invisible into visibility. It troubles, yet also helps to define the boundaries of the apparatus.

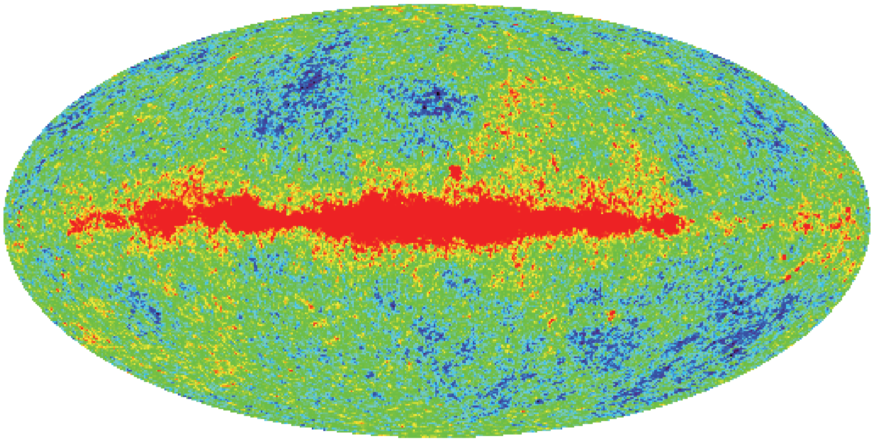


Figure 23: *Cosmic Microwave Background.* Courtesy NASA/JPL-Caltech, ESA and the Planck Collaboration.

The example is a series of photographs produced in the mid-1890s by Swedish dramatist August Strindberg, which he named *Celestographs*. These images of the night sky bear a resemblance to more contemporary astronomical photographs or images of the CMB. Although the *Celestographs* relate to camera obscura or pinhole photographs (which Strindberg also practiced), they are not the product of an apparatus, in the sense of a physical 'black box.' Instead, Strindberg exposed photographic plates immersed in developer to the night sky in the belief that the universe would impress its own image upon the surface.

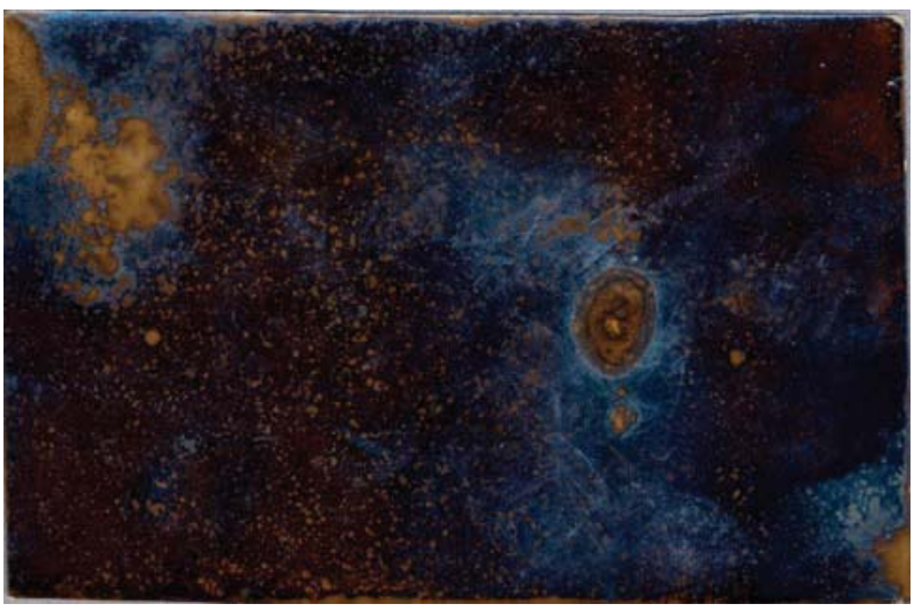


Figure 24*:* August Strindberg, *Celestograph XIII,* 1894.

Strindberg re-directs the pervasive metaphors of early photography as the ‘pencil of nature’ (Talbot 1844) or ‘mirror with a memory’ (Holmes 1864, 130), that produced images ‘impressed by nature’s hand’ (Talbot 1844, 1) and allowed an object ‘to draw its own picture’ (Talbot 1844, 44). Strindberg’s *Celestographs* also recall contemporaneous scientific experiments using photography to reveal invisible phenomena. In 1896, Strindberg noted the resonances between his own photographs and X-ray images, which had recently caused a sensation and were also produced using neither camera nor lens (Strindberg 1996, 163). Indeed, following Wilhelm Rontgen’s 1895 identification of x-rays, a Swedish journal mistakenly cited Strindberg’s earlier photographs as recording the same phenomena (Strindberg 1996, 259n1). Although the *Celestographs* were presented and discussed at the May 1848 meeting of the Astronomical Society of France (Strindberg 1996, 164), his endeavours might be described as a contingent astronomy at best. What the *Celestographs* record is not the cosmos but chemical reactions within their own surface.

Figure 25: August Strindberg, *Crystallograph,* 1890.

The *Celestographs* form part of an idiosyncratic imaging practice that included *crystallographs*, or images contact-printed from ice crystals. They also relate to Strindberg's prescient interest in chance and the production of 'automatic art.' In 1894, around the time he began producing *Celestographs,* Strindberg wrote:

> All at once a point defines itself, like the nucleus of a cell; it grows, the colors group around it and accumulate; rays develop which sprout branches and twigs as ice crystals do on a window pane (Strindberg 1996, 105-106).

Although evocative of his own photographic practices, Strindberg is here referring to the experience of viewing modern painting. Nevertheless, the merging of processes of perception with chemical development seem fitting in this context. As in Blondlot's pursuit of N-rays, an analogy can be drawn here between the specialist perception shared by modern science and modern art in their attempts to represent phenomena beyond ordinary perception. Some commentators have gone so far as to argue that the resulting images should not even be referred to as photographs, because they bear no external referent and therefore record nothing (Pettersson 2012, 762). Alternatively, one might say that the images record their own means of production; they record the interaction of chemicals to produce an image.

My point is not to celebrate either the randomness or romanticism of Strindberg's *Celestographs*, nor to oppose the imaging practice of art and science. Rather, it is to consider the potential for such fringe phenomena in reconsidering the status of the apparatus as blind spot. Paradoxically, Strindberg's photographic experiments were shaped by his mistrust of the apparatus, or at least what he regarded as the distorting potential of the lens. These images forego the use of an apparatus—in the sense of a black box—in favour of an emphasis on the material-discursive *dispositif* of optical, chemical, and environmental elements. The *Celestographs* are entirely products of their own material constitution. In this sense, they represent a total merging of apparatus and image, of subject and material support.

The phenomenon of Blondlot's N-rays and Strindberg's *Celestographs* are the product of particular conceptions of the powers of the apparatus, emergent at the time in the spheres of science and art. They attempt to employ the apparatus to reveal the invisible or capture an experience that would not otherwise be visible. The phenomena that are recorded or observed might best be described as the product of this particular relation between apparatus and world; they are projections in Flusser's sense of the term, rather than indexical recordings of reality. Textual hermeneutics often reveals hidden meanings, or more meaning than is intended in what is said (Ihde 1983, 151). In allowing matter to 'speak,' the perceptual experiments of Rene Blondlot and the material hermeneutics of the *Celestographs* similarly reveal more than we might see. They reveal the relationship between apparatus and image; they bring this particular relationship into visibility.

Merleau-Ponty suggests, 'to see is always to see more than one sees' (Merleau-Ponty 1964, 247). This can be considered a hallmark of the blind spot because the potential of such fringe phenomena lies in the hermeneutic activity that they invite from their audience. What I am suggesting therefore is that the presence of the apparatus is most clearly revealed precisely by a *misalignment* to its referent. In the context of this research project, these examples also provide a means of collapsing ready distinctions and dissolving oppositions into intertwinings; observer into phenomenon, subject into object, visible into invisible, apparatus into image.

3.5 Experiment and Enlightenment

From the early 1920s to the late 1960s, the Danish-born artist Thomas Wilfred promoted what he described as 'the eighth art,' *Lumia,* or 'the art of light.' Central to Wilfred's explorations of lumia was his development of a series of apparatuses termed 'Clavilux,' a name intended to connote their nature as 'light played by keys.' As Stephen Eskilson has observed, discussions of Wilfred's productions highlight the difficulty of positioning technologically engaged art in the first half of the twentieth century. Eskilson draws the conclusion that Wilfred tried and failed to force a 'paradigm shift' in the reception of his work, forming ‘essentially pragmatic’ alliances first with music and then with modernist painting (Eskilson 2003, 65, 68). But this reading itself suggests an all-or-nothing approach to the modernist ideal of autonomy. Instead, I assert that the relationship between Wilfred’s art of light is multivalent, and that a focus on the role of the apparatus in Lumia brings fresh aspects of this relationship to light.

Wilfred drew frequent analogies between lumia and music, describing the new art form as ‘a silent visual art’ (Wilfred 1947, 252). As is often noted, Wilfred’s lumia compositions were titled, scored and notated in the style of musical compositions. The earliest public forum for the Clavilux was an acclaimed tour of concert-style performances in 1922. For these reasons, Wilfred’s works are most often associated with the traditions of ‘colour music.’ However, it is important to emphasise that Wilfred drew a marked distinction between the clavilux and the one-to-one equivalence between music and colour suggested by most designs of ‘colour organ’. It was this sense of equivalence with music that he distanced himself from, rather than foregoing all musical analogy. In 1948 he predicted that in time lumia would come to ‘fully equal those of the seven older arts, will also in many cases conjoin with these (and with other art forms yet to come)’ (Wilfred 1948, 90). Though lumia might accompany the arts of theatre or music, he was adamant that it should never imitate them, but instead should be considered an independent art. While accounts such as Eskilson’s focus upon Wilfred’s lumia concerts and the attendant musical analogies (Eskilson 2003, 65-66), I want to consider the nature of Wilfred’s apparatuses and the various ways that they ‘conjoined’ with other media. By being attentive to the differences that matter in the development of lumia—those differences that emerge through intra-action with/in other practices from the history of art and science—a picture of practice develops that is illuminating not only for Wilfred’s work, but for the notion of the apparatus itself.

A consideration of the performativity of lumia in relation to theatre rather than music affords a different perspective. The branch of lumia, that Wilfred refers to as ‘the projected setting’ involved the adaptation of the clavilux to operate as a mutable and evocative merger of lighting and scenic backdrop. More than simple stage lighting, the projected scenery enables 'the lighting artist at the control board to blend setting and actor-lighting together, as a painter balances light, shade, and accent on his canvas' (Wilfred 1965, 1). The reference to painting here is instructive. Just as an artist might produce a painted backdrop or set design for a theatrical performance, yet remain an independent artist, lumia can function as one part of a theatrical performance without being any less autonomous as art. Although the lighting artist is, like the scenic painter, 'essentially an accompanist who only on rare occasions can justify a solo passage' (Wilfred 1965, 49), the projected setting employs lumia as an integral element of theatre production, 'folding itself around speech and action as closely as music around an opera libretto' (1954, 136). Wilfred's recourse to both painting and music as analogies for the relationship between lumia and the theatre suggests a diffractive relation rather than a simple opposition. Multiple points of comparison and connection, commonality and difference are at play in his attempts to define the parameters of this new art.

The projected setting not only required the adaptation of the clavilux to the theatre, it also necessitated that the theatre adapt to accommodate the performative nature of this new art. As well as adapting his designs for clavilux performance setups and projection booths to the theatre, Wilfred also designed a new type of theatre. Dubbed the "Heptarena," this was a spatial *dispositif* designed to enable the incorporation of lumia as projected setting into the theatre-in-the-round. Aside from these theatrical applications, the spatial dimensions of lumia were a prevalent concern for Wilfred. As early as 1926, Wilfred was fantasising about a grand 'Temple of Light', adorned with a 'silent visual carillon,' illuminated by the lumia performances taking place within (fig. 27). The first physical version of such a space, which he called 'the Art Institute of Light,' was housed in New York's Grand Central Palace from 1930 until 1942. This 100-seat venue was Wilfred's home base, and principal venue for his own Clavilux performances. Like the Polytechnic lecturers described above, he would preface these performances with an espousal of the philosophy behind lumia and an explanation designed to prepare audience members for the edifying experience to come. The Institute's tenancy was interrupted by the war, after which Wilfred continued to dream of a new Art Institute of Light. He described one of its central features as:

> … the Hall of Light, a miniature theatre seating about fifty spectators. Open day and night, it will present an uninterrupted performance of selected lumia compositions in utter silence. No admission charge, no questions asked, no philosophy propounded. You may walk in at any hour of day and night and remain as long as you like, to rest your ears and bathe your soul in the slowly evolving sequences of radiant form, pure color and graceful motion (Wilfred 1947, 254-255).

Notably different in this vision of lumia's future are the intimate and absolutely silent nature of the experience described. The private and uninterrupted nature of the experience imagined here shifts the focus from the skill of the operator to the role of the spectator.

Figure 26*:* Thomas Wilfred, *Unit #86, from the Clavilux Junior (First Home Clavilux Model) series,* 1930.

Figure 27*:* Thomas Wilfred, *The Clavilux Silent Visual Carillon,* 1928. Gouache and watercolour on paper, mounted on cardboard. Thomas Wilfred Papers, Manuscripts and Archives, Yale University Library.

In the 1947 essay cited above, Wilfred acknowledges the primacy of the spectator in lumia: 'the spectator is a necessary factor in the concept: *a* *materialized vision, beheld by a beholder*.' He adds the proviso that: 'the spectator may be only the artist himself' (Wilfred 1947, 252). Wilfred's 1926 drawings of his ideal 'keyboard room' demonstrate a separation between performer and audience. Like the projection booths used for magic lantern display at larger venues such as the Royal Polytechnic, this idealised setting the 'performance space' for lumia is quite separated from the experiential space of spectatorship. Like the earlier magic lantern tradition, this creates a space for the play of revealing and concealing gestures (Morus 2006, 105). Exhibition displays also make a feature of this dialectic. This can be seen in the inclusion of 'peepholes' into the usually hidden interior workings of Wilfred's larger works in the recent Yale University Art Gallery survey exhibition (Orgeman 2017). This spatial sleight of hand recalls Latour's description of the modern scientific laboratory as a site for 'the staging of a scenography in which attention is focused on one set of dramatised inscriptions' (Latour 1990, 42). By directing attention away from the work of performance, the spatial apparatus operates 'like a giant optical device that creates a new laboratory, a new type of vision, and a new phenomenon to look at' (Latour 1990, 42). What is also dramatised in this setting is the perceived separation between apparatus and screen.

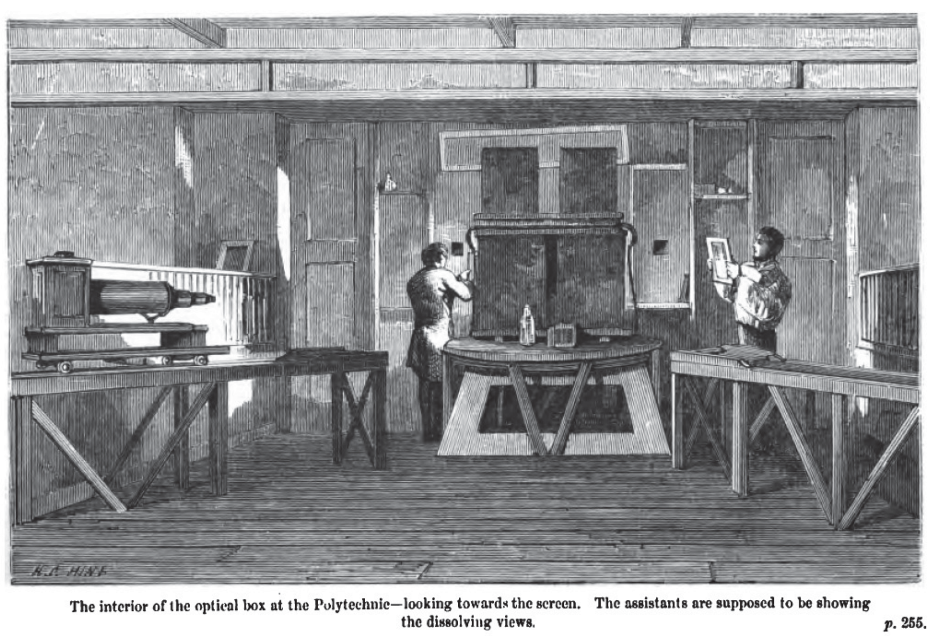


Figure 28*:* The Royal Polytechnic projection room from J. H. Pepper. 1860. *A Boy's Playbook of Science.* London: Routledge, Warne and Routledge. 255.

Figure 29: Thomas Wilfred, *The Keyboard Room in the Temple of Light,* 1926. Ink on Paper.

Wilfred often emphasised the flatness of the screen, a point that has been taken to evidence his alliance with modernist painting (Eskilson 2003, 67). But he also thematised the separation between screen and apparatus in terms of a corresponding distinction between 'the aesthetic concept' presented to the spectator and 'the physical equipment' used to produce the effect. Like Roland Barthes' distinction between the spectator's photograph and the operator's photograph, Wilfred discerns two different fields of vision within the phenomena of lumia. He designates 'first field' what is actually seen on the screen by the spectator. 'Second field' resembles what Vilém Flusser would describe as the Universe of the apparatus: 'the totality of possible combinations of its code' (Flusser 2000, 85). Wilfred urges the light artist to 'work *as if* you actually had all of space for your stage; as if you were seated at the controls of an imaginary space liner,' navigating the spectator through and around 'a celestial architecture of light-year dimensions' (Wilfred 1948, 78-80). The 'first field' of the spectator is 'a three-dimensional drama unfolding in infinite space' (Wilfred 1947, 252), viewed through the window of the space-liner, and composed by means of the lumianist's 'carefully charted course' (Wilfred 1948, 80). While the attention of the spectator is directed to the 'dramatized inscriptions' of the score, Wilfred cautions that the operator:

… not for an instant must you forget that your craft is a room in a building, the magic window a flat white screen, the propelling force an optical instrument. Even while your hands are operating it, you must be consciously unconscious of the physical equipment; in a flash you must be able to turn from a gigantic form far out in space, to its flat image on the screen, and back again (Wilfred 1948, 80).

Performing with the clavilux therefore required that its operator also repeatedly perform a Gestalt switch, between the field of the aesthetic concept and that of the physical equipment.

Figure 30: Thomas Wilfred, *Imagination—the Esthetic Concept; Reality—the Physical Equipment,* c.1940–50. Ink on paper 42.5 x 27.5 inches. Thomas Wilfred Papers, Manuscripts and Archives, Yale University Library.

Though mobilising the space-age metaphor of the viewing window looking out onto infinite space, Wilfred's spectator-space-ship also recalls earlier technologies of armchair travel, the moving panorama and the diorama. Not only were the painterly effects and lighting transitions of these spectacles designed to open a portal onto different times and places, but the dioramas of Charles-Marie Bouton and Louis Jacques Mandé Daguerre featured geared seating that literally moved its audience from one scene to the next. From Wilfred's perspective, this sense of mobility and transformation marked lumia's difference from painting. He wrote: 'the rules governing static composition and static color harmony in painting do not apply to form and color in motion; nor do the rules governing composition in music apply to a visual sequence' (Wilfred 1948, 89). Once again, lumia is positioned as an entirely new and autonomous art, different to both painting and music.

A further point of difference argued by Wilfred is also related to the physical equipment. Contrary to the conventions of instrument construction, which operates in conjunction with the standardisation of musical notation, he argues that 'in lumia the execution of nearly every new work means readjustments, changes, or new additions to the existing equipment' (Wilfred 1948, 89). In the language of the mangle, each composition involves a dance of resistance and accommodation. Each new apparatus represents another interactive stabilisation of these elements. In the case of the clavilux, however, these successive stabilisations enable fresh machinic performances of material agency.

This aspect of lumia is perhaps best represented by a series of Clavilux models that Wilfred designed for the domestic market and for museums. These objects have remained the most durable trace of his experiments in the 'art of light'. While early models featured limited controls, the experience created by these models is spectatorship, not performance. The appropriate analogy would be to a recording of a performance; some models even included a series of discs that owners could change (like a record) to watch different compositions. In Bruno Latour's terms, this is a form of *delegation,* in this case, of live performance by a human actor to an automated performance by the programmed apparatus. This programming often included rotating colour discs and gels, but diffused through a moving network of filters and reflectors. The looping rotations familiar from the chromatrope become part of a series of cycles and epicycles that overlap, alter and extend each other; in this sense, they fulfil the chromatrope's promise of 'endless variation'. Defined in terms of the length of time before the cycle identically repeats, Wilfred calculated the duration of compositions as long as 9 years, 127 days, 18 hours.

Figure 31: Photograph of Thomas Wilfred operating *Unit #86, from the Clavilux Junior (First Home Clavilux Model) series,* 1930.

Figure 32*:* Disc from *Clavilux Junior Opus 75,* c.1930.

As objects, the home claviluxes and their larger museum counterparts function as a black box because they enclose the physical equipment and shield its programmatic performativity from view. As domestic furniture, their clearest point of comparison is the television. As black boxes, they also internalise the spatiality of lumia, and short circuit the possibility of switching between aesthetic concept and physical reality. The design of an early domestic Clavilux makes the point clearly; or rather, its resemblance between the closed Clavilux Jr and his fantasy design for the Art Institute of Light brings the point home. Exhibitions of novelty and innovation hosted by Victorian scientific institutions foregrounded the performative potential of the magic lantern and the potentially illuminating nature of illusions. The domesticated technology of the magic lantern brought these entertaining and illuminating displays into the domestic sphere. The performativity of these light-based scientific spectacles was internalised in Thomas Wilfred's clavilux. The spectacles of lumia were also adapted to both public and domestic arenas, but this move was enabled by the automation of the apparatus.

In constructing a historical survey of artworks employing technologies of light projection, Laszlo Moholy Nagy described Wilfred's *Clavilux* as 'an apparatus resembling a *laterna magica* with which changing non-objective pictorial variations were shown' (Moholy Nagy 1969, 20). In addition to the variations presented within Wilfred's screen-based 'aesthetic concept,' I have shown that his practice demonstrates a variety of approaches to the 'physical equipment' of the apparatus. As the art of light is articulated in intra-action with other creative disciplines, the multistable variations and interactive stabilisations of lumia provides an important context for this practice-led research.

3.6 Contemporary Turns to the Apparatus

In the case of Thomas Wilfred's lumia compositions, produced and presented by means of clavilux, the multistability of the apparatus was reflected in the intermedial position of this 'eighth art.' In this section I will consider the significance of this multistability for contemporary engagements with moving image apparatuses of video and film. In particular, I want to emphasise the deconstructive potential of an engagement with the apparatus by considering early video works by the artist Steina, and recent film works by Simon Starling.

From 1975 onwards, Icelandic-American artist Steina produced a group of works collectively referred to as *Machine Vision*. These works are distinguished by a delegation of camera operations, including pan, tilt and swivel, to various assemblages of cameras, monitors, mirrors and machines. As Steina described it:

> These automatic motions simulated all possible camera movements without making the camera and its operator the center of the universe. Time and motion became the universe, with endless repetitive cycles and orbits (1995, 16).

The artist's description recalls the appeal to the endless changes made possible by the chromatrope and kaleidoscope a century earlier. With the advent of video technology, the mesmerising loops and optical transformations performed by those earlier apparatuses are automated and industrialised. Over the following decade, Steina's 'performing systems' were retooled and presented in varying configurations and diverse environments, including those of the studio, gallery and specific landscapes (Bijvoet 1997, 225). In each case the machine vision of the apparatus records and transforms its surroundings, whether it is presented in the form of a live feed as part of a video installation (fig. 33), or through the generation of video recordings to be subjected to further postproduction (fig. 34).

Figure 33. Steina, *Allvision I* 1975. Video Installation.

Figure 34. Steina, *Orbital Obsessions* 1975–1988. Black and White Video, 25 minutes.

The work *Orbital Obsessions* (1975-1988) compiles much of the footage produced in the studio, recording the process of its own creation through a range of intra-actions involving artist and apparatus. Here, the space of production and the figure of the artist are implicated in the work. In one sequence, the artist and her collaborator, Woody Vasulka, are seen testing the material capacities of the apparatus, observing and discussing its operations and performances. In another, she walks around the rotating machine, keeping pace with one of its cameras while holding up a monitor screening the feed from the opposing camera. The artist moves as part of the assemblage, at the same time directing an additional camera producing 'machine to machine observations' (quoted in Cathcart 1978, 48). The video recording emerges from a network of intra-acting human and material agencies, with the artist not behind but rather in front of the apparatus, amidst its workings.

As the title given to the body of work suggests, these works explore a specifically machinic vision. The movements of the cameras are machine generated, the regularity of their programmed movements highlighted by contrast to the artist's own movements performed in response. The automated movement of the cameras map the space in a way different to that of human vision (Sturken 1996, 44). Yet, the premise of machine vision also encompasses the array of monitors, mixing panels and image modulators that surround the central apparatus. Through live and post-production processes, these technologies intra-actively mangle the video signal: multiplying and nesting images within one another, while also cross-contaminating video and audio frequencies, layering repeated audio fragments over footage of the machine physically looping around the space, and rapidly cutting between the two camera views to duplicate the figure of the artist. The work has a demonstrative function – it both catalogues and exhibits such effects. In this regard, it echoes Talbot and Henneman's panoramic photograph of *The Reading Establishment* (fig. 4), demonstrating the possibilities of the new technology while also turning the gaze of the *appareil* towards a spatial *dispositif* of associated technologies. The point is that Steina's video turns away from both the assumed naturalism of photography and the cinematic association of the camera/screen with a human viewpoint. Her work instead explores the multistable potential of machine vision, by turning the gaze of the apparatus back on itself.

The work of Simon Starling also investigates the capacity of machine vision to record the conditions of its own making. The apparatus is literally central to the work *Wilhelm Noack oHG* (2006), comprising a 35mm film projector and custom made looping machine (fig. 35). This assemblage is used to project a film that documents the factory in which the looping machine was produced. The specificity of the object and the imagery that it screens both link to a particular site of manufacture, which is designated in the title of the work. The film records the sound and vision of the factory floor, as well as the designs, documentation, photographs and maquettes that comprise its material history. These material traces connect the present day factory to the legacy of European modernism, embodying its history as a site for fabrication of works by designers such as Lilly Reich, Ludwig Mies van der Rohe, Fridtjof Schliephacke and Fritz Bornemann. In this regard, the film forms a behind-the-scenes history of modernist design, exposing the anonymous industrial labour that traditionally followed both form and function.

Figure 35: Simon Starling, *Wilhelm Noack oHG*, 2006. Purpose-built loop machine, 35mm film projector, 35mm B&W film with sound.

Starling's work places the *appareil* centre stage within the spatial *dispositif* of the work, potentially dividing the spectator's attention between apparatus and image. In addition to its functionality, however, the apparatus plays a signifying role by referring back to its site of production and becoming part of the spectacle. The looping machine is both formed and informed by the factory — it is based upon a spiral staircase design that is featured in the film. This site for the transformation of raw materials into culture in turn becomes the raw material for the film's production, as the work both documents and adds to this accumulated history.

Both film and apparatus are products of the factory. Beyond its role as location and subject, the workings of the factory were incorporated into the filming process. The camera was treated as an extension of the machinery – its machine vision directed and movements controlled through the use of drills, dollies, pulleys and winches. The activities of film-making are made to mirror those of the factory. As described by Flusser, the factory is a site for 'turning what is available in the environment to one's own advantage, turning it into something manufactured, turning it over to use and thus turning it to account' (Flusser 1999, 46). As he goes on to note, such 'turning movements are carried out initially by hands, then by tools, machines and, finally robots' (Flusser 1999, 46). The custom manufacturing represented by *Wilhelm Noack oHG* is — in the face of increasingly automated mass production — essentially a site of passing skills and traditions, which are in turn recorded using a medium that is itself approaching obsolescence.

Figure 35: Simon Starling, *D1 - Z1 (22,686,575:1*), 2009. 35mm B&W film with sound, Dresden D1 film projector, loop machine, amplifier, speakers.

The histories of material fabrication and digital representation were explored in another work by Starling, entitled *D1 - Z1 (22,686,575:1)* (2009). Analogue and digital technologies come together in this work, which employs a Dresden D1 film projector to present a digitally animated depiction of an early computer known as the Z1. Designed by engineer Konrad Zuse and built in his parent's Berlin apartment from 1936-8, the Z1 is considered the world's first freely programmable digital computer. During World War II shortages, the Z1 took its programming input from manually hole-punched discarded 35mm filmstock (Zuse 1993, 63). For media theorist Lev Manovich, this symbolic consumption of cinema by the computer represents a key moment in the transition from 'media' to 'new media,' while also foreshadowing the absorption of all technologies of representation into the digital (Manovich 2001, 25). While Starling's film focuses on a close-up of the hole-punched analogue film feeding through the Z1's data reader, his work also reverses the evolution described by Manovich, by outputting the digital animation to 35mm celluloid film and then projecting it life size using a Dresden D1 projector. This particular selection reflects a specific place and era common to both represented and representing apparatus.

The work's title obliquely refers to the historical distance from that time and place, as measured by differences in computing power. The memory required to produce the 30 seconds of digital animation was 22,686,575 times the entire memory of the original Z1. Though this comparison is not exact, in that the memory of the Z1 was purely operational and non-rewritable, it nevertheless highlights the vast difference between the capacities of the Z1 and what are now considered everyday technologies. Starling both memorialises and reanimates the Z1, which was destroyed during World War II bombings. A reconstruction of this important, but obsolete, piece of equipment is today located in the collection of the Deutsches Techniksmuseum, presented as a 'read-only memory' immobilised under glass.

Starling's works revisit these material histories in ways that reflect upon the conditions of their creation and re-creation. The specificities of the *appareil* and *dispositif* function as differences that matter, shaping and transforming the production of these historical reflections and their reception by a contemporary audience. Like the works of Steina, Starling's works experiment upon and play against the apparatus in order to explore the performative capacities of its machine vision.

3.7 Contextual Conclusions

This research draws on a history of engagements with the apparatus in which marginal practices and forgotten figures take on central importance. These include a little known Victorian institution that merged science and amusement, the forgotten performative visuality of the chromatrope, the pseudo-scientific activities of Blondlot and Strindberg and the in-between art of lumia. Within these histories, apparatuses operate as boundary blurring practices, provoking engagement across the disciplinary boundaries that normally separate art and science. These contexts directly ground and inform this practice led research.

Public institutions such as the Royal Panopticon of Science and Art employed spectacles of technology and artistry to engage the public and engender interest in the science of the day. The rhetoric of progress and discipline that drove this endeavor are acknowledged as another important element for this history. In practice, however, it is the productive tensions between science, spectacle and amusement that provide a rich source for this research project. Similarly, this popular scientific culture displays an interplay between optical experiments and illusionistic amusements that is valuable for my considerations of the apparatus. Technologies such as the chromatrope played a simultaneously essential and peripheral role within magic lantern culture, and held a prominent position in the programs of scientific institutions such as the Royal Polytechnic and the Royal Panopticon. The significance of such optical amusements can only be appreciated through a consideration of the apparatus in its historical context. This context includes optical and perceptual experiments performed by scientists such as Faraday, Wheatstone and Talbot. I suggest that these historical contexts are also vital for understanding the similarly essential and peripheral role of the apparatus in contemporary art discourse.

The fringe phenomena of failed attempts to observe the invisible are illuminating for an analysis of the apparatus. The instrumental and optical labours of Rene Blondlot in pursuit of N-rays highlight the intra-action between the human perceptual and instrumental apparatuses. August Strindberg's *Celestographs* bring into focus the intra-acting material agency of photographic emulsion and the self-imaging forces of the Universe. The perceptual and material hermeneutics at play in these examples serve to highlight the role of the apparatus, which is considered in relation to the highly constructed techno-imaging of contemporary science. These emerged as pivotal examples in which the figures of observer and phenomena, image and apparatus are not opposed but rather deeply entangled together.

The art of light advocated by Thomas Wilfred foregrounds both the performativity of the apparatus and its precarity in relation to traditional conceptions of medium. Analogies abound to the arts of music, painting, theatre, sculpture, and installation, as well as to the spectacular combinations of science, technology and art discussed previously. As an art form that operates both autonomous from and in intra-action with these other media, lumia emerges as emblematic of the apparatus as a blind spot.

The concept of multistability pinpoints the co-existence of multiple, seemingly contradictory perceptions. The works of Thomas Wilfred embody a mutistable relation to traditional artistic conceptions of medium. At the same time, his work centres on multistable relations between the aesthetic concept transmitted to the spectator and the physical reality of the apparatus. The works of Steina and Simon Starling do not seek to trigger a switch between image and apparatus, or to privilege an experience of one over the other. Instead, they seek to turn the gaze of the apparatus on itself. In the work of Steina, this takes the form of an experimental engagement with a self-reflective machine vision. In Starling's works, the conditions of their production are foregrounded in relation to the material specificity of analogue and digital moving image technologies. As such, these works provide a valuable context for the consideration of this research project's creative outcomes in Chapter Four.

Chapter 4: Operating the Apparatus

4.1 Introduction

In this chapter I undertake a discussion of key individual works from the research project. Each work articulates a specific relation to the apparatus. The chapter further traces some of the histories of the apparatus that directly inform these works. The aim of this approach is not to narrate these histories, but to consider their significance for a contemporary engagement with the apparatus. The process of development in each work varies; it emerges through: material experimentation; the consideration of potential transformations in a specific apparatus; or discursive reflections on the histories of art or science. This variety of approaches is reflected in the discussion of individual works. While the overall focus of the research inquiry has involved investigating the apparatus from multiple perspectives, many of my works concentrate on video technologies in concert with other processes and forms of the apparatus. My concern, however, is not focused on video as a medium. Rather, the research pursues a more specific approach that focuses on an experimental engagement with the apparatus. As stated at the outset, the conception of the apparatus articulated by Vilém Flusser affords the breadth of perspectives required by such an approach. The chapter will conclude with a reflection on the exhibition *You and the Universe*, which brought together the key works for this PhD research project. Through a consideration of the relations between works within this exhibition, I will highlight the conclusions developed through my practice-led research.

4.2 Embodying the Apparatus: *Starry Messages (redshift)* 2016

The work *Starry Messages (redshift)* utilises appropriated imagery, viewed by means of a homemade telescope. Looking into an eyepiece mounted on the side of the tube, the spectator’s gaze is directed through an arrangement of mirrors housed inside in order to view a video played on a ‘Samsung Galaxy’ mobile phone. Much of the imagery in the video was sourced from educational filmstrips held in the collection of the Institute of

Cultural Inquiry, Los Angeles, where I undertook an artist residency just prior to commencing the PhD. These filmstrips were designed for teaching primary school science in the 1950s and 1960s. They combined astronomical photographs with diagrams mapping planetary and atomic orbits. They also extended to illustrations imagining the future of space travel circa ‘A.D. 2000.’ They present a simplified, traditional view of scientific knowledge and progress, including idyllic visions of the scientifically perfected future.

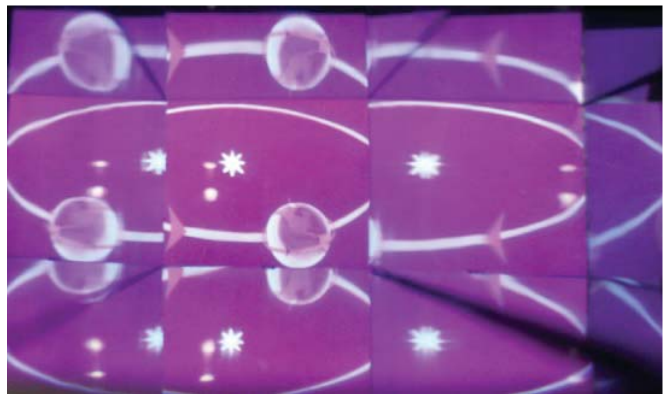


Figure 37: Christopher Handran, *Starry Messages (redshift)* 2016. Digital video, Samsung Galaxy Centura phone, mirrors, Postpak tube, tripod.

Figure 38: Christopher Handran, *Starry Messages (redshift)* 2016. Interior view.

Fragments of this outmoded techno-scientific worldview are presented through a compound apparatus that is itself largely obsolete. The filmstrips featured idealistic illustrations of satellites orbiting the globe, a vision now realised in the form of our global communication network. Yet despite being part of this network, the mobile phone used to screen the video imagery inside the telescope is considered obsolete by the measure of contemporary telecommunications. The technoscientific progress celebrated by the filmstrips paradoxically leads to a constant turnover of planned obsolescence by means of rapid progress. As well as being constructed from a ‘postpak’ tube, the telescope with/in which the video was viewed was modelled on the similarly obsolete technology of the optical telescope. As Don Ihde reports, some astronomers no longer count optical telescopes as instruments in themselves. Instead they describe them as ‘merely a light gathering device’ for use in conjunction with actual instrumentation such as spectrometers or interferometers (Ihde 2010a, 31). This collection of obsolete imagery and technology therefore harks back to an earlier age of scientific practice.

The renaissance technology of the Galilean telescope, on which the portapak telescope is based, figures prominently in Don Ihde's account of 'embodiment relations' in scientific practice. Ihde defines 'embodiment relations' with technology as involving the 'incorporation' of technology *into* our bodily experience of the world (Ihde 2009, 43). The telescope's amplification of vision across enormous distances comes with a reduction in the 'field of vision'. But these factors combined also amplify the effect of bodily movement on what is seen. He concludes that 'both body and moon are thus magnified' and therefore both become 'part of the now technologically transformed observational context' (Ihde 1993, 46). With *Starry Messages (redshift)* I offer a different 'seeing-through' experience than the telescopes described by Ihde. This work highlights the peculiarity of the unaccustomed viewing experience by requiring a physical adaptation by the spectator. The ambition is to reveal the embodied nature of the relation between spectator and apparatus.

While the form of the viewing device in *Starry Messages (redshift)* is modelled on the telescope design popularised by Galileo Galilei, the title of the work also refers to the self-published 'literary technology' (Shapin and Shaffer 1985, 25) that he employed to report on his astronomical observations. The title of Galileo's publication was *Sidereus Nuncius* (1610), which was intended to mean 'the message of the stars,' although it is usually translated as either *The Starry* or *Heavenly Messenger* (Koyre 1957, 288 n1). The metaphor of the starry message reflects the enlightenment positioning of the scientist as an interpreter of the "book of nature," or in Galileo's case: 'this grand book, the universe, which stands continually open to our gaze' (quoted in Shapin 1996, 69). While suggestive of the hermeneutic model of science outlined by Ihde, the figure of the messenger also recalls another aspect of hermeneutics, the root of the term in Greek mythology Hermes (Ihde 1998, 10). In what Flusser would describe as an anti-entropic gesture (Flusser 2016, 71), the twentieth century diagrams, photographs and illustrations featured in this work operate as messages transmitted across time. Originally intended as projections of the future, they instead record the past.

The practices of astronomy merge scales of time and distance; to look far into space is to look far into the past. By employing outmoded technologies, my work, *Starry Messages (redshift),* also fuses varying models of time and obsolescence. The vision of the universe and our place in it presented in the filmstrips is out-dated. So too the images included of past visions of our possible future appear antiquated today. Materially, this obsolescence is manifest in the discolouring of the film towards a uniform magenta. The 'redshift' also referred to in the title is a reference to both this materialization of decay and to the use of light spectra to measure astronomical distance. Specifically, the degree of distortion of radiation towards the red end of the spectrum indicates the distance and velocity of astronomical objects. This material decay also provides a fitting analogy for the distance between the worldview represented in these images and the contemporary perspective from which the viewer is invited to consider them.

The work *Starry Messages (redshift)* 2016 provides a key starting point for this research. It brings together historical and aspirational narratives around science and technology in the form of an apparatus that foregrounds the experience of spectatorship as an embodied relation.

4.3 Philosophical toys: *Liquid Crystal Displaced* 2016

Seeking to convey the value of his technologically amplified perceptions, in 1610 Galileo promised to present 'great things' for his audience to 'observe and to consider':

> Great as much because of their intrinsic excellence as of their absolute novelty, and also on account of the instrument by the aid of which they have made themselves accessible to our senses (quoted in Koyre 1957, 88-89).

The 'absolute novelty' of perceptual experience mediated by apparatuses remained a central feature of their appeal. During the nineteenth century, these qualities were most accentuated in the figure of the philosophical toy. As discussed in the previous chapter, this was a class of popular devices that encouraged an experimental engagement with perceptual phenomena. To modify Vilém Flusser's definition of the apparatus, philosophical toys can be thought of as a 'plaything or game that *stimulates* thought' (Flusser 2000, 83). Such apparatuses therefore operate at the intersection of art, popular culture, spectacle and science. The work *Liquid Crystal Displaced* (2016) revisits the most well-known of these educational playthings, the kaleidoscope.

Figure 39: Christopher Handran *Liquid Crystal Displaced* 2016. LCD screen, Digital video, mirrors, cardboard, tripod. 150 x 85 x 130 cm. 14 minutes 26 seconds.

The work features a 1.2 metre-long kaleidoscope, which frames, transforms and magnifies a ubiquitous and everyday technology: the liquid crystal display, or LCD screen. The work employs microscope elements mounted on cameras to magnify the liquid crystal elements of the screen, which are in turn multiplied, reflected and refracted by the mirrors housed within the kaleidoscope. Though abstracted, the 'source' imagery consists of similarly nested screens within screens, collected from the familiar backgrounds of news reportage. Normally unobserved, the changing patterns of red, green and blue function as the hidden materiality of the screen image. As media archaeology theorist Jussi Parikka has observed, 'media history is one big story of experimenting with different materials from glass plates to chemicals […] to processes such as crystallization, ionization, and so forth' (2012b, 97). The form of the kaleidoscope also belongs to this history. Its roots lay in scientist David Brewster's research into the refractive, reflective and polarising properties of crystals as well as the crystalline structure of insects' compound vision.

Brewster features as a key example in Ian Hacking's argument refuting the dominance of experimental practice by theory. Hacking characterises Brewster as 'the major figure in experimental optics' of his era, but argues that his practice was more focussed upon material manipulation and observation than on theoretical explanation (Hacking 1983, 157). One outcome of this rigorous material investigation was the kaleidoscope. As Brewster tells the history of the device, its first genesis lay in his 1814 experiments with the polarisation of light by successive reflection (Brewster 1858, 1-2). The kaleidoscope therefore belonged to a family of instruments that were grounded in science but crossed over into the cultures of spectacle and popular amusement, which underpin this investigation of the apparatus.

Yet Brewster felt that when used for the 'purposes of instructing the young, or astonishing the ignorant,' scientific instruments such as the telescope, microscope and electrical apparatus were quick to lose their novelty (Brewster 1858, 154). The kaleidoscope, however, was unlike such scientific instruments and it escaped this fate, according to Brewster, due to the endless changes it generated, not unlike those possible with a musical instrument (Brewster 1858, 155). The constant variety of patterns generated by the kaleidoscope would, in Brewster's words, 'prove of the highest service in all the ornamental arts' (Brewster 1858, 6). As Ian Christie notes, the kaleidoscope's potential uses in this regard were close to home for Brewster, including the Scottish textile and carpet industries (Christie 2007, 11). The Jacquard loom had recently increased both the practical possibilities and commercial necessity for pattern making, and Brewster implied that his invention, the kaleidoscope, performed a similar function for the eye. Praising the mathematical values of symmetry imposed by the kaleidoscope, Brewster drew an analogy to the improvements of manufacturing brought by industrial machinery (Brewster 1858, 134-136). The kaleidoscope represented an industrialisation of the eye that finds its contemporary equivalent in the constant cycle of televisual culture.

Figure 40: Christopher Handran, *Liquid Crystal Displaced* 2016. (detail).

Beyond the common thread of constant variation, the visual fragmentation performed by the kaleidoscope also resonates with Don Ihde's description of postmodern media culture. Likening the compound vision of insects (which informed Brewster's development of the kaleidoscope) to the 'screen walls' that background news coverage, Ihde states, 'the compound eye refracts, breaks into vision-bits, produces culture-bits' (Ihde 1991, 174). In the work *Liquid Crystal Displaced,* the compound vision of the screen becomes subject to magnification by the microscope lenses and fragmentation by the kaleidoscope.

The work also brings together an assemblage of technologies to magnify the material dimension of the screen, with the video imagery being recorded using microscope lenses attached to a digital camera. Brewster's kaleidoscope was also a compound technology, designed for use in conjunction with observational instruments, such as the microscope (Brewster 1858, 128-130), photographic camera (Brewster 1858, 148-153), and camera lucida (Brewster 1858, 137), but also with projection technologies including the magic lantern, solar microscope and camera obscura (Brewster 1858, 117-121). Furthermore, it included its own stereoscope (Brewster 1858, 126-127) and telescope (Brewster 1858, 81-87) variants.

The bricolage construction of *Liquid Crystal Displaced* involved domestic materials including an arrangement of mirrors, housed within a “light shaft” from a DIY skylight kit, supported by a camera tripod. Together, this assemblage created an oversized viewing device for spectators to physically engage with in an embodied relation. The kaleidoscope features in this work as an ideal means of collapsing the opposition between image and apparatus. As an optical technology, the kaleidoscope does not merely mediate or frame a view, but actively transforms it. Image and apparatus are, in this sense, entangled together. The transformations performed by the kaleidoscope in this sense evoke the role of the apparatus within the crystal ontology described by Andrew Pickering – that is, the sense that the world appears differently depending on how we engage with it, and therefore ‘the angle from which we approach the world matters’ (Pickering 2015, 119). This is the contingent ontology that is revealed by the apparatus.

Liquid Crystal Displaced connects the crystalline compound vision of the kaleidoscope the microscopic crystalline structure of the screen. In doing so, it also reconnects their shared histories of material and optical experimentation. As an automated apparatus for the production of visual spectacles, the kaleidoscope fragments and abstracts its referent. This work opens the apparatus at the centre of contemporary screen based culture to this process of abstraction and fragmentation.

4.4 Evoking Devices: *Cosmic Background* 2016

Contemporary televisual culture also provides the starting point for the work *Cosmic Background*, but the source in this case is transformed through a method approaching the technoconstructivist material hermeneutics of contemporary scientific practice (Ihde 1998, 177-183). Viewed from this perspective, science is largely defined by its reliance on instrumentation, which is often directed at materialising phenomena beyond the scope of non-instrumental perception. As early as 1620, Francis Bacon noted this strategy of scientific practice, referring to 'evoking devices' that 'reduce the non-sensible to the sensible; that is, make manifest, things not directly perceptible, by means of others which are' available to perception (quoted in Hacking, 1983, 168-9). As noted in the previous chapter, the development of photography promised much in this regard. The scientist Pierre Jules Cesar Janssen asserted: 'the sensitive photographic film is the true retina of the scientist' (quoted in Ihde 2003b, 255). In operating beyond the spectrum of human perception, the results of such instrumentation often take the form of data that requires further interpretation to become 'sensible.' These instances comprise what Don Ihde refers to as hermeneutic relations with technology, in which the apparatus is both 'read' and 'read through' (2009, 43). In *Cosmic Background*, the visual data remains at the level of the abstract, operating interstitially within a chain of apparatuses.

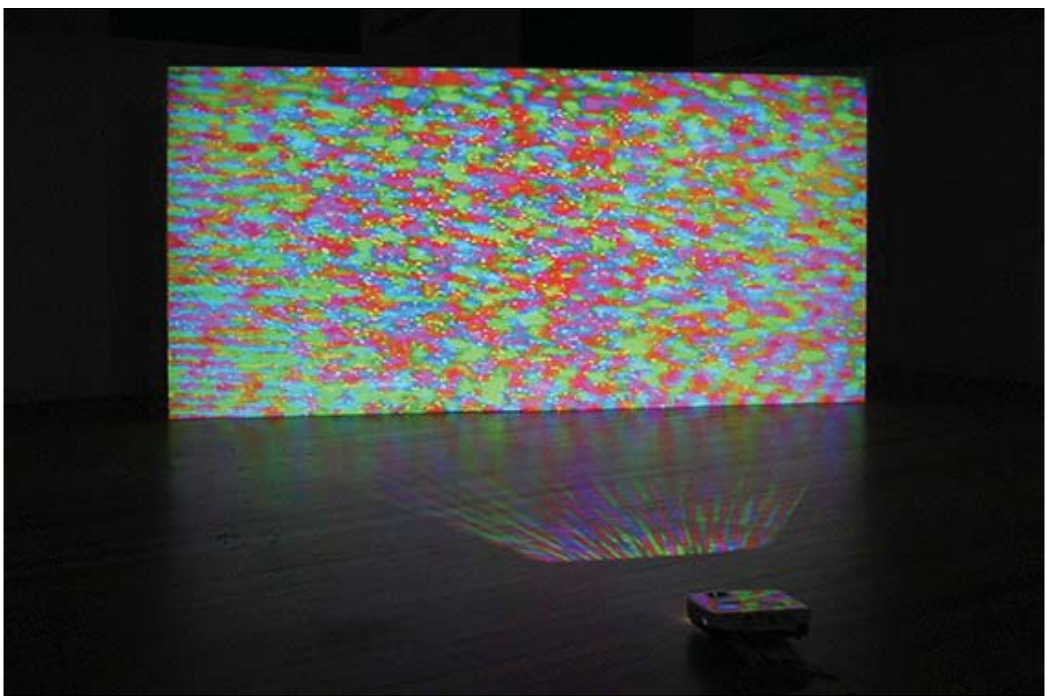


Figure 41: Christopher Handran *Cosmic Background* 2016. Digital video projection. 2 hour 20 minutes

The work *Cosmic Background* (2016) engages with the evocative but unreadable nature of such abstract instrumental 'inscriptions.' Specifically, the work filters static, which was recorded over ten years ago within an analogue television broadcast of the film *2001: A Space Odyssey* (1968), for interpretive patterns. As per director Stanley Kubrick’s instructions, the film was broadcast with several minutes of black screen throughout, accompanying the film’s original overture, intermission and exit music. Poor television reception, however, transformed these blank passages into fields of glitchy visual data. The visual form of this source imagery matches information theorist Abraham Moles’ description of ‘the (visual) message most difficult to transmit’:

> It will appear to us like a gray, perpetually agitated, foggy undulation with little, capricious, constantly changing outlines. In over-all appearance, it will be *indistinguishable* from *background noise*, with a uniform probability distribution for its elements. It loses all interest because it lacks intelligible meaning. […] This paradox arises because the message contains too much information, because it exceeds our capacity for understanding and creates boredom (Moles 1966, 61).

Against Moles’ conclusion, I did find visual interest in the footage and, performing the part of Levi-Strauss’ *bricoleur,* held onto it, thinking that it ‘may always come in handy’ (Levi-Strauss 1966, 17-18). Revisiting this recording, I have scanned and filtered the static seeking to highlight patterns. This process echoed the basic "instrumental phenomenological variations" of scientific imaging (Ihde 1998, 59), including assigning colour values and performing adjustments to brightness, contrast and saturation. In reference to the source material, the soundtracks from the three periods of black screen were overlaid and slowed down, along with the manipulated and edited imagery, to the full length of Kubrick’s original film. This created a rhythmic pulsing that further evoked signals from space.

The title of the work playfully references the project to map the distribution of ‘cosmic microwave background radiation’ (CMB) throughout the universe. Apart from a visible resemblance between the imagery, the phenomenon of static was central to the discovery of CMB. As Ian Hacking recounts, attempts by Bell Telephone Laboratories to isolate and filter out static first identified radiation from outer space as one cause of the interference (Hacking 1983, 159). Indeed, 1% of television static is reputedly caused by cosmic background radiation. As Hacking emphasises, identification of CMB is often mistakenly described as a classic case of scientists performing experiments to test a pre-existing theory. In fact the experiments that identified this ‘small amount of energy which seemed to be everywhere in space, uniformly distributed’ were wholly unrelated to theoretical work being performed on the same topic (Hacking, 1983, 160). It therefore emerges as another key example in Hacking’s exploration of the dynamic relationship between theory and experiment.

This work does not narrate this history, nor does the work rely on it for the audience’s experience. Rather, I assert that this work (and the others I have described) exemplifies the intertwining histories of art, science and technology that are revealed through a focus on the apparatus. The work connects to these histories and philosophies in ways that seek to illuminate and re-imagine their potential. They also seek to exemplify the entanglement of matter and meaning, theory and practice that is central to my methodology. The work *Cosmic Background* inaugurated an important shift in my thinking within this research. Along with the example of August Strindberg’s *Celestographs,* discussed in the previous chapter, this work collapsed oppositions between image and apparatus that had previously been a key starting point for this practice-led research. These examples pointed instead to productive possibilities for a material-discursive amalgamation of apparatus and image.

The scale and spatial dimensions of the projected imagery are an important element of this work. Projection at a large scale enables the work to operate as an immersive experience in relation to the viewer. The play of colour across the wall recalled the psychedelic effects featured in the original film’s famous ‘star-gate’ sequence. This sequence, in which the lone astronaut travels ‘beyond the infinite,’ could be described as the film’s aesthetic climax. It features a range of abstract and processed imagery, including elements that closely resemble the lumia compositions of Thomas Wilfred, discussed in the previous chapter. Though not directly drawing this comparison, art critic Annette Michelson similarly echoes Wilfred with her suggestion that Kubrick’s film ‘converts the theatre into a vessel and its viewers into passengers’ (1969, 60). My own reworking of the film’s interstitial sequences created a different spatial relation to be navigated by the spectator. When the work was first exhibited, the dimensions of the gallery space encouraged closer proximity to the work, with the result that it did function as a literal background for audience members. Subsequent showings of the work in a larger space enabled a more distanced approach. Kubrick's film was cited in the form of a VHS cassette of the film, which was used to prop up the projector. The undulating projection, combined with the rhythmic signals of the sound, created a mesmerising experience in these settings.

Cosmic Background performs a series of translations and transformations directly related to those described by Don Ihde. In the context of contemporary scientific practice, the constructed nature of such images is taken as a measure of rigour and objectivity. As summed up by Ihde, 'the higher degree of technoconstructivity yields the highest result in information – to know is to construct' (Ihde 1997, 380-381). In this work, the transformations performed by means of apparatus are not aimed at revealing messages from the stars, or reading the 'grand book, the universe, which stands continually open to our gaze' (Galileo quoted in Shapin 1996, 69). What is revealed by the material hermeneutic operations at play in this work is the material-discursive nature of the apparatus itself, which carries the imprint of the universe with/in which it intra-acts.

4.5 Impressionist Empiricism: *N-Ray Detector* 2018

The quest for observations of invisible phenomena also features in the work *N-Ray Detector.* While *Cosmic Background* concentrates on the material hermeneutics of instrumental imaging, this work is based upon an example from the history of scientific practice that brings together traditions of instrumentally mediated perceptual observations with an emerging culture of mechanical objectivity. The work reworks early twentieth century experiments performed by Rene Blondlot in pursuit of a new form of radiation known as N-rays. As discussed in Chapter 3, the scientific community soon reached a consensus that N-rays were the products of subjective perception.

The case of N-rays is often cited within science and technology studies (STS), but rarely discussed in depth. This is surprising given the emphasis placed on symmetry, or an equal treatment of science and non-science, in many STS approaches. A representative example is provided in the work of David Bloor, a key proponent of symmetry. After an abridged account of the episode (Bloor 1991, 29-30), in which only one of the N-ray experiments is outlined, Bloor concludes: 'the trouble lay in Blondlot's experimental design. His detection process was at the very threshold of sensation' (Bloor 1991, 30). What was compromised in the affair was 'the reliability of some Frenchmen […] not the whole of perception' (Bloor 1991, 30). The verdict delivered by Bloor is clear and echoes most accounts of the N-ray affair: the two causes of the controversy were the perceptual nature of Blondlot's practice, and the social constraint of scientific nationalism. As previously noted, however, Blondlot's N-ray experiments employed the same methods, in some cases even the same apparatus, as his earlier and much praised X-ray experiments (Bauer 2002, 11). Finally, Bloor cautions that an over-emphasis on such obviously faulty cases only hurts the sociological enterprise: 'Sociologists would be putting themselves where their critics would, no doubt, like to see them—lurking amongst the discarded refuse in science's back yard' (Bloor 1991, 30). In providing too easy a target for critique, the predetermined falsity of N-ray phenomena precludes them from symmetrical analysis.

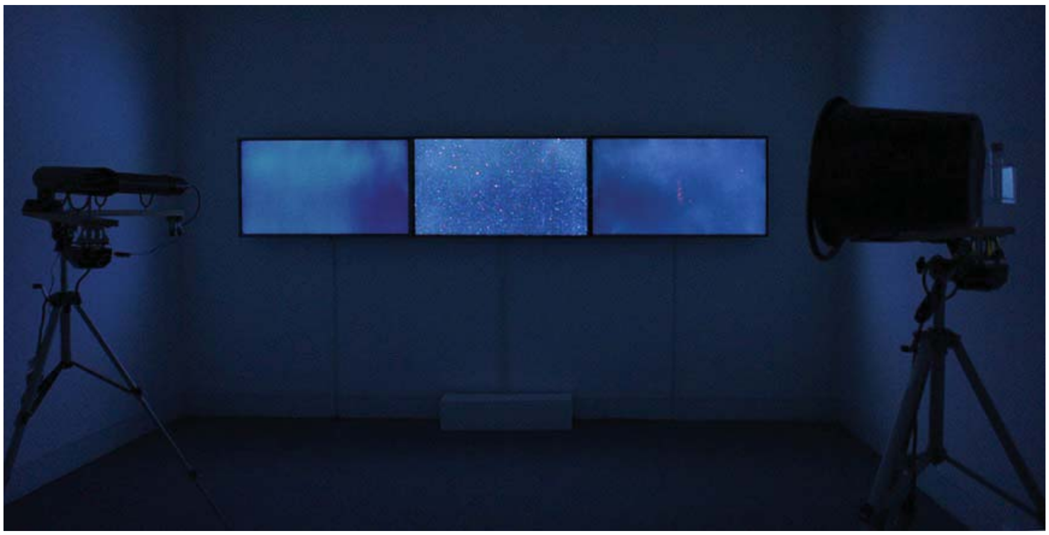


Figure 42: Christopher Handran *N Ray Detector* 2018. 3 Channel video, viewing devices, audio. 18min 40 sec

The aim of the work *N-Ray Detector* is not to use the controversy of the N-ray episode as a tool with which to critique science. Rather than revisiting the phenomena of N-rays as an example of flawed scientific method, the *N-ray detector* instead reworks Blondlot's experiments as exercises in particular ways of seeing mediated by the apparatus. *N-Ray Detector* consists of viewing devices that invite spectators to experience for themselves the phenomena of 'N-rays' plus a three-channel video work that documents my own performance of experiments attempting to record N-rays. This video is accompanied by a narration based on Blondlot's own instructions for observing N-rays. This sound repeats across the three screens as spectators are invited to adapt to the viewing requirements of the apparatus by bending down, looking through, or manoeuvring their body in a performative act of viewing.

One of these viewing devices was based on an experiment described by Blondlot, which involved applying a phosphorescent paste, made by mixing powdered calcium sulphide with collodion, onto a blackened cardboard screen. My version of this experiment involved glow-in-the-dark paint applied to the bottom of a bucket, which also accorded with Blondlot's instructions. This bucket was placed at the opposite end of a focus tube from an assemblage of hardened steel, which operated as a source for N-rays and vials of water as a source of interference. These materials were rotated by a motor in order to alternate the exposure of N-rays travelling down the focus tube and illuminating the screen. Blondlot's original instructions suggested that the visibility of the 'confused nebula' of painted spots would transform under the action of N-rays, so that: 'all the spots will *become distinct and more luminous*; the nebula resolves itself. When the rays are suppressed, the screen resumes its former aspect' (Blondlot 1905, 79-80). With *N-Ray Detector,* spectators were invited to look into the bucket and observe the changing luminosity of the nebulous forms. As in other works, the methods of the *bricoleur* feature here, as they did in Blondlot's original manipulations and observations of everyday materials as he attempted to determine the performative range of N-rays.

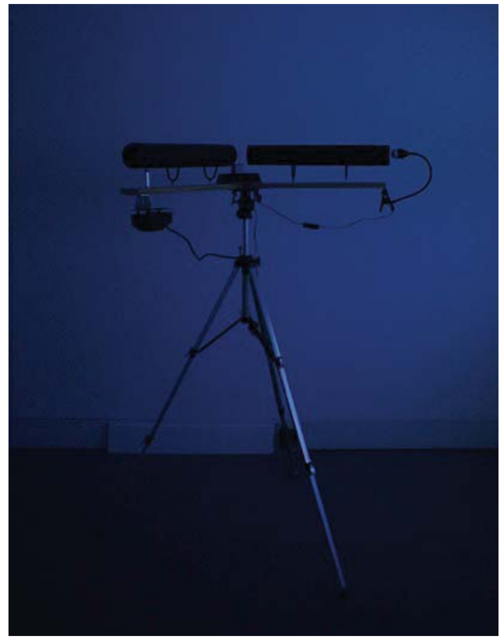


Figure 43: Christopher Handran *N-Ray Detector* 2018 bucket, phosphorescent paint, packing tube, plastic, hardened steel, water, motor, wood, tripod
Figure 44: Christopher Handran *N-Ray Detector* 2018 wire, motor, bucket, packing tubes, prism, lamp, aluminium foil, tripod

The second viewing apparatus was based upon the experiment performed by Blondlot in order to measure the refractive indices of N-rays. This was the experiment that was surreptitiously disrupted by the American scientist Robert Wood, which most commentators cited as conclusive refutation of N-rays. This experiment employed an electric lamp as the source of N-rays, shielded by aluminium foil ‘in order to eliminate the luminous rays which might accompany them’ (Blondlot 1905, 7). Like Blondlot’s original apparatus, mine was based on the form of the spectroscope, comprising a source of light, focus tube, prism and viewing tube. Blondlot measured the refraction using a screw painted with the phosphorescent calcium sulphide. This was moved across the path of the N-rays, subtly changing in luminosity in line with the degrees of refraction. In my reworking of the experiment, this role is played by a bent paper clip, moved across the path of the N-rays by a motor. The material engagements pursued here can be thought of in terms of the dance of agency described by Pickering—movements of resistance and accommodation—with the difference being that N-rays only seem to interactively stabilise with individual observers.

As pointed out in the previous chapter, the specific material attributes of N-rays compromised attempts to photographically record their effects. The three videos accompanying these viewing apparatuses document other reworkings of Blondlot's experiments. These included attempts to photographically register the effect of N-rays on the brightness of sparks; recording the change in luminosity of phosphorescent paint as it is surrounded by the suppressive action of water; and the use of a narrow strip of paper as a registering material for changes in luminosity, observed as various material sources of N-rays are moved in alternately greater and lesser proximity. The video recordings that result from these manoeuvres in the dark are adjusted in terms of brightness, contrast and cropping to bring the phenomena into greater visibility. In keeping with Blondlot's advice, the performance of these movements in the darkness was coordinated with the use of a metronome (Blondlot 1905, 64). The use of such instruments to regulate and discipline the performances of scientists in the laboratory belonged to the tradition of mechanical objectivity (Daston and Galison 2007, 115-189). In applying the disciplinary strategies of industry to scientific practice, such 'companions of the bench' helped to not only correct but create 'the image of unreliable humans and their failing senses' (Sibum 1995, 93). These connotations of unreliability and faulty perception were taken as crucial evidence in the refutation of N-rays, despite Blondlot's argument for his own specialist skills of observation.

In the installation, Blondlot's words of advice for prospective N-ray observers are delivered by a computer-generated voice with a French accent. This audio is interspersed within each video at different points, so that the text cycles across all three screens. The accent references the nationalism that features so heavily in accounts of the N-rays, while also making it clear that these are not my words. An audio filter applied to the heavily accented voice transforms it into a voice from the ether, emphasising that its source is not the here and now. As discussed in the previous chapter, the content of the text frames N-rays as a phenomenon that is only perceptible to a skilled observer. For commentators such as Bloor, this requirement goes against the practices of experimental science, in which the function of instrumentation 'is to avoid putting the observer in the position of having to make difficult discriminations' (Bloor 1991, 28). I suggest that, in place of the 'common sense empiricism' advocated by Bloor, Blondlot's N-ray experiments constitute what might be described as an *impressionist* empiricism.

In the advice for experimenters quoted in this work, Rene Blondlot emphasises that the observer must 'avoid all strain on the eye' and 'in no way to try to fix the eye upon the luminous source.' Instead the observer must employ peripheral vision in order to 'see the source without looking at it' (Blondlot 1905, 82). Recalling Flusser's description of the apparatus as 'a thing that lies in wait or in readiness for something' (Flusser 2000, 21), Blondlot's instructions cast the observer in the role of the apparatus within a game-like dance of agency, as they attempt to catch the phenomena unawares. Similarly, in my work, it is the spectator rather than the apparatus that plays the role of the *N-Ray Detector.* Blondlot encouraged observers to 'look at the screen just as a painter, and in particular an "impressionist" painter, would look at a landscape' (Blondlot 1905, 82-83). Intriguingly, six years earlier the American scientist credited with ending the N-ray controversy, Robert Wood, had made a similar comparison. In the 1890s Wood invented a colour photographic process that used diffraction gratings to create the impression of colour from a black and white image when viewed through a viewing apparatus. Writing of his process in the journal *Nature* in 1899, Wood described a 'peculiar fascination' that accompanied the misalignment of the image in relation to the viewing apparatus; 'the colours change in a most delightful manner,' producing a 'kaleidoscopic effect' that 'should appeal to the impressionists' (Wood 1899, 201). The illusions described by Wood in this passage resonate with my earlier discussion of N-rays and August Strindberg's *Celestographs*. The transformative potential of perceptual misalignment is similarly explored in the work *N-Ray Detector.* Whether it is the fugitive N-rays or artefacts of the spectators' own perception, these works bring the spectator face to face with the apparatus, foregrounding its operations as a direct part of their experience.

4.6 Matters of Fact: *Talbot Carpet (Facts Relating to Optical Science)* 2018

The work *Talbot Carpet (Facts Relating to Optical Science)* reworks optical experiments performed by William Henry Fox Talbot in 1836. The work involves the playful manipulation and observation of materials. In the course of his open-ended experimentation, Talbot identified a diffraction phenomenon that would subsequently become known as the Talbot Effect or Talbot Carpet. These experiments were contemporaneous with a range of other experiments, including Talbot's early photographic experiments and the first of his 'persistence of vision' experiments described in Chapter 3. Talbot's findings were reported within a series of reports in the London and Edinburgh Philosophical Magazine and Journal of Science, under the title 'Facts relating to optical science' (Talbot 1836). Based on Talbot's description of his observations in that article, I re-enacted these experiments using contemporary materials and technologies.

Figure 45: Christopher Handran *Talbot Carpet (Facts Relating to Optical Science)* 2018. Digital video projection. 600 x 399 cm. 23 minutes 41 seconds.

Talbot's original experiments brought together nineteenth-century scientific equipment, such as prisms, lenses, microscopes and the then-new technology of diffraction gratings, with more everyday materials such as strands of hair, paper and copper sheeting. He narrates a series of experimental manipulations of these materials in relation to a light source, and describes his observation of the optical phenomena that result. It is worth noting the open-endedness of these experiments, which is reflected in the empirical nature of his reports. For example, after recounting a 'quite unexpected' result, he simply remarks 'it will be interesting to learn in what manner it is explained by theory' (Talbot 1836, 403). That theoretical explanation would take almost 50 years, when the English physicist Lord Rayleigh was attempting to photographically reproduce diffraction gratings and came across the account of Talbot's earlier experiments (Rayliegh 1881). Rayleigh's resulting characterization of the phenomenon in terms of self-imaging has influenced subsequent discussions (Latimer and Crouse 1992, 80; Latimer 1993). More recently, scientists have returned to explore the Talbot Effect in more depth as a quantum phenomenon (see for example Wen et al 2013; Farias et.al. 2015; Barros et al 2017; Wen et al 2017). In such experiments, however, Talbot Carpets are almost never actually imaged, but are instead modeled based on instrumental readings, or often entirely projected based on calculations. The name Talbot Carpet comes from the appearance of the diffraction patterns when mapped as if viewed from above (fig 42).

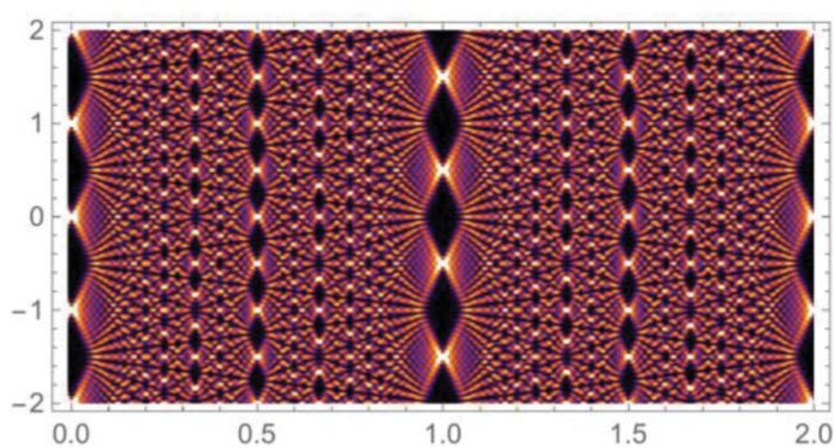


Figure 46: *Quantum or Talbot carpet* from Mariana Barros et al. 2017. "Free-Space Entangled Quantum Carpets." *Physical Review A* 95 (4): 042311.

Talbot Carpet (Facts Relating to Optical Science) documents my own attempts to both emulate Talbot's experiments and to image Talbot Carpets, using homemade diffraction gratings and contemporary everyday materials including adhesive tape, thread, kitchen implements such as a sink strainer and an egg slicer, cardboard and flyscreen. I employed a range of light sources including ordinary daylight, data projector, LEDs, ultraviolet light and domestic light bulbs filtered through coloured cellophane. Like Talbot's original experiments, the material play involved in the development and construction of the apparatus can be described as a dialectic of resistance and accommodation, in which the material and optical performances of different material setups are responsively calibrated to one another. Through this process of experimental development, I found the diffraction effects were best imaged without the aid of a lens, through the intra-action of light and an exposed CMOS digital camera sensor. The recording process involved moving the multiple parts of the apparatus (light source, diffraction grating, camera, operator) in relation to one another in an almost literal dance of agency. In particular, Flusser's description of the experimenters' 'dance around a possibility to actualize it' (2003, 68) resonates with the sensation of attempting to follow the lines of the diffraction patterns with the camera. Just as described by Talbot, the experiments produced changing bands of colour that appeared to emerge and recede from the background, moving in and out of focus, independent of focal length (Talbot 1836, 405). Though mesmerizing, the simple play of forms diffractively produced within this phenomenon are far removed from the dense trajectories plotted by today's scientists.

The phenomena observed by Talbot can be described in terms of Karen Barad's diffractive methodology as being produced by the intra-acting performativity of light waves and diffraction gratings. As a physical phenomenon that is informative about both the nature of light and the nature of the apparatus (Barad in Dolphijn and der Tuin 2012, 52), diffraction reveals the generative potential of difference. Yet the case of the Talbot Carpet also brings into focus other aspects of the critique of reflection made by Barad and Haraway. The dominant reading of the Talbot Carpet as a form of self-imaging overlooks its performativity as an interference effect (Latimer 1993). A visual echo of the diffraction grating that produces the Talbot Carpet recurs within its patterning, but to define the Talbot Carpet as a form of self-imaging requires that one only take into account these planes of recurrence. Like geometric optics, this is a reductive simplification that foregrounds some aspects of the phenomenon while neglecting others (Barad 2007, 81). As Talbot noted, the phenomena he observed did not perform according to the expectations of theory. At the time, theory would have predicted that an in-focus image would only be produced at one point, determined by the focal length of the lens being used. However, the phenomena that Talbot observed intermittently returned to focus as he moved closer and further away from the source, regardless of focal length (1836, 403). The so-called images are produced at multiple points on the trajectory passing through the diffraction grating, as light waves move in and out of phase with one another. Thus, even if the effect was defined in terms of self-imaging, the image in question is produced not through the action of a lens; nor is this image produced by the "self" implied in "self-imaging" – that is, the diffraction grating. Instead, it is produced through performative intra-actions with/in the apparatus that is constituted by the wave structure of light and the diffraction grating.

Figure 47: Christopher Handran *Talbot Carpet (Facts Relating to Optical Science)* 2018. Digital video projection. 600 x 399 cm. 23 minutes 41 seconds.

The insights produced through my own performative intra-actions with the Talbot Carpet can also be extended to further consider the critiques of reflection made by Barad and Haraway. In these instances the reduction consists of an implied human observer and an assumed representational framework. The qualities of displacement and reproduction of the same that are critiqued by Haraway (2004, 70) and Barad (2007, 29-30) are perhaps better described in terms of mirroring than reflection per se. After all, reflection is also part of the performativity of light and it emerges in intra-actions within and between multiple material agencies, without always (re)producing an image. The example of the Talbot Carpet intra-actively collapses the opposition between reflection and diffraction. It highlights the performative possibilities of resonance, considered as something more than simple resemblance, but not a linear cause and effect relation—instead it is about making connections and producing patterns of diffraction.

These insights emerge through the experience of being in the thick of things (Pickering 2008, 8). Although employing the *appareil* of the camera, my own mapping of the phenomena, like William Henry Fox Talbot's initial experiments, operated within a room-sized spatial *dispositif* comprising a light source, materials of diffraction and refraction, lenses and observer. The effect was observed by means of an improvised choreography of intra-actions with/in this spatial arrangement of elements. Talbot originally observed the effect through the magnifying lens of a microscope. My work, *Talbot Carpet (Facts Relating to Optical Science)*, enacted a similar change of scale by means of video projection. The video imagery of the Talbot Carpet was projected at a large scale onto a 3.9 x 6 metre carpet, making the analogy concrete. With sustained viewing, the changing patterns and colours appear to rise up and recede, in an optical play of surface and spatiality. The immersive scale of the projection invites the spectator to place themselves within the thick of things rather than as a spectator external to a representation.

4.7 Machinic Reproducibility: ***Light Space Replicator*** **2017-2019**

The work *Light Space Replicator* reconstructs the iconic kinetic sculpture best known as the *Light Space Modulator* (1922-1930), originally made by Hungarian modernist artist Laszlo Moholy-Nagy under the title, *Lichtrequisit einer elektrischen Bühne,* or *Light Prop for an Electric Stage,* but also referred to as *the Light Display Machine* (Moholy-Nagy 1965, 238; see also Henderson 2005b, 392-3 n67). This changing nomenclature reflects just one of the multiple, shifting identities of this work, which I will discuss in the following paragraphs. As discussed in Chapter 2, strategies of re-enactment and reworking have taken on central importance in this practice-led research. In the case of the replicating the *Modulator,* this process has helped to develop insights about the original work, which allow me to reconsider its significance for the contemporary moment. The same process also enables me to reflect back on the operations of the apparatus within creative practice.

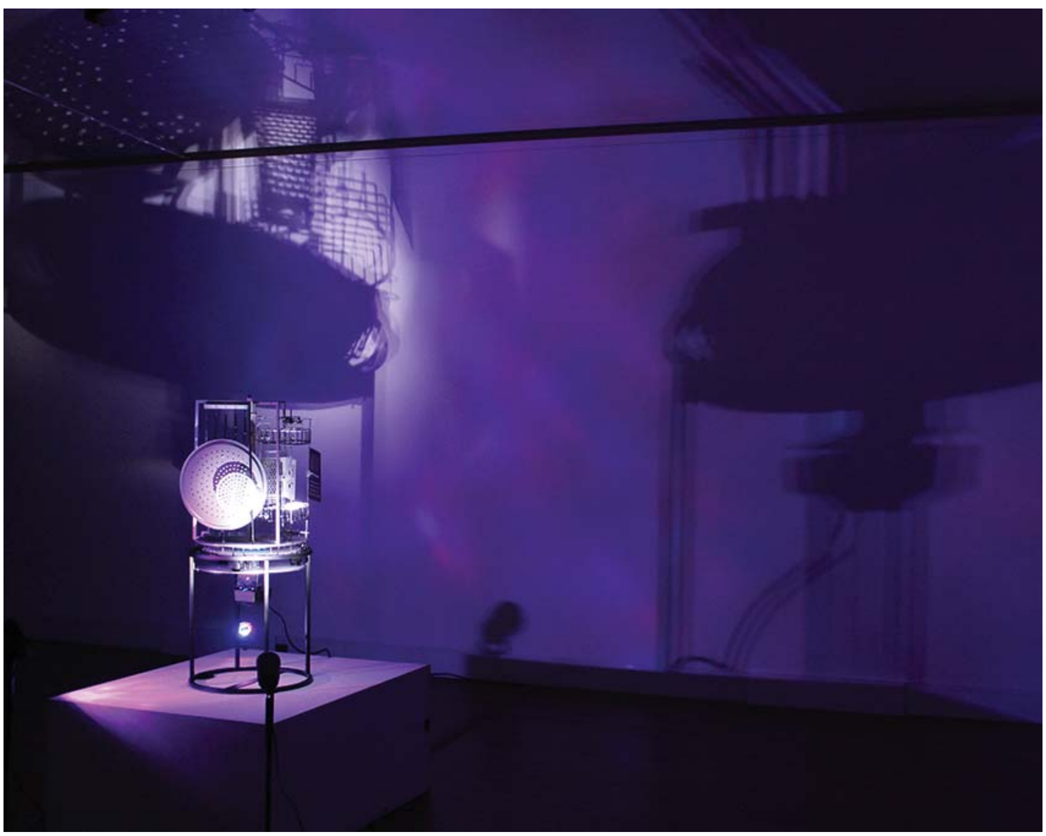


Figure 48: Christopher Handran *Light Space Replicator* 2017-2018. Back scratcher, basting wand, cake board, extendable shelf, fidget spinners, grater, ping pong net, pizza tray, skewers, tin lid, trouser hanger, unicorn horn, whiteboard frames, lights, motor. 65 x 60 x 60 cm

Light Space Replicator (2017-19) considers the continuing significance of the thinking, and the once-new vision that underpinned Moholy-Nagy's original apparatus. Almost a century on from the conception of the original *Modulator*, the *Replicator* re-purposes mass-produced 'junk shop' products, including a back scratcher, fidget spinners, kitchen utensils, pet toys, and even a unicorn headband. The material-discursive capacities of these objects are brought into a dance of agency with the modernist celebration of industrial progress. As an assemblage of mass-produced, globally distributed readymades, this reworking of the apparatus reflects on the nature of contemporary life in the wake of the global industrialisation that the original object is often taken to represent. It also responds to the history of replication and transformation that Moholy-Nagy's original object has been subject to.

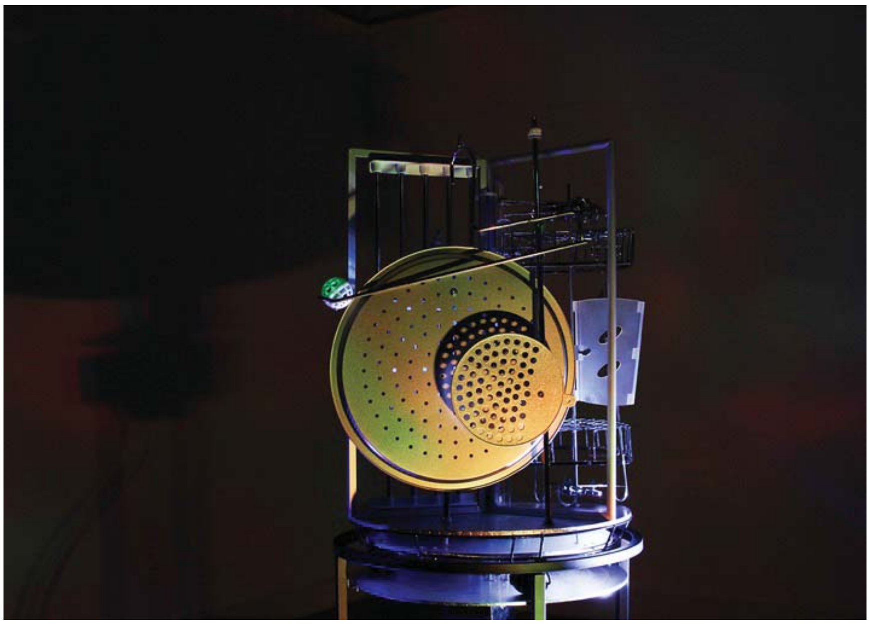


Figure 49: Christopher Handran *Light Space Replicator* 2017-2018. Back scratcher, basting wand, cake board, extendable shelf, fidget spinners, grater, ping pong net, pizza tray, skewers, tin lid, trouser hanger, unicorn horn, whiteboard frames, lights, motor. 65 x 60 x 60 cm

The *Light Space Modulator* has always had a shifting identity. Like the works of Thomas Wilfred discussed in Chapter 3, it occupies an uneasy position in relation to traditional conceptions of media, due to how easily it is related to those traditions. Whereas Wilfred emphasised the need to remake the *Clavilux* anew for each composition, the *Modulator* seems to change identity, moving between multiple functions and operations. These include: a projection device related to traditions of 'visual music' (Moholy-Nagy 1969, 20-

24); a means of kinetic light painting (Moholy-Nagy 1969, 9); an animate extension of photography's nature as the manipulation of light (Moholy-Nagy 1969, 31; see also 1985, 127); a pedagogical tool for students' observation of light and shadow (Borchardt-Hume 2006); a model for the introduction of new technologies into theatre (Moholy-Nagy 1996, 67); an abstract cinematic 'film projector without film' (Elcott 2011, 40); a prop for the production of the 1932 film *Lichtspiel: Schwarz Grau Weiss* (Gunning 2007); and, through a series of replicas produced for museums, an iconic kinetic sculpture (Brett 2000). My work builds upon these diverse functions, which Moholy-Nagy's original has performed throughout its history, and in terms of which it continues to be read.

The changing nature of the Modulator's multiple identities is also reflected in its exhibition history, which is in turn connected to its history of replication. The original object was fabricated by the Allgemeine Elektrizitätsgesellschaft (AEG) according to plans drawn for Moholy-Nagy by architect Stefan Sebök. It was first exhibited in a 1930 display by the Deutsche Werkbund in Paris, within an environment designed by Moholy-Nagy. The work was shown enclosed within a black box, with a circle cut out to allow viewers to observe the revolving sculpture and the play of light on the interior of the black box. After viewing the exhibition, museum director Alexander Dorner invited Moholy-Nagy to design a permanent display for the Hanover Provincial Museum. Dubbed the *Raum der Gegenwart,* or 'Room of Our Time,' this display represented the modernist melding of art, technology and media, with the *Modulator* playing a key role. The project was never completed. In 1935 Moholy-Nagy moved to London, where the work was exhibited again, this time with an external frame added for stabilization. Following a further move to Chicago in 1938, the motor was replaced, and some time after this glass elements are thought to have been broken and replaced with metal and acrylic parts (Lie 2007). In 1956 the work was donated to Harvard University's Busch-Reisinger Museum. Following unsuccessful attempts to restore the object to working order, it was exhibited as a static sculptural object in the 1965 exhibition *LichtKunstLicht* at the Van Abbemuseum (Berndes 2007).

Figure 50: Laszlo Moholy-Nagy *Light Space Modulator* 1922-1930 installation view in reconstruction of Raum der Gegenwart, Los Angeles County Museum of Art, 2017.

Throughout the 1960s and 1970s, there were a range of prominent attempts to archive modernist art of the early twentieth century by remaking lost, damaged or decaying works (see Kamien-Kazhdan 2018, 21-49). In consultation with Sibyl Moholy-Nagy, engineer Woodie Flowers (MIT) working with Nan Piene (Harvard), produced two working replicas of the *Modulator,* which were collected by the Van Abbemuseum and the Bauhaus Archive. In 2006 a third replica was produced by engineer Juergen Steger for Tate Modern, and subsequently donated to the Busch-Reisinger Museum at Harvard University. In additional to this history of material transformation, recent years have seen the replicas exhibited in a range of settings. The various means of presentation can have the effect of concealing or revealing the motorised workings of the *Modulator*. Some follow the conventions of sculpture (fig. 47), while the working Tate replica was first shown within an exhibition that also featured the original, now static, work. In recent years, the replica has been exhibited within reconstructions of the spaces designed by Moholy-Nagy for the *Raum der Gegenwart* (Elcott 2010). Other settings emphasise the work's theatrical stage presence (fig. 48), recalling its original designation as a 'light prop for an electric stage'. These variations are not incidental, but have become an essential feature of both Moholy-Nagy's *Modulator* and my *Replicator*.

Figure 51: Laszlo Moholy-Nagy *Light Space Modulator* 1922-1930 installation view, Busch-Reisinger Museum, Harvard University

Figure 52: Laszlo Moholy-Nagy *Light Space Modulator* 1922-1930 installation view, Santa Barbara Museum of Art, 2015

To read the current title of Moholy-Nagy's work with a Baradian inflection, we might position the *Light Space Modulator* as an object that intra-actively transforms the space in relation to which it operates. Works such as the *Modulator* and the *Replicator* render the spaces, objects and spectators around them as moving parts within their own operation. These transformations are materialized through the performative play of light, shadow and reflection. While Moholy-Nagy's original object was said to be illuminated by a programmed sequence of between 116 and 140 lights (Moholy-Nagy 1965, 238; Hight 2010, 44 n29), this feature has not been preserved with its replicas. In the case of my *Replicator,* this role is performed by a group of modified party lights that project a constantly changing sequence of lights. As an extension of the contemporary culture of spectacle, this connects the work to Moholy-Nagy's celebration of 'new fields of creativity' brought about by 'new technical means' (1969, 20) that included 'the reflectors and neon tubes of advertising signs, the blinking letters of store fronts, the rotating coloured electric bulbs, the broad strip of the electric news bulletin' (1938, 50). The traffic between high and low technological cultures is accentuated in my work through the selection of contemporary low budget and novelty consumer items.

For Moholy-Nagy, the new technologies of modernity offered a ‘powerful lever of liberation’ that freed the artist from representation; the model for the new non-objective vision was ‘the empirical technic of scientific research, that is, the "laboratory aspect" of science where the conditions of observation can be produced and varied at will’ (Moholy-Nagy 1945, 74). In the hands of the artist, the technoscientific apparatus offered a means of transforming space and spectator. As discussed above, the technological spectacles of the *Modulator* offered mobility between media, and performed this function in variable and transforming ways.

4.8 Self-Reflexive Apparatus: *Site Spectrum Speculum* 2019

The final work to be discussed, *Site Spectrum Speculum* employed many of the strategies already familiar from the preceding discussion, including the DIY methodology of the *bricoleur* and the citizen scientist, employed to construct a home-made version of a scientific instrument. What was significant in this small-scale yet immersive video projection was that it was generated by revisiting all of the other works in the exhibition *You and the Universe*, in effect translating them through the performativity of another optical instrument and giving the spectator the opportunity to re-view them in a different light.

The specific apparatus constructed in this case was a homemade spectroscope. While in scientific practice spectroscopic analysis might be used to identify the chemical composition of far-off galaxies, in this case it was used to turn the apparatus back on the preceding works, making them the object of fresh experimentation. The play of light generated by each apparatus was recorded in the manner of an exhibition walk-through. The operations of the homemade spectroscope dissembled each light-based work into their constituent spectra. Recorded in a single take, the resulting video imagery was projected onto a ‘blind spot’ mirror, which reflected the play of light and colour around the room. The sounds of the other works in the exhibition were preserved as they were recorded, giving the spectator a clue to the source of the imagery. Like all of the works in the exhibition, this work once again took a

DIY approach to apparatuses at the historical intersection of art and science. As in other works, the process of recording using the 80cm long spectroscope as an oversized lens attachment foregrounded my own embodied experience as a dance of agency, intra-actively improvised in response to the screen of the compound apparatus. The installation mobilised the phenomena of the apparatus within a spatial *dispositif* that positions the spectator at its centre, inviting spectators to immerse themselves in the operations of the apparatus.

Figure 53: Christopher Handran *Site Spectrum Speculum* 2018. Digital video projection, blind spot mirror. Dimensions variable.

My practice-led research seeks to consider the creative potential of alternate models of the apparatus drawn from discourses other than art. The works in the exhibition draw directly on the history of interactions between art and science; they are also directly informed by thinking around the apparatus drawn from philosophies of science and technology. The works themselves echo the variational practice of science itself, as articulated in postphenomenology. Taken together they offer multiple perspectives on and ways of engaging with the apparatus. The work *Site Spectrum Speculum* foregrounds the material hermeneutics of the apparatus, but it does so through what might be considered a hermeneutic game—by visually transforming the content being recorded, yet leaving it open to interpretation.

This aspect of the work highlights an incommensurability between art and science; put simply, the term 'abstraction' means different things in these domains. In the context of science, 'to abstract' is a theoretical operation, moving from the concrete to calculations—though keeping in mind that the act of calculating remains a material-discursive operation. In the context of art, the material dimension of abstraction is always present – in discourses of material specificity, it is the concreteness of material that is the entire focus of abstraction. There is a long tradition of traffic between art and science, centred around the abstraction of art and its formal resemblance to the documentary images of science. In responding to one such instance, Thomas Kuhn once highlighted a functional difference between these endeavours, by suggesting that the comparisons confused ends and means. The images being compared were, he pointed out, tools, or 'at best by-products' for the scientist, while for the artist they were the end goal (Kuhn 1977, 342).

There is one sub-genre of scientific imaging, especially prominent within astronomy, that is better aligned with the concerns of art. This is the genre referred to as 'pretty pictures,' the production of which is built into big science projects such as the Hubble Space Telescope. As Elizabeth Kessler points out, most of the activity in such projects is directed towards scientific advances 'at the frontier of representation, at the edge of resolution where an image dissolves into fuzz and blur' (Kessler 2011, 66). The production of 'pretty pictures' concentrates instead on creating aesthetically pleasing images of well-studied and familiar astronomical phenomena, for promotional and public engagement purposes. While exploring the mesmerising and captivating performances of the apparatus, it should be clear that the works exhibited in the scientific context are pursuing different ends. It is these transformational performances themselves that are the object of my practice-led investigation.

All of the works discussed in this chapter exhibit qualities that, in the discourse of art, would conventionally be referred to as abstraction. In the domain of science, however, these same characteristics comprise the image's referentiality; from this perspective they record rather than represent phenomena. This includes the ordered geometrical structure of the LCD screen in *Liquid Crystal Displaced,* the play of light and shadow generated by the *Light Space Replicator,* the organic patchwork forms of *Cosmic Background,* the hard-edged compositions of *Talbot Carpet* and the marginal 'fuzz and blur' that are brought from beyond the frontier of representation by the *N-ray Detector.* In the work *Site Spectrum Speculum,* all of these forms are transformed and translated into, nebulous bands of colour that float across the walls. It is this transformative potential of the apparatus that is revealed by playing against its program. These abstract forms are both means and ends, simultaneously material and discursive, phenomena comprising instances of wholeness that bring together apparatus, image and spectator.

4.9 Exhibiting the Apparatus: *You and the Universe*

The exhibition *You and the Universe* brought together a group of works that offered multiple perspectives on the apparatus at the intersections of art and science. The works exhibited exemplified the intertwining histories of art, science and technology that are revealed through a focus on the apparatus. The research connects to these histories and philosophies, in ways that seek to illuminate and re-imagine the potential of the apparatus. In this way, they also exemplify the entanglement of matter and meaning, theory and practice that is central to my methodology.

The title of the exhibition came from one of the educational filmstrips featured in the work *Starry Messages (redshift).* Although this work was not featured in the exhibition, the phrase evokes the desire to orientate oneself within one's surroundings. In both scientific and artistic contexts, the apparatus provides a potent means of performing this orientation. But the exhibition, *You and the Universe,* also sought to orientate its audience in relation to multiple apparatuses, and their diverse effects.

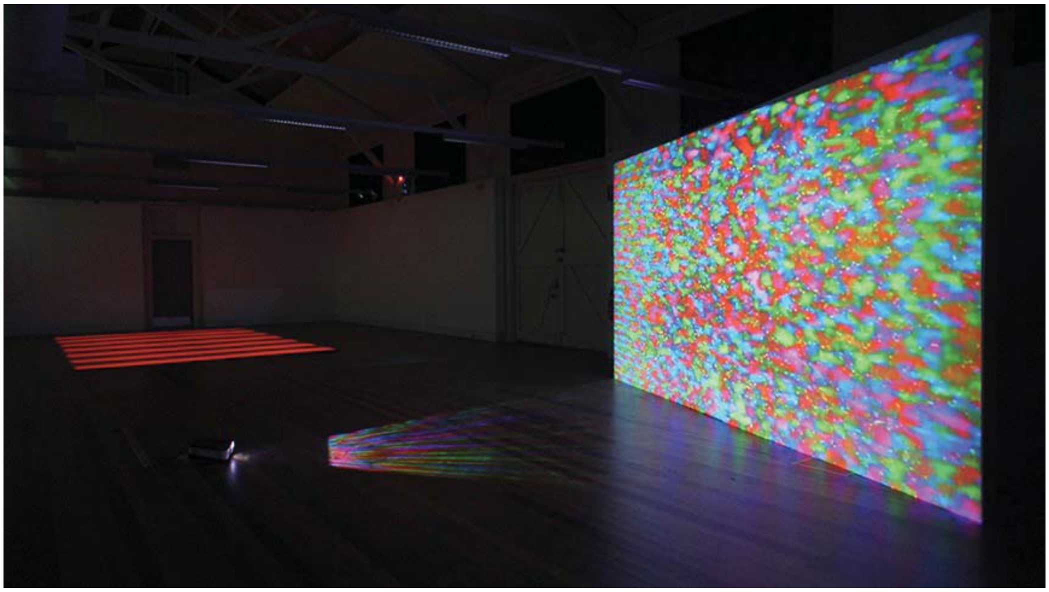


Figure 54: Exhibition view, *You and the Universe* 2019

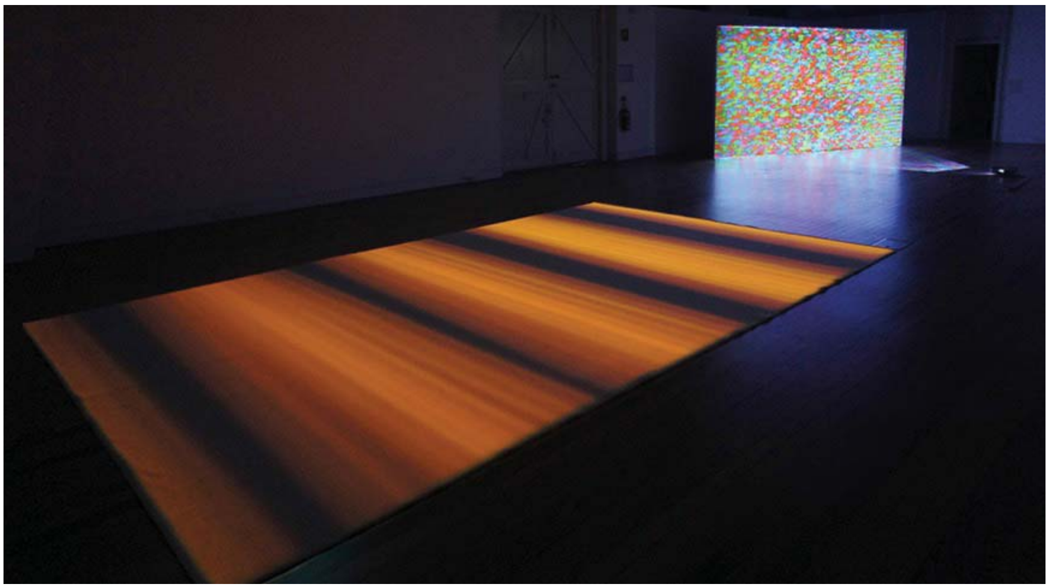


Figure 55: Exhibition view, *You and the Universe* 2019

Works in the exhibition re-enacted and re-imagined engagements with the apparatus across the disciplinary boundaries of art and science. The earlier works featured in the exhibition, such as *Liquid Crystal Displaced* and *Cosmic Background,* explored scientific practices in relation to screen-based media technologies. Later works continued aspects of this media archaeological approach, though extended beyond traditional conceptions of media, to consider the perceptual apparatus of the spectator – for example in the *N Ray Detector.* Throughout the research, reworking and reconstruction emerged as key strategies. This built upon and extended my use of DIY methods and contemporary everyday materials into new directions. Works revisited the technological utopianism of modernist art (*Light Space Replicator*), the optical experiments of Victorian-era scientists David Brewster and William Henry Fox Talbot (*Liquid Crystal Displaced* and *Talbot Carpet*), as well as twentieth-century visualisations of invisible phenomena (*Cosmic Background* and *N Ray Detector*). These phenomena and their related apparatuses were materially re-imagined at a variety of scales, from immersive video projections situating the spectator within microscopic light effects to intimate interactions with individual apparatuses that foreground the operations of the spectator's own perception. Strategies of material and conceptual deconstruction and reassembly generate new patterns of diffraction and dialogue, informing fresh insights into the operations and inter-relations of apparatus.

Research into philosophies of science and technology helped to highlight the entanglement of apparatuses into networks, something that the work responded to. Many of the works featured in the final exhibition presented or were the products of a *dispositif* of networked apparatuses. In the context of the research this contributed to a collapsing of the opposition between apparatus and image that provided one starting point for the research. The entanglement of apparatus and image therefore became an important principle. This insight was supported by contextual research into fringe phenomena such as N-rays and *Celestographs*, and extended through development of the works. The notion of the blind spot of the apparatus being revealed through a misalignment to its referent also emerged as important.

This sense of misalignment could be described using the vocabulary of the mangle as an interactive *de*stabilisation that reveals the presence of the blind spot. Yet the entanglement of apparatus and spectator within a performative visuality also emerged as an important strategy for revealing this blind spot. Linked to the history of scientific spectacle and the abstract patterns generated by devices, such as the chromatrope and kaleidoscope, this performative visuality diffracts and redefines oppositions between abstraction and referentiality, representation and intervention. This is a key conclusion that reflects the mutual material-discursive transformations that emerge from the dialogue between art and science developed within this research.

Conclusion

My own studio-based engagement with the apparatus provided the grounding for this practice-led research inquiry. Within this creative engagement, the apparatus becomes subject to material experimentation and transformation. In this exegesis I have argued that the significance of the apparatus in this working process is not adequately reflected in current art discourse. This research project therefore has developed and extended the creative engagement with the apparatus from my own practice to explore its wider significance in contemporary art. It has done so through an assessment of conceptions of the apparatus as articulated within philosophies of science and technology, and through an investigation of the historical intersections of art and science.

Vilém Flusser's transdisciplinary definition of the apparatus offers an important theoretical starting point for this research project. In Flusser's thought the apparatus is co-defined with the technical images that it produces. The relationship of these intertwining agencies was further developed through the research. The habitual overlooking of the apparatus – its status as a blind spot - is linked to Flusser's description of its operation as a black box, the inner workings of which are hidden from view. His encouragement to play *against* the apparatus as a means of opening up this black box provided a crucial starting point for considering my creative engagement with the apparatus. In order to investigate the role of the apparatus within visual art from a fresh perspective, this research was informed by the philosophies of science and technology.

Chapter One *Setting Up the Apparatus* reviewed perspectives on the apparatus within the philosophy of science and technology. As a preliminary consideration of the relations between art and science, I traced the changing status of practice, and the practical knowledge of art or *tekhnē*, throughout the history of philosophy of science. This history of experimentation, centred on the apparatus, emerged as a contested site of practice. The 'practice turn' that has taken place within science and technology studies (STS) provided an important contextual grounding for the conception of the apparatus in this research project. In particular, the work of Bruno Latour emphasises the role of scientific instrumentation as ‘black boxed’ inscription devices. However for Latour and other Actor Network theorists, considerations of practice and materiality are only a launching pad for the analysis and critique of the networks in which they operate. His writing therefore provided a frequent point of comparison throughout this exegesis, thus highlighting the different framework in which this research operates.

This practice-led research drew directly on philosophies of science and technology that emphasise the embodied, relational and performative aspects of practices that engage with apparatuses. The postphenomenological analyses of Don Ihde were especially informative for this research. Ihde’s work seeks to extend and transform the traditions of phenomenology through an engagement with technological praxis, and the discourses of pragmatism and STS. Postphenomenology’s characterisation of technology in terms of embodiment and hermeneutic relations are especially resonant with the material-discursive approach taken in this practice-led research. As a methodology, postphenomenology extends the Husserlian variational method to consider the transformative and receptive aspects of technology. While traditional Husserlian variations aimed to detect essences, postphenomenology emphasises the multistable nature of technological praxis. Ihde’s characterisation of scientific practice as a form of material hermeneutics also proved to offer valuable insights into my consideration of the simultaneously material and discursive operations of the apparatus in visual arts practice.

The practice-led nature of this research entailed the entanglement of practice, theory, methodology and context. Aspects of the existing literature that helped to contextualise and define the parameters of the apparatus have also proved significant for the development of my research methodology as outlined in Chapter Two *Working Through the Apparatus*. The research developed a model of the apparatus through (and in response to) my own creative engagement with apparatuses. The emphasis placed on performativity by both Andrew Pickering and Karen Barad in their discussions of scientific practice has been especially influential for thinking and working through the apparatus in art. Pickering models practice as a dialectical dance between human and material agencies, each creating and encountering resistance and accommodation in response to the other. The mangle emerged as a means of articulating the processes of creative practice. The performativity of the mangle equally reflects the diverse agencies at play within the process of research itself. Barad's discussion of agential realism goes further, emphasising that these human and material agencies at play in practice are generated through their inter-relationships. The agential identities are constituted within these 'intra-actions,' rather than preceding the encounter. In addition, Barad's definition of apparatuses as material-discursive practices reflects the entanglement of practice and theory that I argue is fundamental to creative practice. In relation to the specifics of this practice-led research, Barad's proposal of a diffractive methodology both articulates the nature of this entanglement and illuminates the discursive dimension of material experimentations performed through the apparatus. The work of Andrew Pickering and Karen Barad expanded the vocabulary around the apparatus and extended my own thinking in relation to the multiple agencies of material and apparatus at play in my own practice-based intra-actions.

The methodology developed in this practice-led research was informed by perspectives on the apparatus offered by the work of Pickering and Barad, both of whom encourage attentiveness to qualities of performativity and potentiality. These insights regarding the material-discursive performativity of the apparatus resonate with the theoretical and practical dimensions of media archaeology. As a methodological approach that creates and reveals connections between contemporary and historical media technologies, media archaeology provided a valuable framework for both the exegetical and creative components of the research. My creative engagements with the apparatus employed specific media archaeological methods of deconstruction, reconstruction and re-imagination of historical technologies.

However, the focus on the scientific context in this research project also extended this approach beyond a traditional conception of media. The methodological import of related practices in the history and philosophy of science was expanded in Chapter Two. In particular, this research explored the transformative potential of ‘reworking’ historical apparatuses and experiments as a means of drawing out connections between these histories and the present. The crux of this discussion was to reveal the apparatus as a blind spot.

Chapter Three *Situating the Apparatus* identified an important historical context for this research in the form of the nineteenth century institutional culture of scientific spectacles. Although the creative works produced in this research do not share their aims of promoting scientific progress and elevating class sensibilities, the historical intertwining of art, science and popular culture represented by these precursors were foundational for my practice-led research. These public presentations of scientific novelty employed a persistent performative visualism in the form of apparatuses such as the chromatrope and the kaleidoscope. However the dialectic of science and amusement travelled in both directions – the novelty of ‘philosophical toys’ such as the kaleidoscope were invested with scientific aspirations, while at the same time the spectacular effects of scientific apparatuses, such as the polariscope and solar microscope, were also heavily utilised in popular displays. Twentieth-century works of art such as the *Precision Optics* of Marcel Duchamp preserved this tradition. In this exegesis, the after-effects of this performative visuality were traced in *fin de siècle* experiments that sought to reveal invisible phenomena. These included the perceptual fringe phenomena of N-rays and the idiosyncratic astronomy of August Strindberg’s *Celestographs*. The performative light-based practice of Thomas Wilfred was considered as a paradigm example that highlighted the operations of the apparatus as a boundary blurring practice. The contextual discussion mapped the dynamic network of performative visual spectacle that marks the apparatus as a point of intersection between art and science.

My examination of the apparatus in this practice-led research has resulted in a creative body of work that played against its status as a blind spot in art discourse. These works displayed the performativity of an intra-active engagement with the apparatus. They reflected strategies of re-enactment and featured reconstructed scientific apparatuses including telescopes (*Starry Messages* 2016), spectroscopes (*Site Spectrum Speculum* 2019) and the popular philosophical toy, the kaleidoscope (*Liquid Crystal Displaced* 2016). Other works brought this blind spot to light by revealing the material hermeneutics at play in the processing of signals (*Cosmic Background* 2016) or deploying the perceptual hermeneutics of phenomena on the fringe of visibility (*N-ray Detector* 2018). Methods of replication (*Light Space Replicator* 2017-2019) and experimental reperformance (*Talbot Carpet* 2018) were brought together with the performative visuality of the apparatus. Presented together within the exhibition *You and the Universe,* these creative works functioned as postphenomenological variations in order to reveal the multistable performativity of the apparatus.

Being practice-led, the objectives of the research were grounded in creative practice. Therefore this research project has contributed to new understandings of the creative potential of the apparatus, by adopting a reiterative and multifaceted methodology. In drawing upon the philosophy of science and technology to address the blind spot of the apparatus, the research offers an original application of theory and elaborates a cross-disciplinary dialogue. Through this research, I have developed a trans-disciplinary model of the apparatus as a discursive methodology in the context of experimental studio practice. This approach employed a materially embodied engagement with the apparatus that was also grounded in a discursive analysis of its history. Therefore, the research has charted a history of relevant practices at the intersection of art and science; in addition it has analysed the connections and trajectories that these apparatuses embody. This historical analysis has informed a reflexive engagement with the apparatus that counterbalances its invisibility while also foregrounding its transformative operations — this holds special significance for other technologically engaged creative practices.

This research project has brought into focus the means of both deconstructing the black box of the apparatus and reimagining its projective potential. This has resulted in a body of new work that explored the potential of creative engagements with the apparatus in relation to these elements of shared history, exploring resonances, reverberations and diffractions between the disciplines of art and science. These works embody a performative engagement with the apparatus, which is developed through experimentation, reflection, and the performative dialectics of resistance and accommodation.

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APPENDIX

Further exhibition documentation can be found at:

https://christopherhandran.com/you-and-the-universe/

Video documentation can be viewed at:

https://vimeo.com/335984111