The Birmingham screwdriver is a golden hammer:

Developing strategies for performing scientific objects

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Declaration:

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature..... Date....21/09/21.....

Abstract

The demonstration of science is a complex activity that can offer more than a passive one way transmission of specialist knowledge from experts to a non specialist audience. Artists can play an active role in creating 'matters of fact' and at the same time inform the cultural conditions which put these matters of fact into context. In examining some current art/science collaborations between performance art and physics the project identifies some problems relating to a pre-occupation with veracity and authenticity, technological fetishism and issues to do with the representation of data.

An in depth study of prominent art duo *Semiconductor* offers insights into the difficulties and opportunities encountered in this work, particularly in the context of the artist in residence in the science institution. My own three month residency at the British Geological Society's Space Geodesy Facility in Herstmonceux provided an opportunity to engage with these issues first hand.

Through the creation of a body of practical work, the project explores strategies for performing scientific objects. Through the application of a heuristic here called 'the Birmingham Screwdriver' several forms of creative resistance (Norman 2013) are identified and put to use. I examine the hypothesis that the 'wrong tool' is an essential and inevitable characteristic of knowledge exchange, whether between an expert and a lay audience, experts from different fields or between research institutions and the wider cultural context in which they take place. Using the artist in science as an analogy for art practice being involved in other research institutions and as a model of conducting research applicable to more general circumstances I aim to contribute to understandings of an 'artistic epistemology' (Schwab 2015).

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Dedicated with love to Viv Wylie.

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CHAPTER 1

THE BIRMINGHAM SCREWDRIVER

1.1 - Introduction

To begin with I would like to explain the somewhat cryptic title of this project. The Birmingham screwdriver is a joke name for a hammer, often used pejoratively to suggest an unskilled craftsperson using the wrong tool for a job in a crude or forceful way. There is an interesting turn to this joke, in that Birmingham was famous for its intricate and sophisticated metalwork such as jewellery and gunsmithing, and the hammer and tongs were the iconic tools used for these jobs. What initially seems to suggest crude misuse is in fact also a symbol of skill. Here it is used to invoke the idea of improvisation, re-purposing and creative misuse. The 'golden hammer' is a related concept used to refer to a fictional idealised tool used to fix anything, a technological panacea. The term is also sometimes referred to as 'Maslow's law' after the statement “it is tempting, if all you have is a hammer, to treat everything as a nail' (Maslow 1966, pp15-16). These phrases together are used to describe the initial impetus for this project. This project subverts the idea of the Birmingham screwdriver as a description of incompetence and ineptitude, and instead use it to enquire into a fundamental mechanism at play in generating knowledge. It will do this by asking:

how can the application of the 'Birmingham screwdriver' help to understand the types of creative resistance involved in performing scientific objects?'

While the subheading seems more tangible it also requires some explanation. The term 'performing scientific objects' is left purposefully ambiguous. This ambiguity is somewhat resolved by example in relation to the practice being presented here, but for the sake of this analysis the uncertainty is useful in understanding the complexity of such activity. The term 'scientific object' in its most obvious sense could refer to literal apparatus, for example a DNA sequencer or a radio telescope. It could also refer to the thing under scientific scrutiny, a strand of DNA or a pulsar. Data too could be considered a scientific object, the traces of scientific activity that can be scrutinised and

manipulated. It could also refer to something between these definitions, a mediating technique or practice, for example genomics or astrophysics. It need not even *be* an object, but only 'belong' to the imagined or real 'realm of science'. This interchangeability is used regularly in such work with definitions often being conflated or elided into one another. The breadth of this term threatens to engulf everything, yet there is a general instinctive understanding among both 'lay' audiences, scientists, academics and artists as to what makes something 'science-y'. Throughout this study I have asked participants what qualifies something as such and invariably terms such as 'experiment' 'knowledge' 'reality' 'technology' and 'discovery' come up. So, to give its broadest useful definition, the scientific object is something involved in producing knowledge of reality that sits beyond immediate appearances and must be contrived some way through particular material and conceptual arrangements.

The term 'performing' in this context can also have a broad and ambiguous meaning. In this case the phrase could refer to the act of performing *with* scientific objects and apparatus. This in turn could refer to the use of scientific objects to produce artwork, by using a novel technology or exploiting a particular phenomenon usually invoked in scientific practice. Work of this kind often focuses on exploring the affordances of a novel technology to produce work, or perhaps the influence of a technology in an 'extra-scientific' context such as the societal or cultural implications it has. It could also refer to the use of artwork to demonstrate a scientific tool or concept which again could be used to develop or explore possible applications of science, further public understanding and communicate science or offer a critique. The omission of the word 'with' in 'performing science objects' is also suggestive of the idea that the objects themselves can be put to a kind of performance. For example scientific instrumentation being arranged to perform some interactive function with an audience. As we shall see later in this chapter, these definitions overlap considerably and work often spans different portions of the spectrum.

1.2 - Practice as research.

Fig 1. Briggs, E 2015 *Book Smarts*

This project is primarily practice based, and as it concerns methods of producing knowledge it is useful to touch very briefly on how various philosophers have related these two activities. A key text that has influenced this project is Hans Jorg Rheinberger's *A History of Epistemic things* (1997). The emphasis this work places on how practical experiment creates knowledge has led to it being much cited in theories regarding the epistemological issues of practice as research in general (Schwab 2015, De Assis 2018 Newman & Tarasiewicz 2013, Borgdorf 2012). These theorists use Rheinberger's framework of the experimental system as an account of the complex way in which practical work establishes matters of fact. In particular it emphasizes the role that the experimenter has in teasing out 'epistemic things' before their nature is fully known, that experiment progresses through differential reproduction and creates networks with and of other experimental systems (Rheinberger, 1997).

Other accounts of how scientific practice yields knowledge are put forward by philosophers such as Ian Hacking and Nancy Cartwright who argue for 'entity realism' based on the ability to manipulate something, '… if you can spray them they are real' (Hacking 1983, p23), Katherine Hayles' 'constrained constructivism' which refers to the 'physical and semiotic constraints that brings language into touch with the world'

(Hayles 1993, p41) or Karen Barad's 'agential realism' describing a reality that emerges through 'intra-action' between practitioners and the material world (Barad 2007).

The way in which art practice might yield knowledge is a subject that has also received much attention. Indeed, theorists such as Schwab (2015) and De Assis (2018) who have had an influence on this project, use the work of Rheinberger as a framework for making sense of this process. Henk Borgdorff (2012) summarizes the unique epistemological nature of art research as generating “knowledge ... which has been variously analysed as tacit, practical knowledge, as ‘knowing-how’, and as sensory knowledge, is cognitive, though non-conceptual; and it is rational, though non-discursive” (p49). Patricia Leavy (2008) similarly characterises the relationship between art practice and knowledge as 'holistic and dynamic, involving reflection, description, problem formulation and solving, and the ability to identify and explain intuition and creativity' (p10).

While the ways in which practice yields knowledge in both art and science both rely on similar mechanisms; the acknowledgement of the knower, the difficulty of grappling with as yet unknown epistemic things, the emphasis on sensory knowledge, drawing on tacit knowledge gained through experience etc, as the following section will demonstrate, these two fields have long been regarded as separate, and even in some cases in opposition. This project will investigate the mechanisms that practice might yield knowledge where both of these fields are taken in conjunction by investigating the question -

How might art practice be understood as a *simultaneous* process of generating knowledge, not only as an activity adjunct to scientific practice but one that works *through* it?

1.3 - Transgressing the Boundaries

The multitude of publications such as Leonardo, The Journal of Art and Science; the many institutions such as the Wellcome Trust, Ars Electronica, and numerous art/science events, all recognise the value of collaboration between art and science. Their activity seems to be bridging the cultural gap outlined in C.P. Snow's *The Two Cultures* (Snow 1959), but having invested in the bridge still want to avoid filling in the gap entirely. Instead, they often involve a conscious othering where novelty comes from apparently disparate, or even incommensurable forms of knowledge being brought to bear on one another.

Art as way of producing knowledge has long been associated with such interdisciplinarity. Research through art practice is identified by Chris Frayling as that which is put to instrumental use investigating some subject outside of itself (Frayling 1993). This 'boundary work' (Gieryn 1999) is frequently situated across traditional disciplinary divisions that put art in opposition to science. The university itself is often characterised as a primarily scientific research institution and that research itself is essentially scientific (Radder 2010) and so discussions of art in an academic context inevitably lead to comparisons with this dominant paradigm of knowledge production. The Journal for Artistic Research for example 'invites artistic researchers to develop what for the sciences and humanities are standard academic publication procedures'[1] perhaps suggesting a kind of borrowed legitimization. Art research is often framed *in terms of* science. There is an asymmetry that is revealed in attempts to reverse this framing. Rarely are the artistic merits of scientific research discussed[2]. There is also a resistance to supra-disciplinary attempts to transcend the distinction altogether with disciplinary boundaries seen as necessary constructs for (or even inherent properties of) the production of knowledge in an institutional setting (Balsiger 2004).

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1 https://www.jar-online.net/journal-artistic-research accessed 28/09/20

2 'Aesthetic beauty' is sometimes mentioned in reference to scientific theory, particularly in mathematics, but this usually refers to a pleasing simplicity or efficiency rather than to any instrumental effect any artistic quality might have. In this respect it is really being used as an analogy for 'artfully executed science'.

The appropriation of science by other subjects has often provoked criticism, this contention perhaps reaching a head in modern times during the 'science wars' initiated by Gross and Levitt's *Higher Superstition, the Academic Left and it's Quarrels with Science* (Gross & Levitt 1994) and the notorious 'Sokal Hoax' which claimed to expose the readiness of cultural theorists to accept scientific sounding language even if it made no sense (Sokal 1994). Sokal and Bricmont then published *Intellectual Impostures* (Sokal & Bricmont 1998) which criticised various philosophers such as Latour, Deleuze, Lacan and others for using scientific language and concepts either incorrectly or in their view simply pointlessly out of a kind of 'physics envy' (Cohen 1971).

It is certainly clear that science can be misappropriated to obfuscate or assume authority or be put to spurious use to push an agenda. The objectivity of scientific knowledge rests on being situated outside personal preference and while it is important to ensure that people understand why this is there is much literature on the subject of why this is a complicated and contentious task (Daston & Galison 2007, Galison 1999). This urge to protect the ideal of objective knowledge might also be motivated by a need to objectify knowledge for exchange within economies. Again perhaps efforts that seemingly undermine the epistemological status of science might be attempts to protect against dogmatic adherence to it or to preserve other forms of knowledge (Feyerabend 1975). Whatever the motivations, there is clearly much at stake when it comes to who is qualified to reflect on scientific practice.

In the case of cultural theorists subjecting science to poetic, metaphorical or other 'wrong' uses it is rarely the poetry itself that is being contested. The criticism, being based in theoretical discourse, and taking place remotely through the medium of articles and published papers invariably ends up being made *on scientific grounds.* The case of art practice pertaining to science (whether regarded in itself as research or not) is an instance of *practice about practice,* where the two cultures are in live interaction, and this modifies the emphases and provides a perspective where science might be examined in terms of art.

The contexts in which scientists and artists come into contact are literally the *grounds* on which this exchange is negotiated. As the following section shows, the artist in residence is a common circumstance where this takes place. Different specialisms and expertise, as well as amateurism and 'inexpertise' are brought together in close proximity, and so serve as an ideal context to explore the concept of the 'Birmingham screwdriver'. Later on in the study this example of using the 'wrong tools' to navigate an unfamiliar epistemic space, serves as an analogy for the artist as researcher. Here is an instance where the particular methods of practice of the artist must be put to use as a 'golden hammer'.

1.4 - Early exchanges

From the earliest practices that might be recognised as scientific investigation through experiment, art has been entwined in the process of furthering public understanding and integrating new scientific knowledge into a wider cultural context. Penelope Gouk's *Music, Science and Natural Magic of 17th Century England* (1999) traces how early scientific practice involved understandings drawn from musical practice in order to communicate new scientific ideas. One key idea was that of 'occult correspondence', a hidden relationship of cause and effect, which was explored and demonstrated through experiments involving sympathetic resonance of stringed instruments. The invisible mechanism of the magic trick perhaps acted as a kind of primordial nescience from which science as we know it could begin to expand.

These ideas in turn drew on much earlier medieval ideas to do with music and the body, and further back still with classical ideas relating to music and proportion. The relationship between mechanics and arithmetical operations were similarly linked and developed through luthiery practices from the late 15th century onwards (Drake 1970) Silverman and Hankins through their study of the magic lantern, trace how conceptions of the demonstration of experiment changed over time, from the proving of a theory to the illustrating of a phenomenon, from scientific argument to spectacle and entertainment, and how these different roles often coincided and overlapped (Silverman & Hankins 1995).

From its earliest conception to the modern day, science has had a public facing role mediated through artistic representations and demonstration. The knowledge produced through scientific practice has been shaped, negotiated and communicated through artistic practice. This process continues today through scientific outreach programmes, popular science publications, reporting in the media, festivals and exhibitions. During the course of this study, I attended number of performances that engaged in this tradition and which provided a context for the practical work presented here.

1.4.1 - 9 Evenings

Technology has often served as an obvious common ground in art and science collaborations, the term 'instrument' for example is revealing in its double meaning as both a device for measuring and a device for creating something new. This common ground was explored in Bell Lab's Emerging Arts and Technology programme (E.A.T.) E.A.T began as a result of the seminal art and science collaborative performance *9 Evenings: Theatre and Engineering,* initiated in 1966 by engineer Billy Kluver (1927-2004) and artist Robert Rauschenberg (1925-2008) to facilitate collaboration between avant garde artists such as John Cage, Yvonne Rainer and Robert Paxman and technicians and engineers from the Bell's laboratories. The event used numerous new technologies of the time, transistor radios, infrared cameras, live video feeds, photocells, to create a sprawling interconnected performance space. It was noted in reviews of the time and more recent reflections that much of the technology failed to work, or was subject to interference from the audience or the sheer vastness of the venue (Garwood 2007). This is frequently levelled as a criticism of the event but in retrospect the struggle they encountered with equipment, its thwarting of intentions and failure to perform as expected, is perhaps a valuable insight into a feature that characterises work of this kind to this day.

Kluver described the stated aim of the event was 'to catalyse the inevitable active involvement of industry, technology and the arts' (1967). Gradually, as new technology

relating to communication, data processing and control and command software became more commonplace and filtered more into everyday life, its use in art for its own sake began to give way to the idea that artists could play an active role in its development. It is revealing that throughout the literature documenting the event there is an interchangeability between the terms 'science' or 'scientists' and 'technology' and 'engineers' suggesting the relationship between science and art has always been one between science, art and technology. Work that is funded by companies such as Bell labs (now 'Nokia Bell Labs') is often expensively produced with high production values with an aim to showcase technological innovation. In some cases work might even end up being used as a method of 'artwashing' a particular technology or industry associated with it (Evans 2015) or simply indulging in technological fetishism. In any case, work funded by large tech companies is likely to reflect their values in a particular way.

1.4.2 - Arts Catalyst

In contrast to this, it is worth looking at a commissioning body with a different set of priorities and motivations - that of an artist led organisation. Arts Catalyst founded in 1993 by director Nicola Triscott states that 'through working with artists, scientists, communities and interest groups we produce projects, artworks and exhibitions that connect with other fields of knowledge, expanding artistic practice into domains commonly associated with science and specialist research'[3].

They have commissioned over 170 new pieces working with artists from a variety of disciplines including those whose practice intersects with performance such as Nahum Romero Zamora, Annie Carpenter and Agnes Meyer Brandis. They recently hosted a series of live events *Ethereal Things* in which artists and scientists were invited to present their work in a performance lecture setting and also used this as an event to launch a publication *The Live Creature and Ethereal Things* in which Triscott explains

[3] https://www.artscatalyst.org/content/about-arts-catalyst accessed 09/10/19

the necessity for 'the expression of physics as a human, material activity into wider society' (Triscott 2018, p13).

The work of Arts Catalyst associate artist Zamora takes up this challenge by focusing on the inclusion of human experience in science. He is also the organiser of *Kosmica* a series of events concerning space, art and culture. The film of *1 Second Drop Tower* submitted to this project was featured in Kosmica Screenings in Mexico City, Berlin and London in 2017. Zamora's performances such as the 2013 piece *Can Science Be a Story of Believing in Magic?* at Obro in Montreal, and his 2015 piece *Evocations of a Forgotten Voyage* at the Museo de Arte de Zapopan, Mexico, involve elements of science lectures, magic shows, hypnosis and highly poetic discussions around the subject of space travel. Most recently he has had a piece sent into space onboard Falcon 9 as part of SpaceX's CRS15 mission. The work consists of a series of mirrors actuated by servo motors and a small camera, creating a kaleidoscopic view of the inside of the International Space Station where it is was installed for six months. The piece allowed for real time audience interaction through a live HD internet video link.

His work places emphasis on the lived experience of science, sensation and embodiment, and affording access to sites that would otherwise be restricted to a specialist body of practitioners. In recognition for his work, he was the first artist to be awarded the title of Young Space Leader by the International Astronautical Federation Paris, a fact noted by Roger Malina, executive editor of *Leonardo* journal[4]. Most recently he was invited to join the SpaceEU Advisory Board to discuss how to foster a more inclusive and diverse European space community. He uses this involvement with science institutions as a platform to emphasise the need for access and inclusivity in science.

Another artist I encountered through Arts Catalyst and who had a profound effect on

[4] http://malina.diatrope.com/2014/05/07/congratulations-to-nahum-mantra-romero-space-artist/ accessed 10/09/19

this project, is founder of the Manchester Art and Science Critical Forum Annie Carpenter. Through playful and insightful performance lectures she cleverly subverts the issues mentioned earlier in this chapter, those of the emphasis on technologically advanced work and high profile research institutes. At an *Ethereal Things* event at Iklektic in London in May 2018, Carpenter explained that her background working as a steam engine maintenance engineer and demonstrator at the Manchester Museum of Science and Industry led to an interest in parallel notions of work in scientific and artistic contexts as well as her interest in 'technical demonstration'.

Her work often plays with contrasting amateurism, the domestic and homemade, with technical or abstract scientific concepts. It includes performance lectures, sculpture, installation and video work. Her installations often reflect her previous role as museum demonstrator, where she will frequently attend to the work as it is running and interact with audiences. While her work often portrays some otherworldly quality (for example the ethereal video piece *Production Rings*[5]) it always retains a human accessibility. Through a kind of playful misleading, the willingness to explain and the ability to retain mystery is carefully held in tension.

1.4.3 - Collide

As well as tech companies and arts organisations other sources of art science collaborations are science institutions themselves. CERN, responsible for the Large Hadron Collider, has a well established arts residency scheme *Collide* which is organised into three sub categories, *Collide Geneva* a three month funded residency facilitating artistic development, *Collide Pro Helvetia* which is aimed specifically at local Swiss Artists, and *Collide International* open to artists from around the world. There are now several other art programmes based at individual experiments at the LHC including *Arts at CMS*, *Resonance at ATLAS, CERN Music Club and EX/NOISE/CERN* among others.

[5] http://www.anniecarpenter.co.uk/production-rings/ accessed 10/09/19

Collide director Monica Bello explains the initiatives aim is to 'explore notions of creativity, human ingenuity and curiosity' where artists *are invited* 'to work alongside particle physicists and engineers...[and] experience the way the big questions of our time are pursued by fundamental science'[6] There is however less suggestion of critical engagement or reflection on the nature of work being undertaken, or that physicists will be encouraged to work alongside artists on their work. This implies that artists are being granted a look at science which will ask the big questions about nature, while they themselves will only be able to ask questions of the scientists.

Several pieces of work to come out of the residency instead engage directly with the infrastructure of the LHC. One such piece, Bill Fontana's *Acoustic Time Travel, Loud & Underground, The Universe of Sound* (Fontana 2013) used a set of custom built accelerometers as pickups to record sounds from inside the LHC. The work then was played back into the space in different places around the LHC while it was switched off for maintenance with the intention that 'The echoes and resoundings which happened in the tunnel turned the LHC into the world's largest acoustic instrument' (Fontana 2013b)[7] In an interview for art blog *Run-Riot* he alludes to the romantic idea of the music of the spheres as a theoretical crossover between the LHC and art, as well as the familiar theme of resonance[8] as both a literal and figurative way in which his work animates the LHC, bringing it back to life with sound.

Another *Collide* commission which made use of the objects of the LHC was Haroon Mirza and Jack Jelf's immersive performance *The Wave Epoch,* the premiere of which I attended at the Brighton Festival in May 2018. Speaking to Tari Joshi for the Guardian Jelfs described the piece as 'Something between an installation, music performance and a rave'[9] (Jelfs 2018). This effect was somewhat undermined by the formal trappings of a theatre piece, it's fixed duration, and it's listing in an arts festival programme meaning that it was suggestive of a rave in name only.

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6 https://arts.cern/welcome accessed 10/10/19

7 Fontana B, 2013b in https://www.resoundings.info/new-page-3 accessed 10/10/19

8 http://www.run-riot.com/articles/blogs/exclusive-interview-bill-fontana-capturing-heartbeat-cern-leslie-deere

9 Jelfs, J. (2018) in https://www.theguardian.com/artanddesign/2018/may/22/big-bangers-wave-epoch-brighton-festival-cern-hadron-collider-grime accessed 19/07/18

The piece involved music from electronic musician GAIKA and grime DJ and producer Elijah, alongside video work in amongst a set consisting of sculptural pieces made using materials from the LHC. There was the suggestion that these objects somehow retained an aura of their previous use, although we were left to wonder what they were for, conveying the ultimate concept for the piece - that the LHC might be discovered one day in thousands of years when its original function is forgotten and instead viewed and re-appropriated as some sort of ritual site. The piece foregrounded the material architecture of the LHC and its machinery as almost mystical and exalted artefacts. Their original purpose, indeed the purpose of the LHC itself, was purposefully obscured.

1.5 - Sonification

As well as engaging with the physical material of the LHC there are lots of examples of work that aim to engage with the vast amounts of data it produces. This highlights another role in which artists collaborating with science are often cast - that of the conduit for scientific knowledge. Artists are often viewed as being in a position to render sensible otherwise esoteric or inaccessible insights gained by scientists and communicate this to a lay public. A typical example of this is seen in the current trend towards 'sonification', taking data produced by scientific means and by some operation translating this into sound.

In 2017, I attended a performance and accompanying workshop by the Birmingham Ensemble for Electroacoustic Research of their piece *Dark Matter.* The piece used live coding along with data taken from the CMS experiment at CERN. The performance began with Scott Wilson explaining that they were taking data from the LHC and using different strategies to turn that into sound. He suggested that this was partly because the data had interesting qualities to it but also that it was just a nice thought that it is somehow connected to this great collaborative effort to understand the universe. The performers improvised using live coding and snippets of this code appeared on screen throughout the performance which appeared fleetingly and often obscured by other

abstract visualisations. During the workshop earlier in the day he had explained that the live coding elements were networked between performers. It was notable that his wasn't mentioned during the performance, perhaps because this is an assumed convention of this kind of work.

The piece focused mainly on the spectral dimension of the sound perhaps because it was dealing with the harmonic spectra of the particle collisions. There was an interesting ambiguity here as to whether this was a compositional choice or something inherent in the data. The tension between presenting the data and trying to make something musical seemed to be treated as something to be got around or resolved somehow rather than explored. This hints at a belief that the efficacy of this kind of work comes from how faithfully it adheres to the science. Here the work is presented as either being 'accurately illustrative' or the science is seen simply as a way to produce aesthetically pleasing patterns.

This issue of 'accurate adherence' vs aesthetic outcomes is a common problem for work using sonification. The piece *Quantiser* by Juliana Cherston, Ewan Hill, Steven Goldfarb and Joseph Paradiso from the MIT Media Lab is one example. The device is a piece of software that takes realtime data from collision events at the LHC experiment ATLAS. This is then calibrated into a usable set of values which are then mapped to a choice of musical scales and then output as midi data which can be used to control any number of midi controlled instruments[10]

The authors explain in their paper presented at NIME 2016 that the platform is intended to be developed by composers and physicists depending on their expertise, with options for those with musical experience but no physics experience, physicists with no musical experience and 'the rare users who understand the data and how to program with OSC (open sound control) messages' (Cherston et al. 2016 p80). It is interesting to note that the assumption here is that users will be *either* physicists or composers but that a combination of the two would be particularly rare. They go on to state that the

[10] http://quantizer.media.mit.edu/ accessed 09/10/19

testing of the efficacy of the system was undertaken by a composer attempting to use the tool to re-create a variety of musical genres including 'samba, classical, pop-rock, electronic and tango' (ibid p82). It is difficult to know what is meant by 'electronic' in this context. The arbitrary choice of vaguely categorised genres mentioned here, as well as the mapping to various set scales and simple 8 beat rhythmic units suggests a naïvety towards the potential musical uses for such a system.

Quantiser is not alone with this issue. The project LHChamber music by Dominico Vicinanza followed a similar line of thought, described as an 'experimental piece and and “experimental” ensemble'[11] whereby data taken from the LHC was quantised and fed through the template of consonant musical scales, then arranged by a composer into neo-classical chamber music to be performed by various scientists at CERN who happened to play musical instruments. The resulting music is far removed from the visceral and high powered experiments it draws on. CERN physicist Piotr Traczyk's sonification of the Higgs boson discovery follows a similar method. A graph of data from this experiment is superimposed onto a stave and then notated to produce a metal guitar riff played by Piotr and a colleague over a generic metal background[12].

These examples highlight several problems inherent in the process of sonification. Where data are kept as 'raw' as possible the mechanisms by which they are translated become opaque. As Wilson pointed out the suggestion is that it is simply enough to know that it is somehow connected. By attempting to adhere faithfully to the experiment it fails to communicate anything about it. Where data are squeezed into arbitrary musical forms either the claim is being made that these forms of (often western classical) music are an inherent quality of the experiment, or perhaps even of nature itself, or else that the outcome of the experiment is somehow completely arbitrary. Whether 'raw' or 'cooked' these treatments of data, seemingly at either end of a spectrum of truth or artifice, both fall prey to the same assumption that the data will retain an aura of its origins and that this will somehow be accessible to the audience. These problems invite the question – why not use any other random data set, or simply

[11] https://videos.cern.ch/record/1950682 accessed 22/09/20
[12] https://www.youtube.com/watch?v=SXEnDM3hydM accessed 22/09/20

have a composer write a piece about the experiment using any number of compositional methods? The difficulty seems to lie in drawing compositional constraints from the experiment in a meaningful way. Perhaps Fontana's work attempts this, instead of sonifying the output of the experiment he instead 'ensonifies' the material arrangements of the space itself.

It seems that in many of the examples cited here the work serves to maintain particular hierarchies of knowledge. Perhaps through attitudes left over from the 'science wars' or more recent attacks on the value of the humanities in research contexts (as noted by Small 2013 and Brighouse & Arbelaez 2019), there is an anxious adherence to veracity and authenticity, to 'getting the science right'. Similarly concerns over the public trust of science (Dommett & Pearce 2019) prompt the need to protect science's own unique status as a method of generating knowledge. As a result, art can be relegated to a passive, illustrative role. There is often a low expectation that the art will have any effect on the science, that its main role is to simply communicate science to a lay audience without significantly transforming the knowledge it produces. Art is expected to present the wonder of science, or else critique or hold to account scientific practice, but rarely to truly collaborate in the production of new knowledge. Consideration of this problem prompted the question - How might art practice be understood as a simultaneous process of generating knowledge, not only as an activity adjunct to scientific practice but one that works through it?

1.6 - Consilience

To begin to explore this process it is useful to understand the concept of '*consilience'* (Wilson 1998) the attempt to synthesise different fields of knowledge into one unified whole. Wilson's book of the same title attempts to show how each discipline is either derived from or foldable into the next, generally in a hierarchical order with evolutionary biology being the ultimate driver of all activity. The science based online comic *xkcd* also parodies this idea in the cartoon titled *Purity* in which the sciences are arranged in

order of purity with mathematics being somewhere off the scale[13]. The reductionist idea that say, biology is just applied chemistry, fails to preserve the kinds of knowledge that might only be achievable in each distinct field. For sure, no biologist would be able to predict the evolution of a particular species using the laws of particle physics alone.

In accounting for art in the scheme of consilience, Wilson puts forward the possibility of understanding it in terms of bioaesthetics. Citing the work of psychologist Gerda Smets, he proposes that our predisposition to various aesthetic forms is governed by inherited genetic tendencies that at some point ensured our survival. Wilson's own background in biology perhaps reveals this as an instance of the 'golden hammer'. He acknowledges the link is tenuous but goes on to say it is a 'promising cue to the aesthetic instinct...that has not to my knowledge been explored systematically by either scientists or interpreters of the arts' (Wilson 1998, p251) It is interesting to note that artists themselves (as opposed to interpreters) are not considered qualified to explore this idea.

I suggest that the main problem of this account of consilience between the arts and other forms of knowledge is that it bases itself on the principle that art is made simply in the pursuit of pleasingly consonant forms, a kind of inert symmetry on which to rest the brain, through a 'precision of [its] adherence to human nature' (ibid, p246). Here in a kind of inversion of physics envy, science is superimposed onto artistic practice from the outside. From the Pythagorean monochord used to understand mathematical proportion in terms of musical intervals, to the modernist composers' pursuit of 'pure' mathematical principles of composition, the borrowing of authenticity, 'truthfulness' or very often 'self-evidence' from across the two cultures is one that has resonated throughout history from before knowledge was ever even conceived as being divided along such lines (Gouk 1999). Consilience could in one sense represent an attempt to collapse such a dynamic by the enfolding of knowledge into ever more 'pure' forms.

Instead, I suggest that what is needed is an understanding of consilience that

[13] https://xkcd.com/435/ accessed 09/10/19

preserves the unique insights each discipline offers, 'instantiating boundaries and asymmetrical forces that offset [them] as 'other'' (Norman 2018, p279). An understanding that acknowledges a kind of differential force between ways of knowing. Wilson himself concedes, albeit with a wink 'there have always been two kinds of original thinkers, those who upon viewing disorder try to create order, and those who upon encountering order try to protest it by creating disorder. The tension between the two is what drives learning forward.' (Wilson 1998, p47) only to go on to say that 'in the Darwinian contest of ideas, order always wins because – simply - that is the way the world works' (ibid.) For Wilson, knowledge about the world *is* order, perhaps to get there some 'zigzagging trajectory of progress' (ibid.) is unavoidable, but ultimately it comes to rest on truth. Consilience for him is the ultimate unwinding of this tension. I counter this idea by arguing for an understanding of knowledge as dynamic and temporal, that the tensions between ways of knowing will never come to rest because its motive force depends on the push and pull between them. Perhaps then rather than understanding practice as knowledge my aim might be better put as understanding knowledge as a practice.

1.7 - Aims and scope

So far, I have hinted at some of the difficulties in characterising art practice as a method of generating knowledge particularly when put into a scientific context. Through a review of work attended at the start of this project I identified some of the dynamics at play in this exchange, particularly around issues of representation, the 'misuse' or misappropriation of science and the role of the artist and other stakeholders in this context. My aim is to understand this process by developing strategies to perform scientific objects in a way that avoids a passive, illustrative role for art, but instead views it as making a transformative contribution to the understanding of the science it engages with. I will do this by embracing the very criticism mentioned at the start of this chapter, the act of misuse, misappropriation or misapplication of science, and instead use these as ways to exert creative resistance in the creation of a body of new works.

My own description of 'the Birmingham screwdriver being put to use as a golden hammer' is an attempt to describe this useful application of friction. It addresses the

struggle encountered in the bootstrapping process of learning something new without yet knowing the shape of the epistemic things that might emerge, as it were with tools that are as yet insufficient. The resistance encountered in using the 'golden hammer', the only tool at your disposal with which you can only treat reality as a nail regardless of the form it inevitably reveals itself to be, and through such use will always change the thing it is looking at. It is the friction encountered in the use of the 'wrong tool' - the fiction and artifice of an art practice used to engage with the objectivity of science, the (mis)application of one form of knowledge read diffractively through another to reveal something of both through the effort. It operates like the joke which can't be explained away, or the hidden workings of a magic trick, the knowledge accessible only through its wielding. Used here, as a poetic phrase it operates as a conceptual starting point, a hunch about a certain mechanism, as well as a provocation to act. Where, like all analogies, it falls short of describing the whole process it refers to, it instead calls for its own enactment.

This chapter began by introducing the idea of the 'Birmingham screwdriver', a way of illustrating a sort of necessary catachresis involved in arriving at new knowledge using the tools already at hand. It is suggested that this mechanism is particularly pertinent to interdisciplinary research practices that span the traditional 'two cultures' of science and the humanities. A brief exposition of some key art/science collaborations showed that while this is an active field with a long history, still more could be done to understand this process. A preoccupation with the relative status and validity of different ways of producing knowledge, born out of cultural and political contention, has led some to believe that the solution lies in a kind of neutral consilience between different fields of knowledge. An alternative idea is put forward here, that the tension and friction between different epistemological approaches might be put to use. The apparent bootstrapping problem of generating new knowledge might be overcome by using the Birmingham screwdriver as a golden hammer. The following chapter addresses the methodology proposed to test this heuristic through a body of practical work.

CHAPTER 2
KNOW HOW?

2.1 Methodology

There is a reflexive riddle at the start of this project, in that it aims to seek out ways in which art practice acts as a method of inquiry at the same time as *being* art practice inquiring into this matter. As a study into a method of study, this project might be deemed what Henk Borgdorf describes as 'meta-theoretical' (Borgdorf 2012 p3) stating that in this work 'we seem to be dealing with a double circle: that which is to be proved is already assumed, and we test our assumptions in implementing them' (ibid p11).To map out the methodology here is to some extent start with the conclusion.

The difficulty described here is in fact an example of what the project is about, how do you go about creating knowledge with knowledge that is as yet insufficient, to begin the task before it is finished? In Margaret Boden's *The Creative Mind* (1991) she recounts the famous anecdote about August Kekule solving the structure of the benzene ring after dreaming of *ourobouros* the self-devouring snake. This anecdote has been cast into doubt by other historians and scholars (Rothenberg 1995) claiming that the story was a way for Kekule to claim ownership of the discovery which in fact was a joint effort. But in any case, as an explanation of how an idea is formed the question is simply pushed back further into an ineffable dream world. Whether the story tells us how Kekule made the discovery is not, however, important. What it does illustrate is that the problem of coming up with an idea, producing knowledge, seems to be a self-starting (or self-devouring) phenomenon.

The methodology outlined here suggests some ways this circle will be broken. First of all autoethnographical reflection provides a set of co-ordinates. The project progresses along a non-linear path, enveloping conceptual space in a rhizomatic sprawl. Finally, the outcomes of the project are framed as open ended, a set of resources from which as yet unknown epistemic things may be brought into being. As Borgdorf states, work of this sort is in fact 'not self-referential at all; it is a dynamic chain of interactions,

transformations, and articulations that may ultimately produce more reality.' (ibid.)

2.2 - Autoethnopraxy

It might be argued that all art practice involves a degree of autoethnography, where art projects define their own terms of meaning relative to other parts of themselves (Dutton, 1974). Here, the autoethnographic nature of this project is presented in two forms. Firstly, as the historical framing and contextualisation of the project, and secondly as the method by which the work itself is made.

Over the last few years, I have been part of collective called Boca2Mouth involved in creating public art research projects. Each project consisted of the commissioning of new work by a group of artists in response to a central theme. They involved people from non-art backgrounds, specialists in fields relating to the project, and more general public participation in the form of interviews, round table discussions and public events that fed into the work. It would often involve the creation of tools developed and drawn from these different spheres to foster dialogue and mediate between them. The output of these projects has included printed and online published media, performances, exhibitions and workshops as well as several site specific works[14].

Making Books with Things, Making Things with Books (Briggs & De Toro 2013) was about looking at books as a technology. It involved working with several artists and specialists in the book making industry, including publishers, printers and binders and resulted in several pieces of work including *Reverse 3d Printer* in which an object is sliced into paper thin layers and printed onto a book, *Being Saved By a Book* a re-enactment of the fable of soldiers catching a bullet in a bible, and *Audio Book* a series of recordings of the ambient sound of people reading silently in different places. These pieces, along with others, were collated in an e-book and presented in a performance at Buffalo University's 2013 conference on E-Poetry.

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[14] Briggs, E. *Land Bells* 2015 and De Toro, X. *Where Do You Draw The Line* - 2014

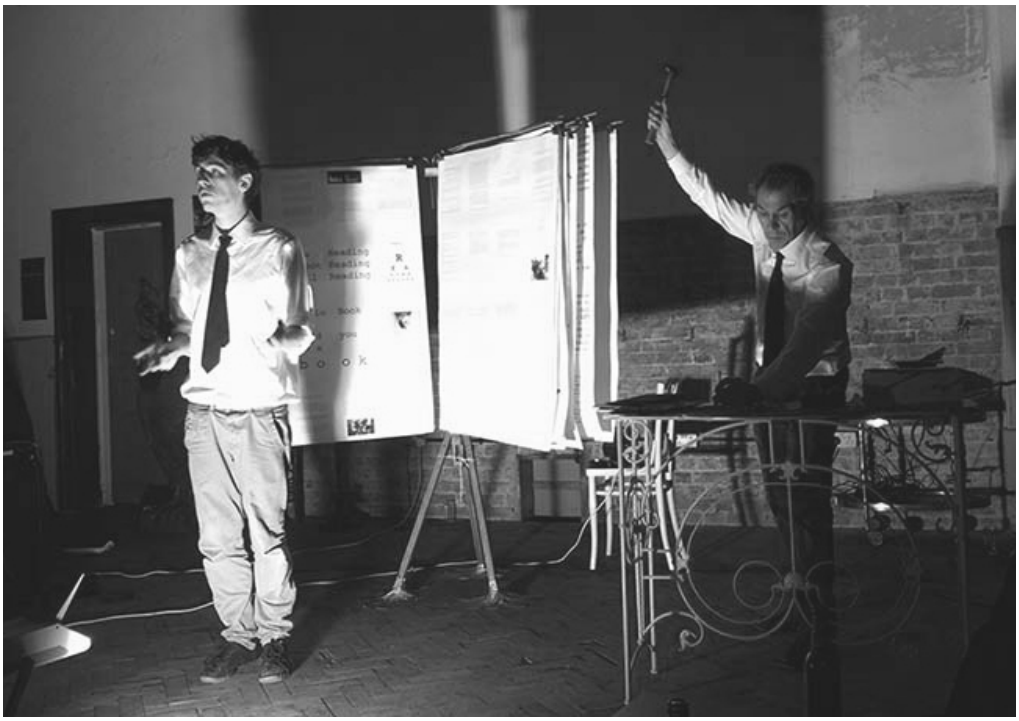

Fig 2. Briggs, E. & De Toro, X. 2013 *Making Books Performance*

The project *ManMade* (Briggs, De Toro, Sanders, 2017) worked in a similar way, involving various artists including Victoria Petty, Mim King, Benedict Sheehan and Jim Sanders in a series of public exhibitions and events. The project explored the ambiguity of the term 'manmade' to explore how knowledge can be embedded in the natural world. It took place in a number of contexts including public performance in the *Open Market*, Brighton, round table discussions with an academic panel including Lorenzo Ippolita, Alex Golding, Guyan Porter and Professor Ann Light at *ONCA* gallery, public workshops at *WhitehawkInn*, and culminated in a large scale immersive performance at the *Spire*, Brighton.

Through this work I became interested in how this process might be a useful model of pedagogical practices in general - the re-contextualisation of expertise across domains and the interaction between different specialisms as a fundamental part of producing new knowledge. In particular I was interested in what it meant to be positioned as an outsider tasked with facilitating communication between specialists. The desire to understand some of the mechanisms in this process provided an impetus for this project.

As well as providing a context for this project, autoethnographical reflection also plays a crucial part in the working method employed here. Carolyn Ellis describes autoethnography as writing about and subsequently analysing selected significant events that take place as a result of being part of a particular culture or cultural identity (Ellis, Adams & Bochner 2011). This traditional view of autoethnography suggests that insights might be crystallised out of the researcher's experience, which is framed by a set of static conditions that give meaning to this analysis. In the case of art research this context is being actively modified by the artist as they go about their work. Art practice not only takes place within a cultural context, but is also responsible for modifying and forming that context at the same time. In this sense the analysis cannot yield static insights but instead only dynamic ones, which change as the project continues. The outcomes of an autoethnographical study are very often codified and analysed in linguistic terms. In the case of art research, autoethnography itself can take place *through* practice and so might be better termed *autoethnopraxy*. In this work dynamic practice is used to feed back on itself and produce further work in a constantly evolving iterative cycle.

2.3 - Wandering technique.

This process began here with an initial phase of research consisting of attending various art/science events mentioned in the previous chapter. I also undertook an in-depth case study into art duo *Semiconductor* focusing on their recent work *Halo,* which I subsequently went on to develop with fabricator and engineer Ash Brosnan. It also involved the formation of networks and connections with science institutions including making work for the British Science Festival, the Brighton Science festival and undertaking a residency at the British Geological Survey's Space Geodesy Facility at Herstmonceux. This experience was then used as the basis for several performances and related works.

This chronology does not do justice to the way in which the work was actually carried out. The performance objects presented here consist of pieces of technology used as

instruments, story telling devices, props or other apparatus. Initial attempts to create a particular effect might result in unintended features, which are then pursued in further iterations. In each of these the technology is adjusted, promising routes are followed, earlier intentions might be dropped and the work is allowed to evolve. The objects are put to use in two principle performances presented here, but were also reconfigured and used in several other performance contexts. The practical output here includes the objects themselves, but also artefacts created by the work such as sound and video, performances where the objects are used, and the creative documentation of all these things. The work then represents a slice through an ongoing practice, the parallel strata of which are revealed as a snapshot of a dynamic process. The strategy they develop then is 'a strategy without finality, what might be called blind tactics or empirical wandering' (Derrida 1982, p7).

This process can be seen to operate on two scales. First of all in the overall development of the project, between pieces, where technology is allowed to be made and unmade in different contexts. The work of Sarah Angliss is influential here. Her piece *Automatic Pipe Organ* consisting of pipes salvaged from a church organ, assembled and arranged to play dance music at Supersonic's *All Ears* festival is one example of this. The organ was subsequently dismantled for further experiments including exploring 19th century Vogelautometon, experiments with surround sound and building bellows driven versions of earlier work (Angliss, 2015-2021)[15] In this way the creation of new tech alongside a particular historical context is used to generate multiple pieces which continue to be deconstructed and reconstituted in further work.

The other scale at which this 'empirical wandering' is put to use is within the performance itself. The performance objects are used to create a set of compositional constraints, whereby the technology may permit certain types of interaction and output and exclude others. By using these constraints to act as a means of structuring improvisation, the processes involved in their development are brought to bear on the piece. Performing in this way produces music (or some other effect) whilst

[15] https://www.sarahangliss.com/allears/ accessed 23/07/21

simultaneously demonstrating the technology and revealing something about how it was made. In this respect I was greatly influenced by Tetsuya Umeda whose work focuses heavily on the theatricality of constructing his performance objects live and allowing different material configurations to organically develop and act as a shifting set of improvisatory constraints (Umeda 2018)[16].

This method of working, allowing an initial impetus to spiral with turbulent unpredictability, is employed here at both these scales. Both between and within performances entire apparatus may be re-used, fragments of mechanisms re-purposed, stories are retold and re-contextualised, meaning is made to swerve evasively and conclusions are deferred in favour of open ended potentials. In this way rather than to produce static artefacts, the goal of this work is to create dynamic networks of interaction, between the objects themselves, the performances they are used in and audiences they are for, the public, specialists in different fields, and the institutions that support them.

Fig 3. Objects in the studio

[16] Umeda, T. 2018 *Performance at Fort Process,* Newhaven

2.4 - Developing strategies

Fig 4. Hand tools in the studio

The final part of the title 'developing strategies' requires some definition here. The networks of interaction created here are considered 'strategic' in that the arrangement of materials, people and their skills hold open the potential for new knowledge to precipitate through ongoing action. The *ways* in which these networks are created and maintained might be thought of as a set of tools which are similarly subject to such arrangement through their use within and across a variety of contexts (Norman 2013)

as well as being subject to instances of catachresis (Rabardel 2014) and which also create the potential for new knowledge through their application.

Rather than aim to provide definitive conclusions, the project results in a body of work and an analysis that identifies some general principles. Through the process of 'autoethnopraxis' the written reflection on this work will begin to crystallise this toolset into the open ended strategies that this project aims to deliver. They are the Birmingham screwdriver, open to misuse and re-appropriation, transforming in the hand as they are put to use. They are tools for disruption, applicable before any solution is found, to force improvisation, for panel beating problems into a multitude of shapes. This shapeshifting toolset will demonstrate some of the unique ways art practice can generate knowledge and at the same time open space for new ways to be found.

Two things are implied when developing a set of tools. The first is that in order to begin such a process the specific function of the tools must first be defined. Here this process is inverted where they are developed through reflexive feedback between themselves and the things they produce. The *physical* tools that are made throughout the project, the performance objects, create certain affordances and constraints which are then used to reconfigure the objects themselves. Rather than producing tools to meet a specific need, they are instrumental in an ongoing and dynamic process.

The second implication is that in developing tools there is the simultaneous development of the skills to use them. In Leavy's description of art practice as research, she cites Saarnivara in saying that art research can be understood as the investigation of something through the use of *craft* (Saarnivara 2003 p582 in Leavy 2008 p11). The assumption is that new knowledge is produced because of the artist exercising a unique skill which grants them access to insights that would otherwise remain hidden. In developing new tools for such an endeavour, it makes sense to assume that they ought to facilitate this skill, after all no tool is created to make something harder to do. However, this is precisely what is being suggested here. It would always be easier to use a screwdriver to fasten a screw, so why is a hammer

being posited here? The reason for this has already been suggested by the mention of improvisation, catachresis and compositional constraints, but it would be useful to outline this mechanism further.

2.5 - Analogy – A spanner is the opposite shape of a nut

Why make tools that 'make a job harder'? The answer can be suggested here by understanding the way in which analogy is put to use in this project. It begins with the idea that when art is being used as a method of enquiry there is the assumption that there is an *outside* or *other* that is being investigated. In order to relate the practice to this other, it is necessary to use some form of analogy. Indeed, there is an argument that analogy is a process that is fundamental to reasoning itself. Hofstadter and Sander's book *Surfaces and Essences* explores the idea that analogy lies at the core of all cognition, that all understanding is always understanding *in terms of something else*. (Hofstadter & Sander, 2013).

Artist Agnes Meyer Brandis' piece *Moon Goose Analogue* (2011) demonstrates the complex relationship between a work of art, the story it tells and the reality it is based in and on. The piece is based on Francis Godwin's 1638 book *The Man in the Moone* in which an explorer is towed to the moon using specially trained geese. Meyer-Brandis raised and trained a colony of Geese, imprinting on them as their mother and keeping them in a remote moon analogue habitat. Several parts of the piece play on an ambiguity between reality and analogy. For example, in *Moon Core* (2018) the artist begins with the premise that geese may have once been on the moon. By recreating an artificial moon sample containing egg shells and droppings, and then artificially weathering it to simulate hundreds of years on the moon she then draws conclusions about whether we would be able to tell if geese had indeed ever been there.

Another piece playing with this idea is Annie Carpenter's *Central Engine* (2016) a piece of work that ostensibly demonstrates the physics behind accretion discs of black holes

using domestic paraphernalia. This consisted of an unstable turntable made out of a collection of household objects, a motor and dry ice. In 2018 I saw the piece performed at the previously mentioned *Arts Catalyst* event. The demonstration was carried out with a great deal of humour with Carpenter collecting dry ice by dramatically filling a pillowcase with a fire extinguisher and engulfing the room in a cloud. The whole device which included a coconut half, an upturned fan and various wobbling and precariously balanced items proceeded to shake itself to pieces spraying liquid carbon dioxide over the audience while Carpenter calmly explained the physics behind the formation of black holes. This juxtaposition between a highly technical description and a homemade apparatus used to illustrate the description while dramatically failing, served as a knowing and humorous allegory for art and science collaboration.

I suggest that both of these examples illustrate a counterintuitive way in which analogy functions. Rather than an analogy working because it maps 'successfully', I would like to suggest that analogical reasoning relies on a type of failure in order to succeed, that as a tool, analogy works by being 'wrong'. The hammer is not successful at banging a screw in by being easier than a screwdriver. Nonetheless it does so because it is at hand.

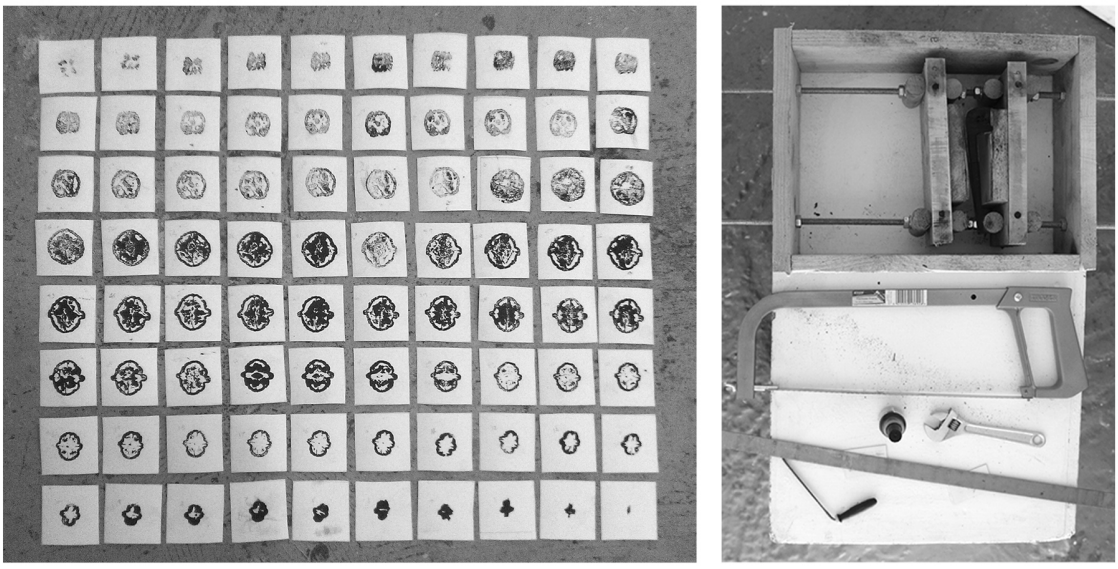

Fig 5. Briggs, E. 2016 Reverse 3D printer and Reverse 3D printed Walnut

2.6 - Friction

To elaborate on this idea I must use an example which both describes and demonstrates this process. It is the self referential idea that for an analogy to be effective, the analog must have some kind of *friction* to catch onto some portion of the reality of the target in order to create *useful movement*. As an analogy draws on isomorphisms between one thing and another, the points at which this comparison fails is encountered as this friction. The *differences* (see Fitje's analysis of metaphor as 'deviation from something better known' [Fitje 2018, p119]) between an analogue and its target amount to a contraction of information which makes it graspable. Faucconier discusses this operation with reference to the idea of 'compressions...useful for memory and manipulation of otherwise diffuse ranges of meaning' (Faucconier & Turner 2003, p57). In Borgesian terms, you must be able to fold the map. The gaps in comparison between the analog and its target, this contraction of information, is what constitutes the friction that allows an exertion of useful movement between them. I use the term 'useful movement' both to extend the analogy of 'concepts as physical objects' and also because it indicates that there is a change that happens to the target in making such a move.

I said the analogy is self referential first of all simply because it is *about* analogies but also because it contracts information in the same way it describes (i.e. using the term 'friction' to stand in for a much more complex interaction). It is also being used in a double sense, while it refers to physical processes in a figurative sense, here when applied to understanding how practice constitutes knowledge, it is also referring to the *actual* process of relating the physical creation of work with the conceptual realm of knowledge. The implication is that for art practice to usefully interact with scientific practice, which is essentially an analogical process, the kinds of frictions generated in this process are entirely necessary. Furthermore, for art practice to act as a form of knowledge making it must itself *exert a kind of friction on the thing it is about*.

Another analogy with physical process useful to this idea is Karen Barad's concept of diffractive analysis (Barad 2007). Here the concept of friction is replaced with the idea

of 'interference' but it retains the notion of a force being exerted between two objects. Barad uses the analogy of waves interfering with each other to describe the process of 'reading insights through one another in attending to and responding to the details and specificities of relations of difference and how they matter' (ibid, p71) Borrowing an idea from Donna Haraway (1997), she contrasts this with another optical phenomenon used to describe creating knowledge, that of reflection. This project then tries to use art practice to go beyond reflection on science, and instead operate diffractively through it. The interplay of differences between ways of knowing goes beyond Wilson's conception of art as subsidiary activity to the serious business of science and instead I suggest that the differential forces between them are in fact an essential mechanism.

Other instances of the use of friction can be found in Andrew Pickering's account of how knowledge emerges through practice where he states 'Resistance (and accommodation) is at the heart of the struggle between human and material realms in which each is interactively restructured with respect to the other' (Pickering 1993, p585). This description of scientific practice describes knowledge emerging through the interplay of human and non-human agency with resistance as the shaping force behind this process.

Another use of the friction analogy, which is crucial to this project, comes from Sally Jane Norman's description of 'creative resistance' through the re-contextualisation of materials in the production of artworks, whereby the 'defiance of normative affordances and patterns of use, generating friction and resistance, is integral to creative endeavour' (Norman 2013, p282). Here a similar interplay between human and non-human agents, again shaped through the mutual friction encountered by each, is what gives rise to new works of art.

In mentioning Norman and Pickering's respective concepts of resistance alongside Barad's use of interference, all related through the concept of 'friction' I wish to draw a parallel that returns to my original description of the Birmingham Screwdriver. It is the difficulty encountered between target and analogy, the friction that can be created

through the deliberate misapplication and 'misuse', that will provoke the conditions of improvisation and wandering, out of which new insights may arise. It is the idea that to probe reality, for the tools of enquiry to exceed pre-existing knowledge, they must be capable of creating an interface where force can be exerted on the thing being examined and in turn be felt pushing back on the tool user. This friction manifests as the compositional constraints that a performance object exerts on improvisation. It is the revealing 'falling short' of analogy. And it is the constructive and destructive interference patterns of one discipline being read through the other. In exploring these practices I hope to better understand the types of creative resistance at play in performing scientific objects.

Fig 6. Briggs, E. and De Toro, X. 2016 *Simulation*

2.7 - Amateurism

Another way of understanding the usefulness of this kind of struggle is the 'advantage of the amateur'. The term amateur is one that has undergone many changes to its meaning. From the latin *amare,* to love, it first meant someone who pursued a discipline purely for the love of it. Over time it began to be used to denote low quality, unskilled work. Now perhaps the amateur is undergoing a renaissance with open-source information and online self publishing seeing non-professionals contributing to various specialist fields. Similarly, citizen science initiatives use non-professional scientists to contribute in numerous ways including data collection such as national

Geographic's *Genographic* project[17], data processing such as the Berkley SETi Research Centre's *SETi@home*[18] and complex problem solving such as University of Washington's protein folding programme *Foldit*[19]. Clearly the amateur has a contribution to make, but can being amateur in itself constitute a strategy? Here I suggest that the position of an outsider may be put to advantage in the same way that using the 'wrong tool' might leverage new insights more effectively than using a tool that one is familiar with. The amateur is forced to ask questions, use what they have at hand, be on the lookout for affordances and work off against constraints.

This technique is reminiscent of the phenomenological bracketing of Husserl (1912). The amateur is able to approach a subject in a way that is not limited by preconceptions, opening up the potential to make novel connections. While a skilled expert might have developed the means to approach a subject in an appropriately efficient way, the amateur, while going 'the long way round' might stumble upon as yet undiscovered territory. The opportunity to involve amateurs in expert fields, such as in the artist in residence, allows for insights that might otherwise be too costly for specialists to arrive at.

Art/science duo Semiconductor, whose work often takes them into science institutions, mentioned in their 2017 Artist Spotlight talk at Phoenix Brighton, that their position as outsiders allows them to adopt a sort of license to misunderstand, or a failure to immediately grasp. They are required to put their understanding and misunderstanding to use in navigating unfamiliar conceptual territory. Pursuing understanding in this ad hoc way, while lacking the theoretical foundations for much of the knowledge, results in the artist effectively adopting the position of the audience at this stage, projecting forward what the effect on a 'further outsider' might be. They then must negotiate between these two positions of expert and non-specialist via a third specialist position - the artist in residence.

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17 https://www.nationalgeographic.com/pages/topic/genographic accessed 27/07/21
18 https://setiathome.berkeley.edu/ accessed 27/07/21
19 https://fold.it/ accessed 27/07/21

Their janus facing position between outsider and insider allows them to act as a bridge between experts and audiences. Dr Derek Muller, who hosts the popular science Youtube channel *Veritasium* writes about the effective design of multimedia for physics education (Muller 2008)[20]. Muller undertook a study to show that simply presenting an explanation of various physics principles to an audience is not effective in changing misconceptions they might hold about the subject. In many cases it was found that participants' misunderstanding was in fact often confirmed after seeing an explanation that directly countered their view. Instead, Muller proposes an approach that begins by presenting the misconception of the audience and then modifying the concept to accord with the correct view (ibid p208). Again, by identifying with the view of the amateur the artist is better able to modify the existing conceptions of an audience to more effectively communicate the concept at hand.

As well as being a way to navigate as an outsider, and to act as a bridge between experts and audiences, the advantage of the amateur is also important to the expert themselves. In a seemingly paradoxical twist consciously 'un-knowing' is a useful part of being a specialist. As Philip Verdoux points out, the extraordinary expansion of human knowledge means that the border with unknowing is similarly expanding all the time (Verdoux 2011 p46). He describes how science necessarily involves nescience, and as fields become more and more specialised the specialists within them are required to deal with more and more uncertainty.

Perhaps then, being an 'expert amateur' means developing the skills to navigate this interface between knowledge and unknowing. The artist, being able to hold and present contradictory and opposing views together in suspension, being able to invoke and put to use 'artificial stupidity' (O'Connell 2016)[21] is best placed to carry out this function in research settings. The work here will test this idea by adopting this stance, working from the premise that rather than an incidental condition of the amateur 'not knowing' is a necessary condition for learning to take place.

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[20] Muller, D *Designing Effective Multimedia for Physics Education*, School of Physics, University of Syndey, Australia

[21] O'Connell, M (2016) *Art as 'Artificial Stupidity'* University of Sussex.

2.8 - Joking

The seemingly paradoxical notion of creating tools that make a task more difficult, of putting oneself in a position of being an outsider to the thing being investigated may seem entirely counter-intuitive but here it is used in order to allow actions that 'exceed' the knowledge of the practitioner in order to open new insights. But what is meant by this? Leavy (2008) mentions the possibility of art research to articulate that which otherwise might not be possible to codify in linguistic terms (p12). One of the ways this can be understood is the use of humour.

A difficulty for anyone carrying out practice as research is how to engage audiences, collaborators, institutions and funding bodies in a way that still allows the work to speak for itself. One facet of this is the difficulty of putting a joke under academic scrutiny. As has been noted, humour can be dissected like a frog with the inevitable consequence (White 1941). Rather backwardly, the comedian has to perform this surgical act during the joke's conception, and then later, through the electric shock of performance its legs are set kicking back into life. The performance of a joke requires a kind of suspension of disbelief for both the performer and audience. It is a type of lie used to tell the truth, a fiction whose affect on reality comes about through its undoing - analysis after the fact is too late. There are some insights that must be conjured into being, but like a magic trick the mechanism has to stay hidden for it to work.

In preparation for this study in 2016 I attended the conference *Fiction As Method* at Goldsmiths University, where I saw Tim Etchells deliver a paper consisting entirely of abstract vocalisations. The audience reacted to this performance with more liveliness than to any other presentation that day, nodding along, laughing, exchanging looks, walking out in disgust, applauding in delight. They became part of the performance, which was no longer just contained in the context of a conference but *made of it*. The piece seemed to evade analysis, no-one was able to sit there taking notes and no questions were asked afterwards. But while the affect it had on the audience might have been irreducible to written conclusions, it nonetheless 'produced an understanding of the incomparable, the rare and the unique' (Molderings 2010 quoted

in Schwab 2015 p129). This experience prompted my own question 'how do we tell something about reality by making things up?' Identifying such interventions as knowledge presents a particular challenge since '...a lack of identity in knowledge is what [artistic research] requires if it wishes to express what happens at the heart of practice as it becomes knowledge' (Schwab 2011, p244). There is a temptation to try to explain what is being done in order to say what can't be articulated in the first place. This holding knowledge in suspense, keeping the frog alive, is a feat that has to be somehow negotiated between practitioners, the institutions that they work within and the audiences that the work faces. This project will attempt to navigate this exchange using humour as a guiding principle.

2.9 - Performing.

Humour is perhaps an inherently performative act, it must present one thing while meaning another. Performance then is a necessary part of this work. As has been stated at the beginning of this chapter, performance is the principle outcome of the practical work presented here. The objects that are created are done so primarily to be used in performance. This performance may be explicitly public as in the pieces presented for the British Science Festival and others, or it may be 'semi-public' as in fieldwork such as the residency at SGF Herstmonceux. It may also be private in the case of the re-enactment that followed this work. In all these cases performance is used as a way of thinking through. Performance here is taken to mean both the formal context of carrying out actions in front of an audience, and the more general definition of emphasizing and being led by action.

In terms of public performance, this 'thinking through' comes in two forms. First of all, the dynamic engagement with performance objects in an improvisatory context involves a type of embodied thought. Thor Magnusson (2010, 2019) and Alice Eldridge's (Eldridge, Brown & McCormack 2009) various descriptions of how an instrument may have embedded epistemological mechanisms which a performer uses to think with have had an influence on how the performance objects were put to use in

this project. The second sense in which thinking is done through public performance is in terms of how the audience is invited to follow an idea. In the manner previously described, the performance aims to engage in an audiences' preconceptions of a particular scientific object. These conceptions are 'thought through' vicariously by the performer. The 'wandering technique' of the study as a whole will be applied at a different scale here, where the performances will be structured as a chain of experiments, the conclusions of which are ever deferred.

In terms of 'private performance' the idea of movement as a thought process is explored by artists such as Marcus Coates, whose work inspired the re-enactment element of the work presented here. His video *Creative Fitness part 1* (Coates 2016) demonstrates a series of instructions to make certain movements. Throughout the piece a voiceover explains 'you are only movement, there's no need to add on other stuff' implying that all thought, all creative endeavour, language, culture, knowledge can all be regarded as a performance in the sense of an action that is performed.

His work explores the idea of using performance to explore a problem and find a solution. In his work *Journey to the Lower World* (2004) he takes on the form of a shaman whereby he descends into a spiritual animal realm and embodies the characteristics of various animals to try and unconsciously encounter solutions to problems put to him by his audience. The idea that movement happens before thought also has some basis in neuroscience with some studies claiming to show that a decision is 'made' before a person is aware of it (Haynes. J, Heinze. H, Brass, M & Soon. C, 2008). Here, movement in the form of neuro-signalling, 'precedes' conscious thought.

This idea of movement precipitating thought in the form of private performance is explored in this project through work involving re-enactment. This was carried out during my residency at the SGF and also in private during a piece that resulted from this time. The idea of re-enacting on ones own is one that is particularly interesting to me. Can the productive deception, the suspension of knowing required for a joke, be

carried out on oneself? This problem is explored with the work involving a free space optics communication device, where the person I am communicating with is myself. This mirrors the riddle stated at the start of this project, that creating new knowledge means somehow being able to know what you do not already know. As in Coates' use of shamanism, performance is perhaps another way to break out of this circle and allow epistemic things to emerge of their own volition.

Performance will be one of the primary outputs of this project. As has been stated, the methodology described here is both the way in which the project will be carried out and also the subject of the project itself. The performances themselves, as well as the physical objects used to provoke performance, also become the driving force of the study and in this respect also act as 'input'. This circularity is another example of the non-linear nature of this work. In this vein I will end this chapter on what I intend on doing, with an anecdote of a performance that I have already done and that informs this project. In 2015 I was invited to speak at a conference put on by members of the Creative Critical Practice Research Group entitled *Impact!* Myself and my colleague Xelis De Toro decided to perform a Haruspex, the act of interpreting entrails of a sacrificed animal to tell the future. By taping a bag containing a calves liver around my waist we were able to simulate the removal of the organ. We then followed with a stream of conscious speech which involved reflections on what we had heard at the conference with ideas we were working on. At that time I had not considered undertaking this project and had no idea I was talking to what would later become my fellow researchers. In the end the Haruspex proved very successful, through making an action, performing before analysis or consideration, we managed to predict the future by introducing a number of themes that I would later go on to explore here in this project.

Fig 7. Briggs, E. 2015 *Being Saved By A Book*

To write about the methods employed in this project is to also describe the conclusions these same methods aim to uncover. Suggestions have been made as to how to circumnavigate this riddle. An auto-ethnographical approach offers a starting point to the loop by diving midstream into an ongoing practice. The practice is allowed to evolve by using this reflexivity as part of an iterative cycle which will ultimately generate a set of conceptual tools that constitute 'strategies' for performing scientific objects. The interdisciplinary nature of the work will necessitate the use of analogy and metaphor, which will be tested through the principle of generating friction, or creative resistance in contrast to the 'direct correspondence' of representation suggested in such practices as sonification. Extending the analogy from the use of objects to the *act* of being an artist in a science setting, the same principle of creative resistance will be explored here. This will be through a focus on amateurism, the use of humour and through an emphasis on performance. The first part of this method involved locating the work within a wider context and to do this the project makes an in-depth study into some other figures in the world of art and science collaboration. The following chapter looks at the work of prominent art/science practitioners *Semiconductor.*

CHAPTER 3

SEMICONDUCTOR – A CASE STUDY

3.1 – Introduction to Semiconductor

While attending various art science events and exhibitions in preparation for this study I met artist duo *Semiconductor* whose studio are currently based in Brighton. They were kind enough to speak with me on a number of occasions regarding this research and I decided to undertake an in-depth review of the work of these prominent art/science practitioners. The study aims to look at how the pair came to work at various high profile science institutions and the kinds of influences and pressures they encountered on their work in doing so. I was interested to know how their work started and what led to a focus on science as a subject matter. I was also interested to hear about how they managed their interaction with scientists for whom working with artists up close might be an entirely new experience. To do this, the study reflects on some of their works and was conducted by attending public talks and exhibitions, face to face interviews with the artists, studio visits, as an observer and eventually as an assistant in the creation of a new large scale installation.

Semiconductor are made up of artists Ruth Jarman and Joe Gerhardt. Their work is internationally recognised and has taken place in several high profile residencies, such as NASA[22], the Smithsonian[23] and recently as part of CERN's artist residency programme *Collide*[24] , exploring scientific experiment, lab culture and the relationship between human observers and the physical world.

In March 2018, they gave a talk as part of the Phoenix Gallery's *Spotlight* series where artists are invited to present their practice to an audience made up largely of other artists. They described their origins as sound and video artists working with early computer technology and the subsequent direction their work took.

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22 Jarman, R and Gerhardt, J *Magnetic Movie,* 2007

23 Jarman, R and Gerhardt, J *Inferno Observatory,* 2011

24 Jarman, R and Gerhardt, J *Halo,* 2018

They explained that their name *Semiconductor* refers both to semiconducting material used in electronics, but also to the relationship they felt they had with computers. Gerhardt explained that they initially used the computer to produce video and aural effects, and how they came to realise that with the medium of computer code the *output* of the system was arbitrary. Code created specifically to produce sound could also be used to produce a visual pattern, or vice versa. The medium allowed for a translation of data. Their early work (films such as *Puffed Rice* 2000, *Yes You Are Right* 1999 and *New Antics* 2000) clearly played with this notion, where levels of translation and abstraction operate with varying degrees of transparency.

This ambiguity about which element precedes which, various forms of data and their means of translation, creates a self sustaining iterative cycle of information, drawing attention to process and to the substrate of this information processing itself, the semiconductor of a computer chip. Gerhardt also points out the name constitutes a pun on the idea of a conductor only partially in control. He described the computer at that time as a 'third member' over which they had only limited control and to whose mechanisms we as an audience only have partial access. He states that the computer 'like any medium [is always] present and it is taking part in the conversation'(Gerhardt 2017)[25]. He also stated that while these ideas were prevalent in their early work they are less so now. Perhaps the analogy can be made whereby scientific practices and cultures now play a similar role in their work, providing the means to produce and translate data, to act as a virtual third member.

They went on to describe key works in the development of their practice. Pieces such as *Brilliant Noise* (2006) and *Black Rain* (2009) developed at the NASA Space Sciences Lab, UC Berkeley involved creating film using data before it had been cleaned up and idealised for whatever research purpose it was originally intended. The artists state that the inclusion of raw data, noise and artefact are important for “what it reveals in the act of looking...highlighting the signature of man” (Jarman 2017). Indeed, the inclusion of noise draws attention to the act of looking, the means of production.

[25] Gerhardt, J *Phoenix Artist Spotlight Talk,* given on 30/10/2017

Artefacts introduced by the technology used to create these images are unfiltered from the thing being depicted. The suggestion is made that these two things are inextricable. This idea is further explored in their 2014 piece *Catching the Light* in which footage from the Hubble telescope and other terrestrial telescope arrays are projected onto variously shaped screens. The screens represent the areas of night sky being observed by the telescopes and their relative sizes. By drawing attention to the frame of the images in this way, the viewer is invited to consider the technology used to produce them, and perhaps more enticingly to imagine what falls outside the frame and has not been captured.

Footage from *Brilliant Noise* was included in the BBC's 2006 documentary *The Wonders of the Solar System*[26] Such documentaries often use highly rendered cgi depictions or otherwise processed footage, or else some other abstract visual device to accompany voice overs. *Brilliant Noise* used in this context both depicts the actual phenomena being talked about while fulfilling this aesthetic role at the same time. Following the use of this footage more documentaries have since copied this aesthetic and 'raw data' is commonly used in science programmes such as *The Edge of Space (*BBC 2017) and *The Parallel Universe (*BBC 2018).

Jarman explained that they were apprehensive about playing back footage to the scientists involved in creating it, feeling that they were only about to show them footage they had watched many times already. The reaction however was positive, with the scientists remarking that they had not watched all of the unprocessed data together in that setting. In an exchange of specialisms the artists invited the researchers to re-consider their work for its value as a piece of art.

Jarman mentioned the initial reluctance of the scientists involved to give them unprocessed data. She explained that they felt the data was too full of artefacts to be meaningful. Here the different conceptions of what is useful about the data is made apparent. Did the artists explain their approach to noise, the idea of the signature of

[26] BBC2, *The Wonders of the Solar System, Episode 1- Empires of the Sun*, 10/02/2015

man? Here the scientist is reluctant to hand over data which to them represents something problematic. The inclusion of noise as evidence of man highlights a subtle problem here. The noise comes from instrumentation, but some noise comes from the external environment. Is it then that the noise implies man because it is evidence of human made technology that necessarily mediates between nature and human knowledge, or does it simply highlight the human activity of delineating between signal and noise, evidence of the reasoning faculties of the humans involved? It reveals a continuity between these processes, where technology stands in for or maintains the epistemological constraints necessary to make meaning (Cazeaux 2007).

3.2 - Earthworks

In 2016 they were commissioned to make a piece for Sonar Festival, Barcelona, which describes itself as a 'unique cultural event...that combines the playful with the artistic, the avante-garde and experimentation with new electronic music'[27]. Following a residency at La Planta quarry, Spain, *Semiconductor* made a piece consisting of a five channel animation, made to resemble the stratified contour lines produced by scientists simulating tectonic activity in the lab. The scientists use physical models of coloured sand and mechanical devices to simulate the ways in which land masses seismically interact. Jarman mentioned that they were struck by the analogue nature of this work and the fact that this model could be used over such vastly different scales. Returning to earlier techniques used by the artists the animation is 'activated' using sounds recorded at the quarry, owned by construction company Sorigué. The piece itself was funded by Fundació Sorigué, an art foundation set up by the company, recognised as one of Spain's largest collections of modern art.

In October 2020 the piece was installed in Fabrica Gallery Brighton. Described as 'an immersive experience of the phenomena of landscape formation through the scientific and technological devices that are used to study it'[28] the piece consists of a twenty metre long screen onto which is projected an abstract animation set to an electronic

[27] https://sonar.es/es/2021/que-es-sonar accessed 09/11/2019
[28] https://www.fabrica.org.uk/earthworks accessed 10/10/20

score. On experiencing the piece first hand I was struck by the sense of weight the visuals imparted. It is rare to see such a large unified moving image. It was possible to stand so that the screen filled my field of vision entirely. The shifting patterns at times resembled mountain ranges, stratified layers of rock, bright agate geodes or fine shifting sediment. This ambiguity of scale was echoed in the way their movement suggested waves superimposed on waves, so that they could be viewed at different harmonic scales. Sudden jumps in response to large geological cracking sounds left the viewer in no doubt of the intricate connection between the sound and visuals. At times colour would bleed in and out of the image suggestive of subterranean chemical processes. The rich cracking and almost infrasonic rumbles were tactile as well as aural and seemed to sit somewhere between organic and synthesized.

The piece as a whole had a great sense of dramatic movement throughout, as patterns morphed from large solid plates to almost dizzyingly fine grains, and the sound developed from deep seismic rumbles to groaning and wailing reminiscent of materials tortured by being slid over one another. While its presentation was sculptural and almost architectural, it felt more like a linear composition and film than an installation, such was changing sense of tension and drama. At the same time the piece was truly immersive. In the dark of the gallery it felt like we had been transported deep underground to view aeons of geological activity unfold like a play.

In terms of its construction, the meeting of the various people involved in the piece is interesting for the constraints and influences it exerts on the work. The agendas of each agent in the project are different, perhaps even at times conflicting. The scientists at IRIS (the Incorporated Research Institutions for Seismology) would like their research to be communicated, to be seen to be reaching an audience and having measurable impact. Thus for them the priority is for the clear communication of a scientific concept and an explanation of the methods being used. For Sorigué other factors are at play, their stated mission is to “unite our understanding of social responsibility through art and its confluence with architecture, landscape, science, knowledge and enterprise” Interestingly this seems to suggest that the purpose of the

foundation is to edify the patrons themselves. The artists on the other hand aim within this to create a sense of the 'technological sublime' (Jarman 2017) and a visceral experience that perhaps involves elements of obfuscation, ambiguity and open endedness. That these influences may be at odds points to the complexity of any artistic collaboration and again, it is the status of the knowledge produced in this activity that is at stake.

The audience are being presented with a complex set of data, in a manner that allows an immediate experience and perception of certain aspects of it and an obfuscation of certain other elements. They are invited to consider the relationship between the sound and visuals by virtue of the fact that one affects the other, but they are not immediately invited to consider the relationship between the data and sound that it produces. The 'sound' originated as subterranean vibrations created by machinery working overhead interacting with larger geological forces. These vibrations would not be experienced as sound, but they would have been monitored and recorded as numeric data with a particular function. To present this through a large speaker array as sound immediately re-presents the data in another form. There is a subtle mechanism here, whereby the 'sonification' is such a small step sideways it almost goes unnoticed. To move from seismic data to sound is such a small leap that the translation almost appears invisible. For the audience, their 'visceral experience' creates a sort of fiction whereby this data, the phenomena that produced it and the intention of the artist and other agents involved, are conflated into an single experience.

For the both the scientists and the construction company, the piece is viewed from entirely the other side. Knowledge for them is about where in a cultural landscape their work resides. Having full knowledge of what has produced the piece, insight is afforded to them more in terms of how the audience reacts and feeds back their understanding. The piece for them begins as specialist knowledge, that is then opened up to an audience of non-specialists and in doing so some of that aura of authority is traded off. In order for the piece to function, the techno-scientific partners involved are required to relinquish some of their control over the work they do and how it is going to be

understood. This is pertinently illustrated in an anecdote from Jarman who explained that Sorigué asked that there be a explanation of the work (both the piece and the scientific and commercial work behind it) before the audience actually encounters it. The artists of course dismissed this idea.

This introduces an interesting aspect of how the knowledge produced by the piece is conceived by the artist. The insistence that the audience experiences the piece before having an 'explanation' of it points to a different understanding of how knowledge is produced here. The audience is afforded a creative freedom to interpret the piece and the phenomena that produced it. They are left to speculate what is triggering what, where the source material comes from etc and they are free to make mistakes in their interpretation. The source data of the piece is first uncovered by the artist, the rendering of seismic data into sound turns an abstract geological process into lived experiential sound. This is then further complicated by the ambiguous presentation of the sound without an explanation. The artist's role here seems to be to facilitate a simultaneous uncovering and covering of the phenomena under investigation. This puts them in an interesting position - where the audience is invited to understand and the scientists are invited to explain, the artist is required to do something in between these two efforts.

3.3 - Collide Residency

In 2015 *Semiconductor* were invited to take part in CERN's *Collide* residency at the Large Hadron Collider where they were invited to interact and discuss work with physicists and make work in response. *Semiconductor* explained that they started by conversing with various scientists and that this involved a particular challenge of grasping sometimes very specialised subjects and finding pertinent questions to continue the conversation. Jarman explains how this initial interaction is often very intimidating and that this is partly dealt with by trying to adopt a provisionally naïve approach.

She explains that there is a fundamental difference with how they are trying to apprehend the science and how the scientists understand it. In acknowledging this in their initial encounters, to some extent they protect their outsider status, adopting a sort of anthropological stance. I would suggest that instead of their activities being either truly outside, or completely absorbed into the institution, their grasping at as yet (for them) unknown 'epistemic things' (Rheinberger 1997) positions them as part of a now extended experimental system, one in which parts of the system are as yet unknowable to itself.

3.4 - Do You Think Science

The act of directly addressing the scientists themselves was explored in video work *Do You Think Science* (2008) conducted at the LHC. The piece is a video work where scientists are asked various questions off camera. Their responses are edited together and the viewer is left to deduce what question was asked. One such question seems to be 'do you think science can explain everything?' the response to which is usually quite measured, and often answered with the counter-question 'what is meant by 'explain' here?'. Several of the scientists answer quite simply 'no' and suggest there are things not in the reach of science. Certainly none of them seem to address the questions in 'scientific terms' rather they resort to humour, appeal to some ineffable quality of 'meaning' or question the premise entirely. Many of them would seem to suggest that the job of producing meaning falls outside of scientific enquiry. How much they decide this falls to the job of artists is another question.

The focus on the epistemological status of this sort of work highlights an important consideration in any art/science exchange. Are they representing knowledge of the same thing but translated and how does this translation effect its meaning? Are there forms of knowledge exclusive to certain communities (i.e. specialists, non-specialists, general audiences), and how does making art with this work change this relationship? While these questions are raised by the piece *Do You Think Science,* like the omitted question mark, their conspicuous absence draws attention to the open ended-ness of

the answers. While their stated aim is to uncover the signature of human activity in seemingly objective observations, in *Do You Think Science* they somewhat invert this relationship, whereby they draw attention to their own signature by bucking the convention of an interview and leaving their questions out.

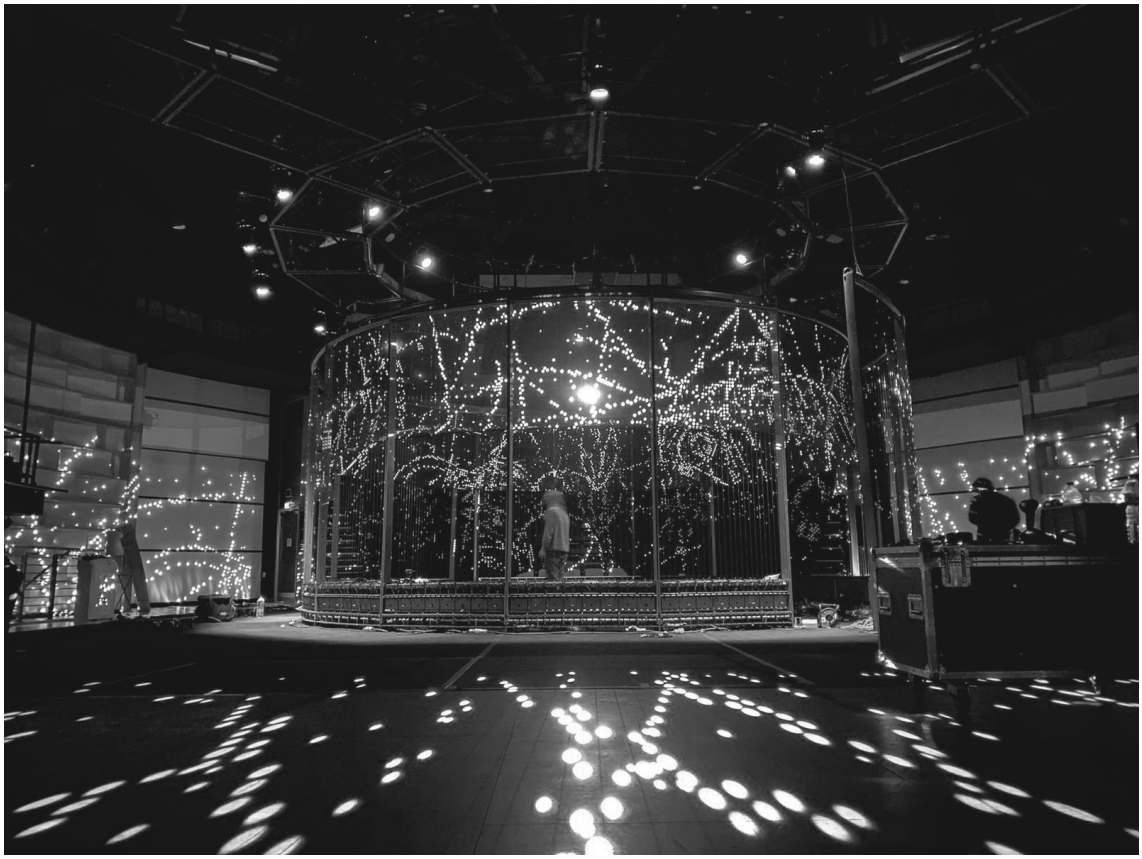
3.5 - View From Nowhere

Semiconductor used the footage gathered during the residency to produce the film *The View From Nowhere* which premiered in Nance in 2018. The film uses footage from interviews with theoretical particle physicists alongside footage from CERN's fabricating lab. The stated aim is to 'explore the dichotomy that is revealed between the surprisingly creative pursuit of theoretically modelling our physical universe and the fixed/hard classical nature of producing instrumentation to test these notions' (Gerhardt 2018)[29]. There is an implication here that the theoretical work is perhaps less constrained, is mutable and speculative, casting the term 'theory' as a 'yet-to-be-confirmed truth'. This epistemic instability charges theory with an almost literal motive force to produce experimental action. In contrast, the manufacture of equipment designed to test any given theory is presented here as stable and rigid. In order to test a phenomenon the apparatus must 'stand still' against the thing being tested (Hayles 1993).

[29] Gerhardt, J *https://arts.cern/article/view-nowhere-semiconductor* accessed 12/12/2018

3.6 – Halo

Fig 8. *Halo* Installed in the Attenborough Centre for the Creative Arts in 2021



Alongside the films *View from Nowhere* and *Do You Think Science* the duo were commissioned by the Audemar Piaget prize to create a large scale installation. The piece, called *Halo,* would be in development for over two years following their residency at the LHC. It was finally finished in June 2018 and installed at Art Basel. *Halo*, made to somewhat echo the form of the LHC itself, consists of several audio visual elements. A large 20m diameter 3m high circular metal structure holds 512 high tension piano wires. The wires are strung vertically and are roughly tuned to a frequency of around 40hz. The structure then consists of a large room like circular harp.

Each string has its own dedicated magnetic coil pickup and preamp, and these signals are networked to be processed at a later stage. At a point about a third of the way up each string is a mechanical hammer, actuated by a solenoid in such a way that the

hammer can be flicked against the string and will rebound using just gravity[30]. At the base of the structure is a sound box, constructed with a similar working principle to a sub speaker with a resonant cavity made of plywood stiffened with wooden struts arranged along the nodes of the principle mode of vibration. This results in a light and very resonant box with a resonant spike roughly corresponding to the strings attached to it. Again, there is a borrowing from a traditional instrument building technique here, that also has been adopted for electro acoustic purposes. Within each sound box is a speaker driver, but instead of being attached to a cone they attach via a transmission rod to every third string along. Signals coming from the free strings are fed back after some signal processing into the strings that are attached to drivers, causing them to resonate.

The initial triggering signal that fires off some of the solenoids is determined by data collected from the LHC. *Semiconductor* worked with Professor Antonella De Santo and Dr Mark Sutton at the University of Sussex to interpret the vast quantities of raw data produced by a number of collision events at the LHC. Each event consists of a number of co-ordinates stating where and when various particles ended up in the fractions of a nanosecond after two packets of protons are collided inside the LHC. This data was translated into midi control data, with space mapped onto pitch (or more accurately onto a set of midi note values) and time mapped onto more macroscopic timescales of a couple of seconds per event (many orders of magnitude longer than the actual events they represent). The midi data is used via a MaxMSP patch to fire off solenoids corresponding to the locations of particles in each collision.

In addition to the sound making apparatus is a circular screen running around the top of the structure. This shows an animated depiction of the collision data, rendered as

[30] It's interesting to note that the engineering problem of how to allow a hammer to strike and use some of that energy to recoil from the string is one that has received much attention throughout the development of the piano. The principle challenge is to emulate the highly accurate strike of a beater held directly by a performer. For any percussive instrument, the most resonant sound will generally be achieved by allowing the beater to strike only once before lifting off and letting the object vibrate. (By implication further articulations such as damping effects, rolls etc can be obtained by doing the opposite). It is also perhaps interesting to note that a similar concern is faced by designers of analogue and digital electronic apparatus, where a button or switch is required to be 'de-bounced' reducing the push to a single impulse. A motor skill that is learned fairly intuitively by a human, becomes harder once it becomes more automated and abstracted by mechanical elements.

trails of white dots tracing the paths of the particles. The paths have presumably been rendered at some angle to their original collision i.e. not radiating from the centre of the machine as depicted by the sound.

After Halo premiered at Art Basel I went to see Semiconductor in their studio. At that time they were in the process of finishing some subsidiary pieces relating to the work. They had created three square, black screens depicting animations of the data used in the piece. They explained that one of these had been bought by the owner of the business that manufactured the superconducting magnets used inside the LHC. They were intending to visit the business and approach them about doing some work in their manufacturing facility. This points to the multifaceted nature of this work where the artist must involve themselves in many stages of the scientific practice. Jarman explained that no single stage of the work can be untangled from the rest and that the scientific activity must be understood as a series of parallel processes happening at different scales and in different contexts. Their work was another one of these processes which intervenes at several stages. The artistic work also exists in many formats, the object itself, the sound it produces, the process of documenting the scientists at work, and the data as it is transformed and represented in numerous ways. These moving pictures then were evidence that work of this kind can never have a final part in as much as the science it engages with is never finished. Slices can be made through the process at various stages and different strata are revealed, but that the whole thing must be regarded as a continuum of work, an experimental system in itself. It is the intimate involvement of the artist and their inclusion in the actual scientist's place of work that allows them to make these cross-sectional slices of the work.

3.6.1 - Construction

The piece was built by fabrication company *Millimetre* who employ around 30 people including carpenters, digital designers, metal workers and engineers to realise artworks and architectural projects. *Halo* was under construction for a number of weeks, eventually seeing every employee being drafted in to help. Director Matt Ridsdale was taken by *Semiconductor* to the LHC to see the manufacturing processes involved

there. He was taken around the metal working labs which manufacture parts for the actual experiment and was given a sense of the strict tolerances and precision involved. This almost certainly had an effect on how *Halo* was built. With the entire company working on the piece, it was interesting to see how each discipline would feed into the next. Problems solved by metal workers at one stage would impact carpenters at the next and so on. People working on the electrical wiring were required to wait for software elements to be developed before they could begin a particular stage. Various build challenges saw the piece develop from the original designs. The piece was built as several modular units that could be assembled into a whole. Each unit consisted of a large metal frame, around 20 strings and their associated electronics and solenoids, a section of soundbox and its accompanying amplification system. The pressure that each frame was under meant that despite using thick steel bars the units were compressed and bent by the immense tension of the strings. The overall piece would be subject to several tons of pressure in the final build.

Various specialisms were employed to make the final piece. Engineer Ash Brosnan, who has a background in prototyping as well as a musical practice involving custom synths and pedals, designed the circuitry using generic circuit designs modified for this specific purpose. Halldor Ullfarson, luthier and researcher from the University of Sussex was brought in to consult on some technical points of the piece. His work on a self resonating feedback instrument called the 'Halldorophone' meant that he was ideally placed to advise on the operation of the machine. Later on during construction I was also asked to help with various stages of construction, including constructing circuits and working on the MaxMSP patch controlling the installation.

During this process Gerhardt mentioned that he in fact had no musical training, despite producing lots of sound based work. Similarly, Ullfarson made the distinction that while he was a luthier he was not in fact interested in making the music himself. The suggestion here is that they were able to carry out their various roles not *despite* being from a non-musical background, but *because* of it. They seemed to suggest that their outsider status was operating in a manner similar to *Semiconductor's* outsider status in

science institutions, revealing an aura around musical practice similar to that which is conferred on scientific practice. This characterises *Halo* as an intervention not only into science but also into musical practice, and that part of its meaning, its effect, is brought about by its subversion of these cultures.

The final days before packing and shipping the piece to Art Basel were frantic, last minute wiring was being completed, circuits were being installed and tested as other modules were being packed away. The sheer scale of the piece was unprecedented and tested the capabilities of everyone involved. It was noted by Ridsdale and business partner Marc Thomas that this had been a learning curve for them, having never made an electroacoustic device of this scale. Specialist knowledge about sympathetic resonance, the harmonic spectra of a vibrating string, and the aforementioned technical challenges that are part of historical instrument design such as the hammer mechanism all had to be learned by *Millimetre* through a careful process of development, testing and consulting with outside partners. This complex exchange of specialisms worked not simply by an efficient 'filling-in' of gaps in knowledge by relevant experts, but by the push and pull of tensions between them.

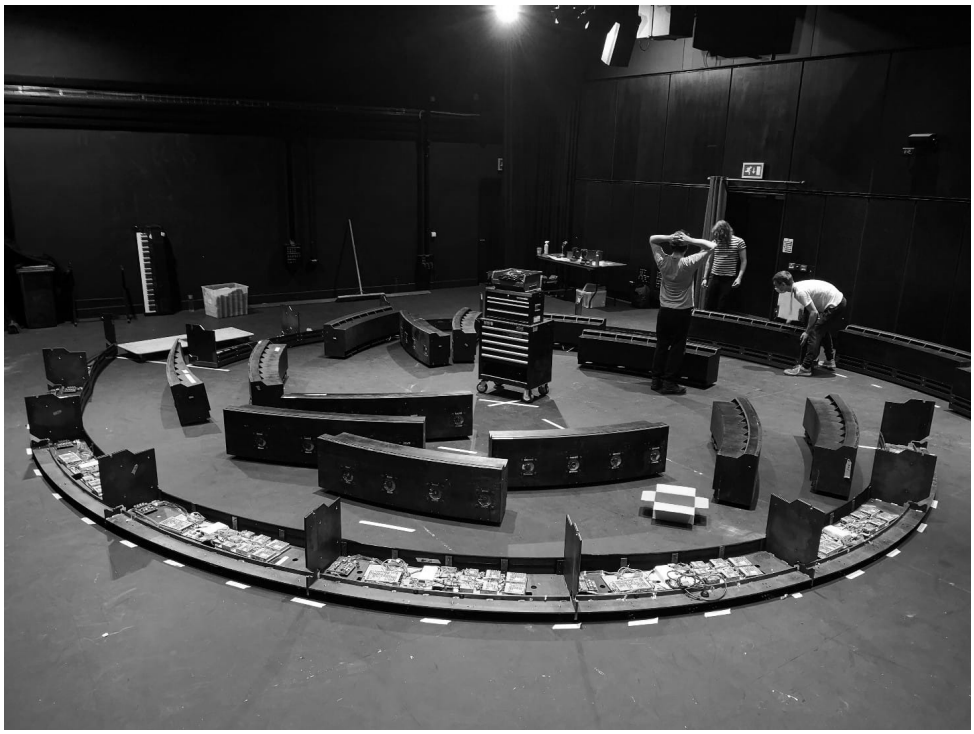


Fig 9. *Halo* during installation at the John Hansard Gallery 2021

Fig 10. *Halo* being modified at Polyspace fabrication studios prior to installation at the ACCA 2021

3.6.2 - Operation

The overall effect then, is of a giant complex machine, its bare welded steel structure suggesting an industrial function. The strings, being all the same length, are not immediately recognisable as the strings of a harp and instead seem to serve a structural purpose. The complex and extensive wiring involved in the machine is housed underneath the sound box and so, although it is understood to be an electro-

acoustic device its workings are hidden from the public. These elements, which might be regarded as the 'noise' of the physical structure, are curated in a way that contrast the artist's treatment of data. On entering the circle the viewer is met with a large band of screens showing abstract lines of white points streaking unpredictably around the circle. The piece is dimly lit to allow the audience to find their way in but the majority of the light is produced by these screens, lending a theatrical quality to the experience.

Periodically a packet of midi data, representing a collision event, is sent to the solenoids and a flurry of strings are struck. The click of the solenoids suggests some mechanical process, adding to the attack of the sound. The strings are struck in all directions around the circle, corresponding to the shower of particles from the collider event. The low-pitched strings growl and rumble like a peal of thunder in response. This in turn starts a number of strings resonating via the speaker drivers. The effect is that after the initial shock of hammer hits, the harmonic spectra of the sound is teased out as certain strings begin to resonate with various harmonics, recalling the aforementioned 17th century experiments with sympathetic resonance.

3.6.3 - Halo as analogy

To understand what the piece represents it is useful to understand how the LHC itself works and how this piece acts as an analog to that process and where it diverges. The LHC accelerates particles to within an appreciable fraction of the speed of light, around a huge 27 kilometre circular track. The particles, packets of protons, are steered using a huge array of supercooled magnets. At a specified energy level these particles are crashed into each other and the resulting particles are analysed to give us an idea of conditions close to the theorised start of the universe. To begin with the data is collected by an array of detectors around the point at which particles are crashed together. The sensors are arranged in concentric layers, with each layer designed to detect the passage of a particular type of particle. This filtering of types of particle is achieved in a variety of ways, some detectors will only sense a certain charge or the arrangement of detectors is such that only a particular type of particle will get through

to a particular layer.

This constellation of points is then separated from the vast quantities of noise using a combination of machine learning algorithms and human judgement. The paths particles have taken as they decay into other types of particles must be pieced together from this information. This data is usually visualised with three dimensional models of the paths the particles are assumed to have taken given their position when detected. Time is represented by the continuous path the particle has taken within a given event.

It is worth mentioning right away that *Halo* is not intended as a direct analogue of the Large Hadron Collider. Here I will describe some of the ways in which it functions as such and ways in which it diverges. As has been explored in the previous chapter it is a recurrent theme to use sound as an analog for other physical processes in physics modelling and simulation. Recently black holes have been modelled using fluid dynamics and sound waves to represent electromagnetic waves to look at phenomena associated with light being dragged beyond the black hole event horizon(Visser 1998). With *Halo* sound energy is being used as an analog of the particles produced by the LHC.

The analogy works to the extent that the particles in the LHC and the sounds from Halo are both ways of understanding how the energy propagates around the system. Of course they are very different phenomena produced by completely different means. Even so, the fact that they are causally linked in this relationship reveals something of the dynamics involved in *Semiconductor's* work as a whole. As an audience we are invited to speculate about the boundaries between nature, data, technology and in particular the role of artefice and construction in this relationship.

The initial pattern of strings firing corresponds to actual data from the LHC regarding the paths that particles took in each collision event. In this respect the input to the system is an entirely predictable, pre-ordained order of firings. The actual sound output is however complicated by the fact that, although the strings are all the same length,

variations in tension mean that they occupy a band of pitches anywhere between 40 and 60 Hz and may change with environmental factors such as heat. This being only in partial tune is interesting, creating a degree of instability and unpredictability to the system. Certain strings will resonate with others that share harmonic spectra, each set of data will create a different outcome on different occasions. The piece differs from a tape score for example, in that it is situated and based on the material relationship of the sculpture to its environment.

Furthermore, the outcome of the LHC experiment is being put through another system. While this further abstracts the data, it is at the same time made sensible by converting it to electromechanical processes and then into sound. This points to an interesting dynamic, that the further the data is abstracted from its origin, the more it is rendered perceptible by our own senses.

The LHC can be run at different energy levels and different bandwidths of energy can be explored. Economic constraints mean that before a bandwidth can be investigated, it must already have a vast amount of theoretical basis for doing so. Here *Halo* 'borrows these decisions' with data that has been subject to these influences, but its output is subject to an entirely different culture. What then does this translation mean, whereby a particular research culture determines what will be studied, to serve a particular function, and then the results of that study are (re)presented in an entirely different context? What do the original intentions of the scientists involved in working on the LHC become when they are presented in this way?

Peter Galison asks in his paper *Objectivity is Romantic* 'What characteristic new relations do the scientists have to the machines, and what status do images have that unapologetically leave a mechanical objectivity in favour of expert judgement?' (Galison 2000, p39). This is particularly pertinent here, when the new machine, *Halo,* is yet to be built at the time that the original experiment is carried out. Here the status of the 'image' (or in this case packets of data) produced by the machine have already to some extent been defined by the experts in question, before being subject to *another*

machine and assessed by experts from a completely different field. In this sense *Halo* acts like a meta particle collider, a machine for observing the operation of another machine. This nesting of expertise is a common dynamic in art/science collaborations. In the same way that Semiconductor are intervening in the lab during their residency, their machine intervenes in the data produced by another machine and by extension intervenes in the intention of the science research community involved.

Fig 11. Artist Joe Gerhardt experiments with *Halo* using feedback loops through speaker arrays.

3.7 - Conclusions

I have presented Semiconductor's work as having started by exploring the idea of partially relinquishing control of the compositional process to some other agent. Using this constraint unexpected outcomes are created and the act of composition becomes a dialogue between the intention of the artist and the technological mechanisms involved in producing the work. Their work with early computing allowed them to play with notions of the translatability of data, and introduced the idea that through the medium of code, data could be abstracted arbitrarily and presented in any number of

ways. A similar process is observed in the labs in which their residencies take place, whereby scientists must arrange experimental apparatus in such a way that the natural phenomena they seek to observe is outside of their control, and operating as a constraint on the manipulation of the experimental system. In this case, instead of replicating this process, *Semiconductor* assign this role not to nature, but to scientific practice itself.

Their work then progressed to outsourcing this external agent to other things. Their work with specialists involved in technical, industrial and scientific activities meant that this compositional constraint was now also positioned in a cultural, historical and commercial sphere. By directly working in the laboratory, interacting with scientists and making technology that derives from other technology the work critically reflects on the dynamics of knowledge exchange between scientist, artist and audience. Differences in intention of these parties is brought to bear on the work and by doing so creates its effect. It is the scientific practice itself rather than the phenomena that it investigates that is brought to the fore.

Their focus on the ethnographical study of scientists through their residency documentaries resulted in a focus on the cultural status of the work carried out in these institutions, and in turn of the work created by *Semiconductor* themselves. This then opens up a dialogue around the status of knowledge produced in these different contexts. By positioning themselves as interested outsiders their work allowed them a different sort of access to that of the scientists themselves. Jarman mentions being included in the staff photo for the Smithsonian after a vote was taken by the scientists working there, revealing a sort of 'semi-inclusion' as a necessary position for the art/science practitioner.

At the same time their work was received by the wider world as if coming from a new kind of specialist, with work being included to illustrate mainstream scientific documentary. In particular their aesthetic of using raw data including artefact and noise, a luxury not afforded to the scientists involved in creating that data, was seen as useful

in communicating the work being done in the lab. Their work continued to reflect on the role of technology in this context, with work such as *View From Nowhere* drawing attention to the means of production of the data, and to the 'signature of man' in scientific activity, again raising questions about the epistemological status of the work carried out by both the scientists and themselves.

The creation of *Halo* marked another progression in their work - that of creating new technology itself. The piece operates on the principles of resonance and feedback in the acoustic sense, but also in terms of how it functions within artistic and scientific culture. *Halo* exists as a machine for the sonification of data. As in their earliest work, data is treated as infinitely translatable, and attention is drawn instead to the means of that translation. The large scale spatialised sound field of the piece immerses the audience within the machine itself inviting them to speculate on their own position within the process of knowledge creation. *Halo* draws on a long history of using the principles of resonance to demonstrate seemingly hidden connections between things, while situating them in a realm of embodied sound experience. Its effect is not produced by creating an accurate analogue of either the methods or the subject of scientific investigation that it originates from, but instead brings to the fore the context within which such activity takes place and the teases apart the dynamics involved in this process. Both literally and metaphorically *Halo* works through themes of feedback, resonance and tension.

The principle outcome of this study into *Semiconductor's* work was the decision to go and experience a residency myself and develop some work in this context. Having already by this point made contact with the British Geological Survey's Space Geodesy Facility at Herstmonceux I decided this would be an ideal place to do it. I met a final time with Semiconductor to ask their advice. They first of all said it was useful to come up with a short presentation of my work, saying that even after several exchanges with the Mineral Lab at the Smithsonian it was only until they met in person, with concrete examples of their work that the scientists finally understood what they intended to do. They stressed the balancing act involved in leaving options open, dealing with the

inherently uncertain nature of artistic work to be produced, and the need to be specific about my intended activity at the lab. They also mentioned the need to carefully identify and engage with the expectations of the scientists themselves. They explained that because scientists use the scientific method as a starting point that they might have difficulty in understanding the uncertainties and vagaries of the artistic process. That being said they also stressed the shared ground in working with unknowns and that this could be a good way to articulate the open ended-ness of this stage of work. Finally they said that it was important to explain that the role of an artist was not simply to illustrate the work they do there and that it would necessarily engage critically with it. At the same time they would require reassurance that they or their work would not be misrepresented. Having spent this time studying *Semiconductor's* work up close and taking heed of this advice I felt ready to approach the SGF and arrange my own residency there.

CHAPTER 4

THE WANDERING SCHOLAR – ART RESIDENCY

4.1 – Introduction to Space Geodesy Facility, Herstmonceux

The SGF is a small satellite laser ranging station, located in the grounds of Herstmonceux Castle. The facility is funded by the British Geological Survey and the National Environmental Research Council. It shares its site with the much larger observatory, now a science outreach centre, a 15th Century brick castle, and part of an international university campus for Queen's University, Ontario. The facility is tucked away amongst these buildings and is easy to miss next to the large observation domes of the ex-observatory. It consists of a small bunker-like, red brick building, its most striking feature a large white dome covering its telescope, and a smaller dome housing radar equipment. Two smaller domes containing a pair of remotely operated telescopes and a tall aerial sit next to the building, all of which are surrounded by trees and partially hidden amongst what look like iron age tumuli. The treasures entombed in these earthworks include a large subterranean gravimetry lab housing various expensive and delicate pieces of equipment.

Work at the SGF includes keeping track of numerous satellites as they pass overhead, accurately ranging them using a high-powered laser and various telescopes. In the gravimetry lab, careful measurements are taken using two absolute gravimeters which are maintained at the facility. In addition to this they run a hydrogen maser atomic clock that times the laser ranging apparatus, as well as assisting in the highly accurate timing necessary to use GPS satellites. This data is used in a number of contexts relating to environmental science, for instance in supporting satellite missions to accurately measure changes in sea levels and monitoring ice caps. More locally their work concerns environmental science with the use of a sun photometer and visiometer which measure haze and atmospheric visibility in the local area. Their second major function as a geodesy facility is to make measurements which contribute to the terrestrial frame of reference. As part of a network of many other satellite ranging stations around the world they build models of variations of the earth's gravitational

field and shape, as well as setting precise co-ordinates by measuring their own position to track tectonic movement.

Fig 12. The Space Geodesy Facility at Herstmonceux

4.2 - Bracketing

The various strata of historical buildings, including the castle, the university campus, the old observatory and the SGF itself being in such close proximity was of particular interest to me. My intention was to try to understand the work of the SGF through the lens of the medieval re-enactors at the castle. I would use this idea to guide my observations and activities at the residency, to bracket off my pre-existing knowledge of the work going on there and instead force a new understanding of the site.

There is a parallel here to Latour and Woolgar's device of describing the purpose of the laboratory primarily as a system to produce literary inscription(Latour & Woolgar 1979). In both cases outside knowledge is imported into the ethnographical study (Latour and Woolgar's knowledge as writers of literary inscription and my own knowledge of re-enactment as a performer). In *Laboratory Life* the authors' expert knowledge of writing and literature is used to understand instances where literary inscription is taking place, not only to describe the ultimate outcome of the lab, published papers, but also as an

analogy to describe a scientific instrument taking a measurement and making a mark. Similarly, in my own case expert knowledge of re-enactment is used to make sense of the work happening in the lab to understand where in fact a form of re-enactment is taking place - that of an experiment. Parallels are drawn to describe how scientific activities and historical re-enactment both involve the careful recreation of a process to gain a kind of embodied knowledge that would be otherwise unattainable. The attempt at accurate repetition highlights unexpected differences that emerge, the epistemic excess spoken about by Rheinberger (Reinberger 1997). While both Latour and Woolgar's approach and my own serve to suspend pre-existing knowledge and invoke something like phenomenological epoché (Husserl 1912), there are some key differences. Firstly Latour and Woolgar seem to have applied their literary device retrospectively, after their time in the lab as primarily a method of framing. In contrast, the idea of viewing the SGF as a kind of re-enactment informed my initial approach. I went into the situation explaining to the scientists that this was my intention and my observations were made there with this in mind.

Secondly Latour and Woolgar state that their account is that of a fictional observer (Latour & Woolgar 1979 p45). In doing so there is a kind of double layering of bracketing, firstly of the fictional character imagining the lab as an 'inscription factory', and secondly by the authors imagining their observations through somebody else's eyes. In my own case the idea is presented as part of a performance. The physical presence of a performer (as opposed to the physical absence of an author) allows for a different kind of ambiguity. Instead of having to state that it is a fictional observer mistaking the lab for a re-enactment, I present as myself having made this mistake.

Finally, Latour and Woolgar's report is to a large extent factually true, and works by shifting the emphasis of activity in the lab. If the term 'literary inscription' were substituted for (the more ambiguous term) 'scientific knowledge' the account would hold true to most peoples' understanding of what a lab does. The content of Latour and Woolgar's observations are largely true and factual, and the framing of the account, made after the event and as a literary device is largely fictional. In my own case, the

content itself is fictional (for example the SGF is described as a monastic order) but the framing of the account is largely true (I did in fact go and work as a re-enactor in the lab).

Both approaches involve a 'useful misapprehension' but the differences outlined above result in a different mechanism of operation. In Latour and Woolgar's account their useful misapprehension takes place through the action of re-positioning emphasis, shifting the focus onto an activity that is usually regarded as subsidiary to the main function of a lab. In doing so the reader is invited to see where literary inscription counts as, or stands in for knowledge production. To borrow an analogy from physics, it is as if force is imparted on the system by stressing one part of it over another. This then sets the whole mass in motion and knowledge of it is arrived by observing the points about which it pivots, its nodes and anti-nodes of vibration. By introducing the notion of literary inscription the reader is invited to see where the actual activities of the lab resonate sympathetically with this description. In my own case, rather than sympathetic resonance, new understanding is attained through a kind of dissonance. The stretches and stresses involved in trying to 'fit' the wrong picture of activities taking place invoke a kind of awareness of the *actual* activities taking place. Here the theatrical device of re-enactment is used as a conceptual constraint that shaped my approach during my residency at Herstmonceux.

As well as through my own interventional efforts, instances of dissonance were encountered throughout this residency in other ways. I should be clear that I am not at all talking about the 'instances of gossip or scandal...sociological muckraking' (ibid, p31) described by Latour and Woolgar as favourite subjects of sociological studies of science. Intra-personal dissonance, either between the scientists, or between them and me, was never at all an issue. Rather, dissonance describes instances that broke either with my own expectations or general understandings of how science proceeds. In some cases dissonance was introduced by my being there, such as when restoring a lute with Toby Shoobridge the mechanical engineer in the lab's workshop, or presenting my activities to the British Geological Society representatives in medieval dress. Other

times incongruity was encountered in things found there. For example, Vicki Smith who was in charge of the incredibly delicate gravimetry lab had two spaniels who would lie like heraldic devices on either side of the gravimeter while she worked. Understanding the place through dissonance meant both paying attention to such incongruities, as well as creating new ones through the attempt to act as a re-enactor at the facility.

4.3 - Initial Meeting

The initial meeting at the SGF was in itself a useful and illuminating experience. I went armed with some examples of my work and a concise explanation of what I intended to do there. I was introduced to Rob Sherwood, head of operations at the SGF and Matt Wilkinson who had kindly agreed to be interviewed by me last year. Rob explained that he was very happy to have me there and Matt had vouched for me in terms of the work I was making. He mentioned that he would take a soft approach in terms of explaining the work and my involvement at the facility to his managers. They arranged for me to carry out a risk assessment and do some general health and safety training with regards to equipment such as the high-powered laser and as long as this was done and documented he felt that it would be fine for me to be there.

One concern they had was that I might get bored, and Rob stressed that they couldn't be responsible for keeping me entertained. He explained that their work was largely dependant on weather conditions and often they would have to undertake quite boring routine work sat at a computer. I re-assured them that I wouldn't need any entertaining and that the site itself was so interesting to me that at the very least I would be able to film footage of the facility when nothing else was happening. They explained that when they had work experience people to stay they would train them up to do basic satellite observations and record data, and that they could do this for me.They kindly arranged a space for me to work in their meeting room and said I could use this for the duration of my stay.

Initially I had planned on spending a couple weeks working there, but they suggested

that due to the unpredictable nature of the work schedule it would be better if we spread the residency out over a month and that I could be flexible about when I would come in. In the end the residency happened over two months, with me attending the facility about three or four times a week and several times subsequently throughout the year.

I was keen to explain that I would be sensitive to their work, to try and stay out of the way and observe from a distance without taking up too much time. Rob explained that actually it would be fine for me to get involved and help if I wanted to, but that I would have to negotiate with each individual in terms of how I got involved. He explained I would have to do the same thing in terms of interviews and filming, and that some members of the team would be less inclined to get involved in this part of the process.

I also explained that it would be hard to predict the exact outcomes of the work, but that my intention was just to observe, to get involved where possible and that I would probably do some filming and sound recording. I was most concerned to explain that I would be very careful not to misrepresent their work and that while the work contained elements of comedy in all cases I would be the butt of the joke. Contrary to my expectations they seemed quite relaxed in this respect..

4.4 - Setting

Fig 13. Disused observatory, Herstmonceux

My first impression of the SGF was of the landscape in which it sat. The journey there each day involved a cycle across a large marshland crossed with drainage ditches and sluice gates. The observatory itself could be seen for miles which added an air of reverence to the approach. The verdigris domes on the hillside resembled pieces of giant armour, and the lattice radio towers echoed the church spires from nearby villages. Somehow it managed to look both alien and at the same time firmly part of the surroundings, having the effect of making the landscape itself seem to belong to the facility. I imagine a similar effect must have been created when Herstmonceux castle was built. A lot of time was spent either travelling through or else actively exploring the surrounding area and it would go on to inspire work later on.

On one occasion working late at the SGF I journeyed back only to find that all the trains had been cancelled. By this point it was pitch black and I had neglected to bring any lights. I had no choice but to cycle back the ten or so miles across the marsh guided only by the eerie light of the facility's green laser scything across the sky. Later on I would set up my own hermitage version of a satellite ranging facility out on the marsh and spent some nights camped out amongst the whispering reeds. Dozens of satellites could be observed passing overhead, some named after mythical characters, Jason,

Odin, others with acronyms suggesting new mythical heroes, LAGEOS, TIROS. The lines they cut across the sky, expressed in azimuth and elevation, sliced through terrestrial maps, redrawing the landscape in my mind's eye. By day the facility linked its buildings to the landscape, but by night it drew lines between the land and the sky.

The building itself suggested all sorts of forms. From the outside the minarets and domes of the various telescopes resembled a religious building. The small office outbuildings and telescope enclosures gave the impression of a small village. Inside the main building felt at times like being on a large boat. The small crew of seven would meet in the galley for lunch or tea breaks signalled by an electronic ship's bell. Just next to this was the main control room, the walls of which lined with panels of buttons and switches. Some of these were analogue devices created way back when it was first built, large illuminated push buttons and heavy metal switches. A red LED numeral display was used to time periods between satellite observations, dividing up the time of whoever was on duty into irregular chunks.

An adjacent room housed the main body of the laser. When I first arrived I was warned that I would not be able to go inside as the laser was too dangerous to even be around. Gradually I was introduced to it until I even got the chance to work on it myself. First I was taken in briefly to see the banks of steel cabinets holding old pieces of equipment. Various clear plastic dust curtains separated the room into sections. Then I was shown the internal workings of the laser. Vicki removed the cover of a large box about seven by two feet across to reveal a series of optical components and tubes. It almost looked like a large coffin full of medical equipment, pumps and hydraulics, a different vocabulary of objects to those I would expect to relate to light.

I was particularly struck by the use of optical resonance, something I had only encountered in acoustic terms, used to tune the beam. Portions of the beam at this stage would be invisible but nevertheless very dangerous. Vicki took great pleasure in describing what would happen if I were to be hit in the eye, first hearing a pop followed by the eye filling with blood, which would appear upside-down, until vision faded away

forever. Despite this extreme danger, much later on I was furnished with a pair of high end laser goggles and invited to take part in an experiment with Toby to test out some new polarising filters. I was able to hold optical components in the path of the beam and adjust portions of the laser. At one point we needed to determine whether the beam strength was changing by a subtle amount. I was able to help by using an analogue device I had designed to render light into sound. By recording the light as sound it was easy to determine whether the amplitude was changing, an example of sonification being put to use in the lab.

From here the laser was transmitted through fibre-optic tube up to the telescope. The process of focusing the beam correctly for this process involved an old analogue monitor with various dry marker pen inscriptions drawn directly on the screen. During this process we fired the laser onto the inside of the dome covering the observation deck, bathing the space in a powerful green light. The laser safety goggles rendered this into a fiery red giving the impression of working inside a huge furnace.

Normally the observation deck was used to range satellites. In the centre stands a large telescope on an automated gimbal. Various modifications and tubes, the laser emitter, apertures, cameras and smaller scopes were bolted onto this. In one corner sat various computer screens and control panels. From here various buzzers and alarms periodically go off. When being shown how to operate the laser and make observations I narrowly avoided hitting an aeroplane passing overhead. A variety of alarms sound at the facility including buzzers when someone walks in front of the building, the bell for tea breaks, door bells and of course the radar alarm. Not knowing which was which I was rescued by Matt diving across the deck and flipping the chunky toggle switch operating the emergency laser cut off. On a number of occasions such a dash was made when a ride on lawnmower went by, having been mistaken for the engine of the small aircraft that frequently fly past under the radar. Matt showed me various image detection programmes he was developing to try to spot these, the difficulty being distinguishing the planes from a bird or the edge of a cloud. I asked if they had ever used directional microphones to detect them and we did some research and found it

hadn't been tried. Matt asked me to do some preliminary experiments to see if it could work as a method of detection.[31]

Standing on the deck for long periods of time further gave the impression of being on a ship. The large dome panels resembled sails, and as the clouds rolled over the flat landscape it seemed as if we were moving. Added to this was the knowledge that we were firing the laser at moving targets overhead while the planet moved through space. The normally fixed terrestrial perspective, the very frame of reference the SGF was involved in establishing, gave way to a wider picture of planets and celestial bodies in motion. I was reminded of *Semiconductor's Heliocentric* as the sun wheeled by, and also of Matt's comment that 'to measure the earth it's necessary to get a perspective off it' (Wilkinson 2018).[32]

Below deck I was shown a trapdoor that led down a ladder into a long curved corridor stacked up with crates of obsolete equipment. Banks of servers hummed and blinked and heated the place up like an engine room. This then led down into the Gravimetry lab, where two absolute gravimeters are kept, devices that are used to measure gravity to an incredibly fine degree of accuracy. They sit on the stable concrete floor along with various laser units linked with optical cables. Above the door is a handwritten sign quoting Clayton Christensen 'You May Hate Gravity, But Gravity Doesn't Care'. In various other places on the walls there are other scribbled notes, including diagrams to help with the setting up of the gravimeters. Dotted around are several carpets: much of the work on these machines is done from a sitting position on the floor. In the corridors leading from the lab were stacks of wooden crates for transporting the gravimeters. Periodically they must be calibrated alongside all the other such gravimeters in the world. They are brought to the same location and placed in a circle on specially marked steel bases. The bases themselves are in fact 'piers', steel bars that run vertically deep

[31] In the process of doing this we discovered a curious acoustic effect. As planes pass overhead the fundamental frequency of the engine gets higher in pitch as it approaches and lower as it recedes as would be expected due to doppler shift. When I looked at sonogram analyses of passing planes I noticed that the higher partials did the opposite to what was expected causing the spectral content of the sound to 'narrow' as it reached overhead. Listening carefully it could be detected in the sound proving it wasn't just an artefact of the microphones. This was a puzzle to all the scientists there and we spent lots of tea breaks discussing possible mechanisms for this process.

[32] Wilkinson, M 2018 interviewed in *Weighing Almost Nothing*

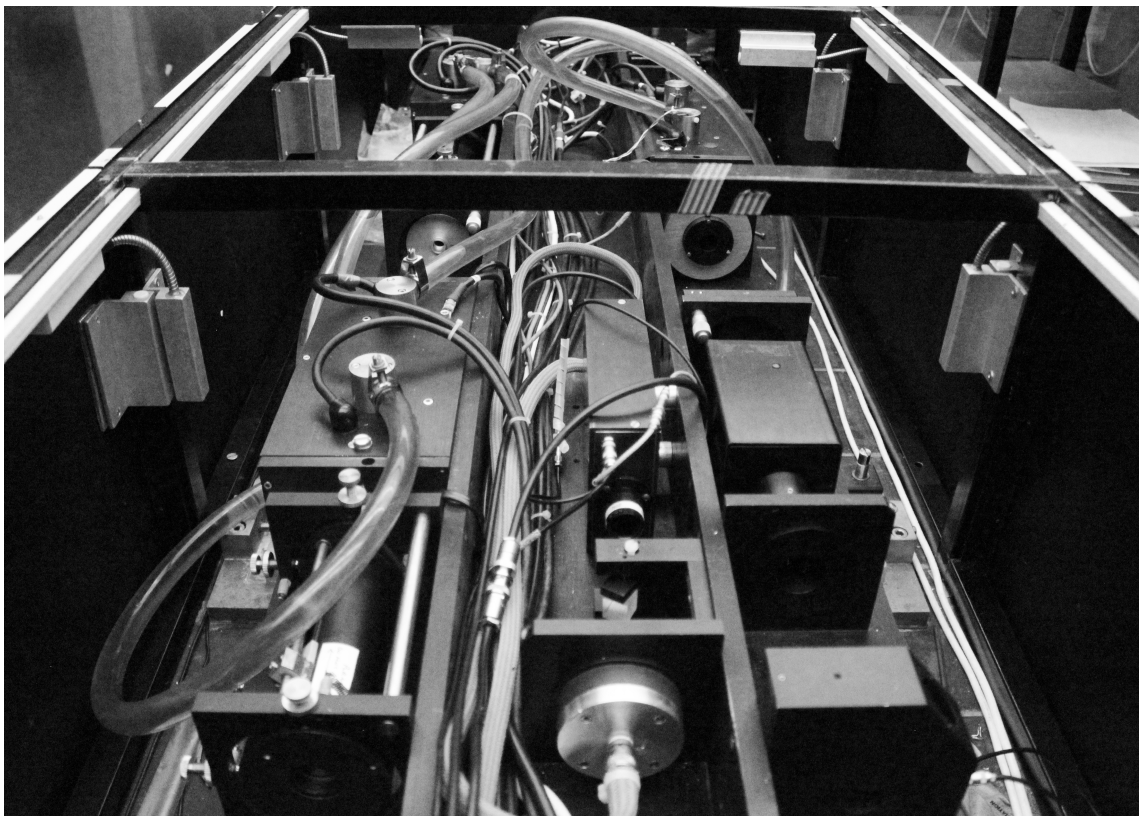
into the earth. These provide a stable foundation from which to make measurements. They make each measurement in turn in each position and then an average is calculated and the devices are calibrated. When the gravimeters sit in the lab the exact co-ordinates are noted in marker pen on the wall next to each machine.

The network of cables, optical paths, trap doors and passages created a sense that the building is a unified machine, that its rooms are simply incidental spaces created by the various bits of machinery. The space was difficult to define, part spaceship with its crew steering it day and night, part monastery with carefully performed rituals to invisible and complex celestial machinations. The place was sometimes animated, radar spinning, domes opening and shutting, telescope pointing in all directions. Sometimes it felt embedded deep in the landscape, the large bunker like earthworks of the gravimetry lab blooming with wildflowers.

Fig 14. Herstmonceux Castle.

4.5 – Operations

Fig 15. Inside the laser



In 1958 the Royal Greenwich Observatory was moved to Herstmonceux in order to escape the increasingly smoggy skies over London. At this time one of its primary jobs was to make observations by which Greenwich Mean Time could be established. Later it housed an early atomic clock which was used by the BBC to broadcast its 'six pips'. With its focus on such universal time standards, it was notable that the people working at the SGF kept to very different clocks. Working hours were determined by the passing overhead of satellites not subject to earthly time standards. The workers there would work in shifts doing alternate day and night observations. Day shifts would start at 5 and end in the afternoon. Night shifts would start late afternoon through to the early hours of the morning. These shifts were also dependant on the weather conditions which would often make observing impossible. Perhaps in the same way that measuring earth meant leaving it behind, maybe measuring time also required a similar working 'outside'.

At another scale of time entirely was the hydrogen MASER atomic clock. Deep in the SGF basement was a blank inscrutable machine, about the size of a fridge. Various optical data cables trailed out from it but apart from that it had no other markings. I was reminded of the importance of very early clocks in monasteries used for denoting times for various prayers, calculating astronomical events, and determining the dates of various feast days. In contrast to mechanical timekeeping devices the MASER had no decoration, no visible mechanisms or displays, but instead invisibly output its signal to various components at the SGF. This included use in GPS and also to measure the 'time of flight' signal between the laser and satellites. The use of the word 'flight' in relation to light was striking, as was the concept of being able to time it.

Matt explained that despite a degree of precision unrivalled anywhere else on earth it still needed to be adjusted and would gradually drift. He also mentioned that the level of precision involved started to almost make the idea of accuracy meaningless. While accuracy is in reference to a known value, here that value is actually being defined, and only makes sense to other values being referred to it. When it becomes the most accurate thing making a universal measurement, there is little else to compare its accuracy to.

I was reminded of a tangentially related concept explained to me by the person in charge of modelling and predictions, Jose Rodriguez. He mentioned that when the earth's gravitational field is measured, in order to start refining the measurements a prediction is made based on previous data and a model is created. Only when this model is made can the predictions be tested and refined so that a clearer picture is made. In both cases the 'true value' of a physical thing can only be approached by first constructing a conceptual model and bootstrapping towards more and more accurate pictures. This is in line with Hacking's observation that 'Once there is a practice of representing, a second-order concept follows in train. This is the concept of reality, a concept which has content only when there are first-order representations' (Hacking 1983, p136).

The SGF itself, by contributing to the terrestrial frame of reference, was in the business of constructing such a point of reference against which all other geodesy measurements can be made. It was jokingly noted by manager Rob Sherwood that 'the SGF is one of the most carefully measured places on earth that no-one knew the whereabouts of'. Although he was referring to the fact that the site is relatively unknown it also illustrates the paradoxical notion that the ruler seems to disappear behind the measurement.

A surprising thing that struck me immediately was the interaction between the handmade, activities performed by hand, and incredible precision involved. Throughout the lab were interactions between levels of precision that far exceeded normal human capacity and very manual activities. Perhaps one common conception of modern science is that most activities are automated. There is perhaps an assumption that at a certain scale, whether it be the processing of huge amounts of data, immense degrees of complexity, or infinitesimally small measurements, certain tasks must be confined to the digital realm. Something I realised while working at the SGF was that this is often not the case. In fact, it is precisely *because* such tasks here are pertaining to physics that the body is re-introduced into the system.

First of all physical properties and processes are involved, and while these could be electronically actuated such a system is prone to errors and needless complexity, so processes tend to be done manually when they can. Secondly an analogue scale offers literally an infinitely finer resolution than a digital one. So very often there is no other way than to perform these tasks manually using analogue systems that are directly coupled to the physical properties they are measuring.

A particular instance of this was when I was trained to set up the gravimeters in the basement. Part of the process of setting this up was to look at a small area where a laser beam is split and recombined to create an interference pattern. This is the working principle of an interferometer which I then went on to recreate in the studio. The two beams are oriented exactly above one another so that measurements can be

made to within a distance equal to a fraction of the wavelength of the laser. The laser has to be physically manoeuvred into this position by means of a pair of adjusting screws. There was a distinct awkwardness and challenge to setting this up. I had to position myself so that I was sat next to the device (along with the two aforementioned 'hounds en couchant' watching closely) and then contorted to reach around some very easily damaged and irreplaceable elements to reach the adjustment screws. Then, by barely touching the screws the machine could be tuned so that the lasers created a 'bullseye' pattern. This had to be done incredibly delicately and from an awkward sitting position while breathing slowly. An internal visualisation of the shapes produced by the two waves of laser light was essential to know which way to adjust it. The operator is forced to conform to the physicality of the instrument and a sense of its extreme precision is bodily felt.

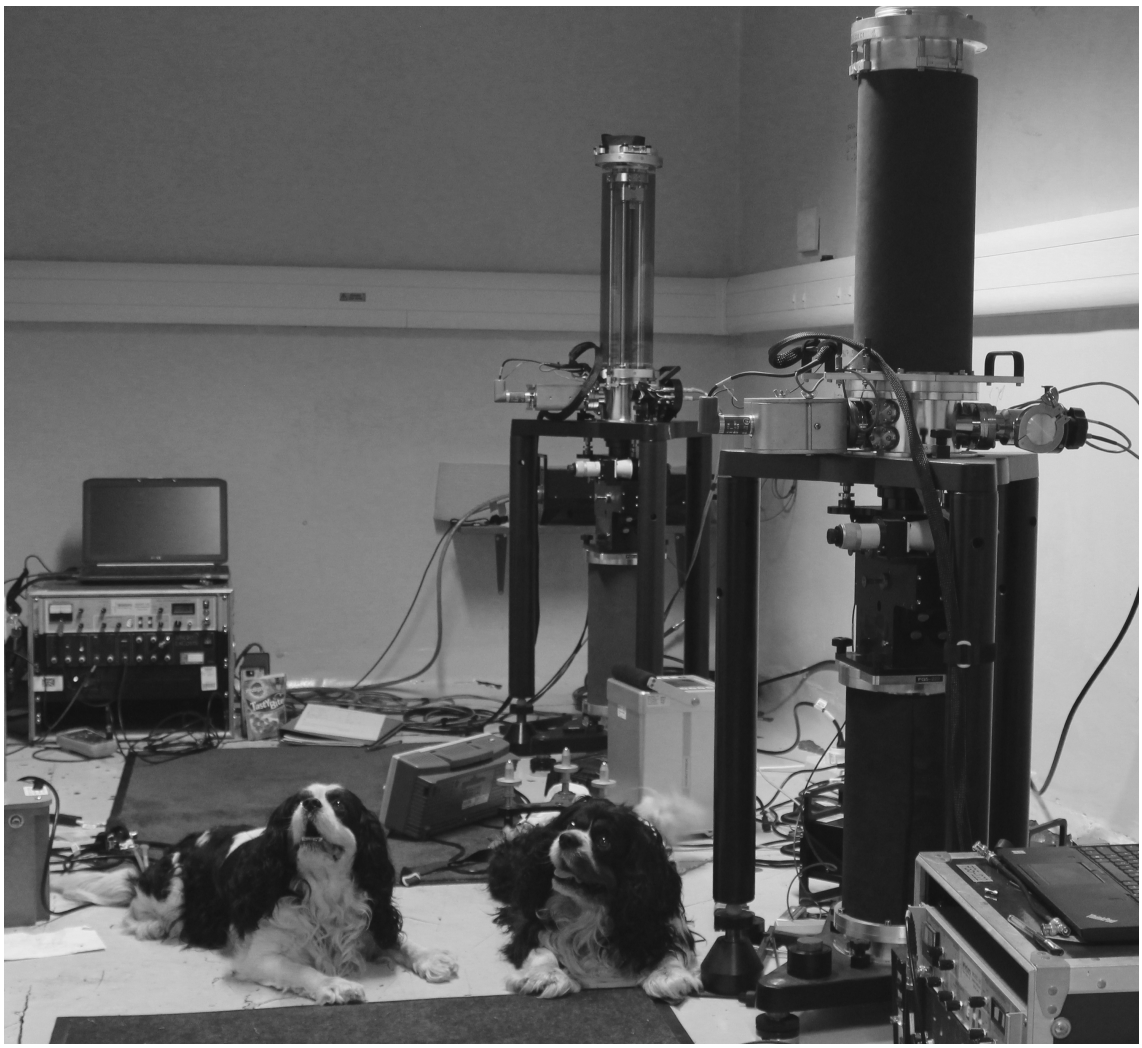
Although there was a constant effort to automate whatever could be there were many other processes that were carried out by hand, or involved simple sometimes crude analogue solutions. Up on the observation deck next to the telescope and laser emitter that would fire at passing satellites, the control panel consisted of a series of screens, some of them modern LCD flat screens for computer displays, along with one or two cathode ray monitors. One such monitor was used for making adjustments to align the laser. I was shown how to focus the beam by Vicki and to judge where its focal length was by looking at a tiny television screen. The centre of the screen had a faint white spot on it, and she pointed out that the laser was visible as a faint triangular area of light. It was virtually impossible to see and the level of expert judgement needed to do this correctly was impressive. Using a white board marker to directly draw on the screen she showed me how changing the aperture of the emitter tightened the beam focus. There were several occasions where the adjustment of some highly accurate and sensitive precision equipment relied on being able to see a barely perceptible artefact on a screen. Later on while working with Toby on the laser, another very old monitor screen was used to align the beam from the enormous machine responsible for creating the laser light in the basement. Again, measurements were calibrated and adjusted by drawing directly on the screen with a marker pen.

Many parts of the SGF were handmade on site. Mechanical elements were made by Toby in his workshop and I was delighted to see how much this space resembled my own studio. Various tools lined the walls, and along with metal lathes, pillar drills and various others were some more mysterious specialised tools, a number of which were handmade for some very particular purpose. The corners of the room were stacked with raw materials, various lengths of steel rod and metal sheets, gears and motors. Things would arrive by post almost daily, tantalising precious objects such as super fine threaded bolts, polarising filter glass, beam splitter cubes or lenses. At one wall stood a drawing board covered with large printouts that had been scribbled on and annotated. All around the place were examples of handmade artefacts, craft skills and manual processes.

I tried to imagine these being demonstrated at a re-enactment in the same way that blacksmiths or fletchers set up at such events to demonstrate their work. I was reminded of the laborious process monks would have undertaken hand illuminating manuscripts, the painstaking physical task in service of a heavenly causes. Or medieval masons working between abstract geometric forms and heavy earthly materials. The construction and operating of the facility, a place concerned with physics, frequently also involved the physical. Craft, dexterity and handiness were essential components here. Before any measurement could be made, it was in some way measured against the body, in the same way measurements were historically established, and even now where measurement standards are defined by physical processes. What would appear to be a very 'high tech' and specialised facility was created in a very recognisable and earthly environment. I began to think about the link between the bodily actions of individuals and the body of knowledge to which they were contributing. If the lab is a place of inscription, where impressions of nature are made into some other form, I was reminded by this positioning of the body in these operations, that inscription is not only the action of the hand on the pen, but also of the pen upon the hand.

4.6 - People

Fig 16. Dogs attending two absolute gravimeters



So far I have described the SGF in terms of its site and material arrangements as well as some of the activities taking place there. While these factors seem most pertinent to describing a place dedicated to science, the social, cultural and historical all play an important part in its operation.

The people at the SGF included mechanical engineer Toby Shoobridge, gravimetry specialist Vicki Smith, software specialist Matt Wilkinson, electrical engineer Graham Appleby, analysts Jose Rodriguez and Christopher Potter and head of operations Rob Sherwood. Everyone in the team had to do observations as well as their individual roles. A lot of the time individual people worked on various parts of their own projects. It was interesting seeing each person working on various things relating to their

speciality. In a similar manner to researchers in a university they would make funding applications to support the various parts they were involved in. Toby was involved in developing several things in the running of the facility particularly related to the laser. As I have already mentioned, while I was there I was able to get involved in experiments relating to the polarisation of the laser. In between observation shifts Toby was either working directly on the laser, or making parts in his workshop. All members of the team showed great enthusiasm and self motivation in their various fields.

In addition to this they often demonstrated great generosity with their time for outsiders. On one occasion a school group came on a night visit to see the laser operating. Vicki had been contacted by an undergraduate physics student interested in gravimetry and mentioning how she was impressed by the student's enthusiasm agreed to take her on as an intern. On another occasion someone who had come to fix the heating asked what they were doing there and was given a tour of the facility. They mentioned that frequently students from the nearby campus would wander up to the place and see what was going on. One night while doing observations just this happened when a student studying chemical engineering wandered in out of curiosity. José had studied the same course and so the two of them chatted about the links between geodesy and chemistry. On many such occasions they showed themselves to be incredibly welcoming.

I spent a lot of time with each team member during observations. One very notable instance of this was while working with José. At first I sensed a wariness on his part about my being there. I initially assumed this reticence to talk freely was because he thought I was going to misrepresent what they were doing there. Eventually I broached the subject and had a very enlightening conversation. To begin with I spent a lot of time trying to re-assure him that I wanted to understand very clearly what they were doing. I had assumed that the 'silliness' of dressing up and doing music there might be viewed as trivialising their work and I took great pains to show that I was trying to engage with their work truthfully and accurately even if the eventual outcome might involve including fictional accounts. José pressed me on the subject of my research and I mentioned that

it involved looking at how art practice might engage with science through the concept of creative resistance. I was a bit hesitant describing my work thinking he might not be altogether sympathetic.

To my surprise José thought it was funny I that I was so hesitant, and that he had thought I was 'just a science nut'. He said people he often met people in his field who had a naïve view of science as the be all and end all of describing reality. It was interesting that he had assumed this of myself, despite being from an 'art background' and he added that he had met plenty of artists who had shared this fetishising of science. We were both surprised that we had assumed that the other had the exact opposite viewpoint. He mentioned how important he felt culture was working in combination with science. He spoke about how his partner was a historian and that he often socialised with academics from the humanities. Perhaps he had an insight into my own position trying to grapple with amphibious 'in-between' work. He had a great interest in the philosophy of science and he spoke about reading Kuhn and Feyerabend. Throughout the rest of the residency and afterwards we stayed in touch and had many interesting email exchanges on this subject.

He was also very interested in music and we had many conversations about this. On the observation deck there was a stereo set up and people often played music while observing. It was interesting the choices that people made. Frequently I would come outside to hear Toby playing dance music. José often played classical music and we listened to several pieces while observing. He was particularly interested in early minimalism and played a lot of Terry Riley and Steve Reich saying that the mathematical feel of it somehow suited doing observations. Rather surprisingly he also told me how he enjoyed musicals, in particular flash mob type public music events. He showed me several videos of people making music in unexpected places. We spoke about how the SGF itself was an unexpected place to find music and how it felt like listening to pieces while observing was somehow 'scoring' the action. Having instruments in the place felt somehow transgressive as I suppose it would do in many

workplaces. Or at least, musical instruments felt like charged objects somehow. The scientists seemed to regard musical instruments in a similar way that I regarded scientific ones, with a cautious reverence and with the urge to have a go.

The place in general was very sociable with everyone taking lunch and tea breaks together and various homemade cakes being brought in. One thing that struck me was how playful everyone was. In the corner of the break room was a set of tennis rackets and golf clubs for use on the castle grounds. I was told that Sir Richard Woolley, the Astronomer Royal based at Herstmonceux in the fifties and sixties, would employ people depending on how good at cricket they were. Rob, who was keen on wood turning, had created some wooden spinning tops which were dotted around the facility. They devised various ways of measuring the rpm of the tops including colouring one half black and filming it spinning. In the end they drilled a hole through one and used the frequency of the whistling to determine the speed of rotation. Examples of this kind of playful activity, scientific enquiry for its own sake, greatly interested me. Occasionally I would explore my own sense of playfulness and come to work in medieval dress. It was surprising how quickly this felt normal. I spent a lot of time looking at the place from this perspective, trying to imagine medieval equivalents of things at the facility. A lot of this became material that I used in the final show made in response. I spent some time renovating a lute in the workshop and playing while doing observations. Again, the synthesis of the two sites felt quite natural. While sitting out on a sunny day on the observation deck waiting for the next satellite to pass overhead, it didn't seem out of place to be working out music on the lute while overlooking the castle grounds. The contemplative ambience of taking observations, and the panoramic pastoral views and soundscapes lent themselves to the activity.

As well as playfulness, another recurring theme during breaks were discussions about the local elections and the various implications of brexit. Politics was clearly something everyone there was interested in and there were many discussions along those lines. José mentioned that he was once at a conference and began a conversation with another attendee. They had claimed that they were not interested and that they

regarded science as being 'outside politics'. This was discussed with much derision amongst the team. In particular the implications of brexit on their work was very much felt. The team relies on collaborating with other satellite ranging stations across the world. The terrestrial frame of reference that these stations collectively establish is an internationally agreed measurement and so the political implications are of great significance. On several occasions while I was there contact was made with another station in Graz in Austria in order to calibrate some new equipment. On another occasion the facility received a letter from the director of the Global Geodetic Observing System based at the Smithsonian Centre for Astrophysics thanking them for their contribution to the terrestrial frame of reference. This amused Rob who said they were essentially just thanking them for doing their routine job.

As well as being aware of the importance of the political context in which they were working, they were also very aware of their historical context. Vicki shared with me some photographs documenting the installation of the telescope and dome. These were in a box full of historical photos of the site. She also told me about when Herstmonceux was the site of the Royal Observatory. She mentioned how the cobbled pathways around the castle, in lieu of lights to limit light pollution, acted as guides for the astronomers so as not to fall into the moat at night, not always successfully. She also showed me a felt hat in the shape of a truncated rugby ball, that was used by the head astronomer. He would wait in a blacked out box on wheels wearing the felt hat over his eyes to preserve night site while his assistants would set up the telescope. He would then be wheeled to the eyepiece where he would emerge, take off the hat and make his measurements. He would then go back in the box until the next observation. As well as colourful historical stories a historical awareness also had practical implications. Vicki also showed me photos of the gravimeter set up inside a church in Cornwall. The church was chosen to be a stable surface that would be likely to still be standing year on year to be able to make repeat experiments. This image stuck with me as another example of the juxtaposition of the new and ancient.

Reflecting on their position in this historical process I asked Vicki and Toby whether

they considered their work in this larger picture. I was told that they found this difficult to do because they felt they played such a tiny part in such a huge mechanism. It occurred to me that rather than the remoteness of these two perspectives, the individual and the universal making it hard to consider their part in the 'bigger picture', it was in fact their intimacy that made the two viewpoints difficult to untangle. When the type of knowledge they produce, specifically through scientific practice, is formalised and inscribed their role in its authorship seems vanishingly small. But I believe this is a result of the codification of such knowledge. What often gets communicated about scientific activity is one or the other crystallised state, either a material, technological artefact or the traces left by it, the 'hard data'. The act itself which is embodied, situated and temporal gets lost behind these traces along with the people who carry out these actions.

My experience of the lab was that it was very much a site of intra-personal interaction, culture, history and science all superimposed upon one another. It was a place where knowledge of nature was constructed using compositional constraints that were felt through the manipulation of materials, a knowledge arrived at through physical action. The procedures being carried out here are given meaning by being situated in a historical and cultural context. In subsequent work, the making of *Re-Enactment,* I tried to capture this multidimensional process by creating an image of a fictional world made up of real-world traces, by constructing material arrangements that interact with physical properties to make an unreal image. By describing and creating new cultural, social and historical artefacts routed in scientific processes I hoped to demonstrate that while science is about nature it is also *of* human action.

4.7 - Initiation

The ultimate conclusion of this residency was the work made in response to it, the piece *Re-enactment.* But perhaps a more important task during the residency itself was to try to understand my own position as an artist in this situation. Latour and Woolgar describe the difficult balance to be struck as an observer in the lab describing the two

extremes of 'total newcomer' and 'complete participant...unable to usefully communicate to his community of fellow observers' (Latour & Woolgar, 1979 p 44). My own experience in the lab moved between these two positions throughout my time there.

My expectations had initially been informed by the preceding activities, carrying out a review of similar work in this field and my involvement with *Semiconductor*. My initial anxieties as an outsider, possibly even as an irreverent interloper were to some extent matched by anxieties on the part of the scientists as to what my expectations would be of them. I felt I went from being an outsider to something like a work experience student to being a collaborator and even finding my own role for a short time at the facility. From being shown round as a visitor gradually I was allowed to participate in more and more activities. To begin with I was formally shown around and later I would see visiting students being given similar tours with similar descriptions of what they were being shown. This then progressed to being able to observe the actual day to day operations including getting involved in problem solving. There was a marked difference between having something described to me and being told how it worked, to seeing a thing break down and watching the scientists try to figure out the problem.

Being included in the social and playful activities there felt like an important step. Going for walks around the grounds, playing with the spinning tops, walking the dogs, all allowed time to speak informally with the team, particularly about things outside the facility. Another key step was being given access to more parts of the facility. I enjoyed going from being tentatively allowed in the room to being shown the laser in pieces to actually donning laser goggles and being able to experiment on the laser itself. It was only after a couple of weeks of being there that I was shown the trapdoor leading to a passage connecting the main building with the underground gravimetry lab. This granting of access also included being told about the history of the place, being given documents showing the place being built. At one point during my stay some people from the British Geological Society, who fund to the SGF came on a visit to share some developments and also see how things were going on. At the start of my stay I was told

that when they came I might have to keep a low profile and as they had only given the vaguest description of what I was doing there. By the time the visit actually came I was not only included in the meetings but I was also introduced to the BGS as artist in residence and asked to describe what I was doing.

Throughout this time my own position as an outsider conferred particular advantages. I was lucky in that I was able to work across the various roles spending time with each team member and learning about their specific specialism. Having begun by stressing that I wasn't sure of the exact outcome on the advice from *Semiconductor* I was free from constraining expectations. In a similar way I also didn't have any expectations on what the scientists there were going to do. This meant that my activities could evolve naturally and remain responsive to the circumstances. Initially I was anxious about how this process would pan out, but in the end it became one of the most enjoyable things about it. It felt like rather than imposing myself on the situation the experience was jointly navigated with the site and people there. It allowed me the freedom to reflect on the space from multiple angles, reflecting on my own work but also reflecting something of the work of the scientists back to themselves.

My involvement in the day-to-day operations developed over the time I was there. Starting with being given simple tasks such as oiling the shutters on the telescope domes. I was given a space to work in a conference room and I was left to do my own thing when I needed to edit film or work on my computer. Gradually I was allowed to participate in more work, firstly with the routine observations, I was shown how to make satellite ranging observations and with a tentative finger on the emergency off switch I was allowed to operate the laser. I was then shown more specialised operations when Vicki allowed me to set up the gravimeters and take measurements. This then progressed to being involved in one off experiments such as determining the efficacy of new polarising filters in the laser. I was then able to not only assist in experiments but also to contribute when I was able to use my light to sound device to make measurements of the beam during this procedure. Finally I was able to develop my own experiments looking at the possibility of using microphone arrays to detect low

flying planes over the facility. Eventually this culminated in setting up my own 'satellite ranging facility' combining elements of re-enactment both of real and fictional historical accounts, as well as of the experience I had at the SGF. This final step was important in tracing a trajectory of the experience. In being allowed 'further in' to the facility and its operations, to understand the physics being investigated, this momentum carried until I was going 'further out' into work pertaining to a fictional place and time into the 'pataphysical, science of imaginary solutions (Jarry 1911).

This residency has revealed through its incongruities, thwarting of expectations and playfulness, that even a place of 'normal science' carrying out routine operations must undergo interesting metaphysical, sometimes contradictory contortions to function. To determine universal measurements upon which other earth science will be based, it takes a vantage point off the earth. At the same time it is rooted in and forms the same landscape it measures. In its measurements of time it must operate at scales that defy ordinary experience, to the point at which accuracy becomes difficult to talk about. The people who work here adhere to cycles of time that run out of phase, in syncopation with ordinary hours of the people around them. Their work is at scales that are difficult to comprehend, machines that measure down to the wavelength of light or many kilometres into space, and yet at their root these measurements are made by hand and read with the eye. These solid tools are made by hand alongside constructed conceptual models that act as solid points against which reality is measured. In all the serious business of making objective measurement they are acutely aware and bear the traces of the historical and political culture they are operating in. Their working life includes a great deal of playfulness, socialising, storytelling, cooking, music and during this residency even the inclusion of artists.

From my own perspective I didn't expect to be so warmly welcomed and have my own activities so included in the place. To return to Woolgar and Latour's spectrum from newcomer to participant, I would like to propose a further extreme to the scale - that of the 'initiate'. In *Re-enactment* I likened the SGF to a kind of monastery, where the scientists were using 'occult means to communicate with celestial bodies'. To borrow

from the language of monasteries, this move from newcomer to participant is referred to as the transition from 'postulant' to 'initiate'. While initiate here means to be included into a society, its etymology also suggests another meaning – to bring about. It suggests more than simply being included into a society but also to play an active role in forming it. The people at the SGF did more than just allow an artist to participate, but actually enabled them to form new activities entirely. In my time there I was able to create my own experiments in the lab, borrowing their expertise and bringing in my own. For a short time, the SGF included in its operations the creation of new artworks. This realisation was acutely felt when Rob was introducing a new work experience student to the members of the team and casually included me in the roll call as artist in residence.

If the role of the scientist in the lab is to inscribe, then perhaps the active role of the artist in the lab is to transcribe. As has already been shown in previous chapters, the artist is often seen as a communicator between cultures, and this communication involves a degree of translation. Just as the act of inscription (to misapply a law of physics) is an action that produces an equal and opposite reaction upon the scribe, so too must transcription obey a similar law. The act of transcription must also have an effect on the script. The artist in residence not only passively reflects the situation they are in, but attempts to transmute it, to initiate new realities.

Fig 17. Heralding the telescope

CHAPTER 5

DOING KNOWLEDGE – EXPERIMENT AND PRACTICE

The practical work presented here was completed during the period of research in two main parts. The first part involved the creation of several pieces of experimental apparatus relating to gravity science. These were tested in a scratch performance as part of experimental music night *Spiel2* in 2018, and then developed into a full show presented at the British Science Festival 2018. After this followed a period of fieldwork in the form of an artist residency at the SGF Herstmonceux. Here further experimental apparatus were created, and this was organised into another performance showcased at several venues. Rather than organise the work by this chronology, instead it is presented here along the lines of the key themes explored in the work which are then expanded upon in the following chapter.

The performance work presented here is devised through the creation of 'performance objects'. As has been already described, these consist of physical objects used to provoke performance. They might take the form of musical instruments, devices for producing visual effects, kinetic sculpture and scientific apparatus. This facet of the work comes out of my ongoing practice of making instruments to perform with. These have included in the past home-made analogue synthesisers and electronics, digital systems and acoustic instruments that I have used with groups such as *Laboratoro*[33] [34] [35]*Champagne Dub*[36] and *Chop Chop* [37]. It also draws on my experiences performing in a theatre context particularly the site specific work undertaken with Catherine Ireton, in shows such as *For All The Fires Not Yet Lit* (2017) *In Good Hands* (2016), and *What Is It About That Night?* (2014) where I was required to make musical devices that operated in unexpected ways.

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[33] Briggs. E, & De Toro, X *Simulations* 2015 https://vimeo.com/144664687

[34] Briggs. E, & De Toro, X *Live at Real Music Club* 2013 https://www.youtube.com/watch?v=bLtaeZ0ifIQ

[35] Briggs. E, & De Toro, X *Live at Hundred Years Gallery* *https://www.youtube.com/watch?v=zJkgFhAYsnk*

[36] https://champagnedub.bandcamp.com/album/drops

[37] *Chop Chop live at MOTH club,* London *https://www.youtube.com/watch?v=I3fumW0sJpA*

This interest in electronic, acoustic and mechanical devices has had a direct influence on the work presented here. Since 2012 I have shared a studio with three other artists in the Phoenix Art Space, Brighton. This has given me access to a vibrant community of artists from a wide range of backgrounds including film, painting, sound, engineering, plastic arts, and performance. Working in this context has been an invaluable resource for my practice as a whole. Being able to discuss ideas with other artists, and particularly being able to exchange skills and ideas has meant that no piece of technology feels out of reach, at least in principle.

Fig 18. Briggs, E. *Island Man* Performance at Hundred Years Gallery, London 2016

5.1 - Making performance objects

These performance objects are documented alongside this project and should to a certain extent speak for themselves. A summary of these pieces is made here with a brief explanation of their development for context.

5.1.1 - 1 Second Drop Tower

A piece of scientific apparatus normally used to do zero gravity experiments on earth. Here my own portable version is put to use to choreograph various objects in a zero gravity environment. It was put to use in various contexts including to make a series of short films, and as a live performance object in the show *Weighing Almost Nothing.*

The piece began by observing the weightless moment of a pile of coins in my hand while jumping. I began to wonder if this could be captured on film and made a series of experiments involving jumping with a camera attached to my arm and filming with a blank background to eradicate the perspective of downwards motion. This then progressed to filming inside a sealed box. At the same time I had been working on a theatre show which involved using a 'crash box' a sealed box full of broken crockery which could be smashed behind stage to create a sound effect. I spent some time recording dozens of crashes and then editing together the sound of crockery in mid air in a sustained weightless moment. Following these experiments I built the drop tower itself, with a set of pulleys and guide ropes to keep the box straight. I wanted to affect the objects inside the box and so developed a series of apparatus to spray water or to flick or let go of objects and so on. These used nylon threads running through the box to determine when to actuate the movement at the precise moment of weightlessness. It was only after I had built the apparatus that I found out that it is in fact already used to research how things will behave in a low gravity environment before being sent into space.

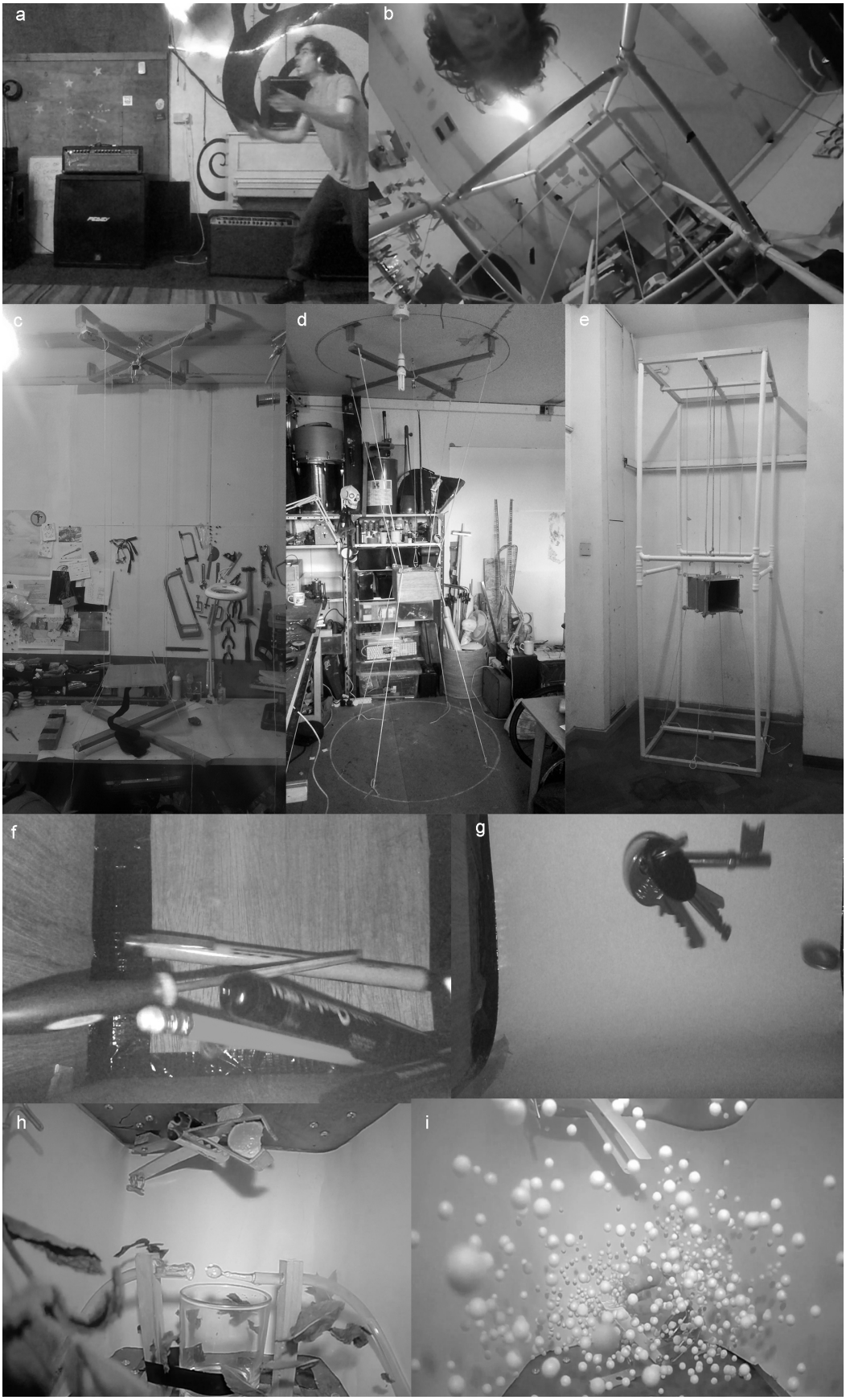


Fig 19. Drop Tower development – a) Crash box recording. b) Loading box. C-e) Development of tower. f-g) Initial experiments. h) Making a cocktail in zero G I) Experiment visualising rotation of drop path

5.1.2 - Clinostat

A musical instrument used to grow plants in a simulated weightless environment. Closely related to bagpipes, hurdy gurdys and other drone instruments, a pair of counter rotating platforms create shifting harmonically rich patterns. The resultant weightlessly grown pea-shoots are then sampled using a specially made device for simulating dinner in space.

The clinostat came about after researching gravity experiments that could be done on earth. I was interested in the very terrestrial act of growing crops being re-contextualised in space. When programming the arduino to run the servos I managed to find some code that was originally meant for stepper motors. As a result the servos ran in a very noisy way. Rather than try to eradicate this I added pickups to amplify the sound and used it for a while as a drone instrument in a number of performances, the visual element adding to the way the sound was modulated by the rotating platforms. This then led to speculating how sound might be further used in its design. The harmonic relationship between the two servos could be visualised in a similar manner to an oscilloscope using long exposure photography and this was used to determine the most efficient way to overcome the gravitropic effect in the plants that were subsequently grown on it.

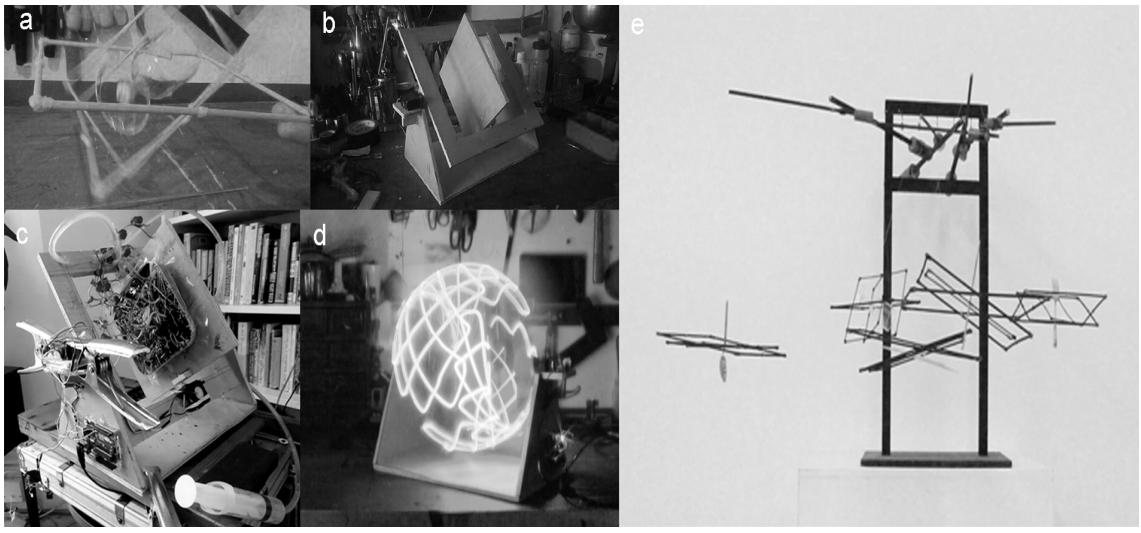
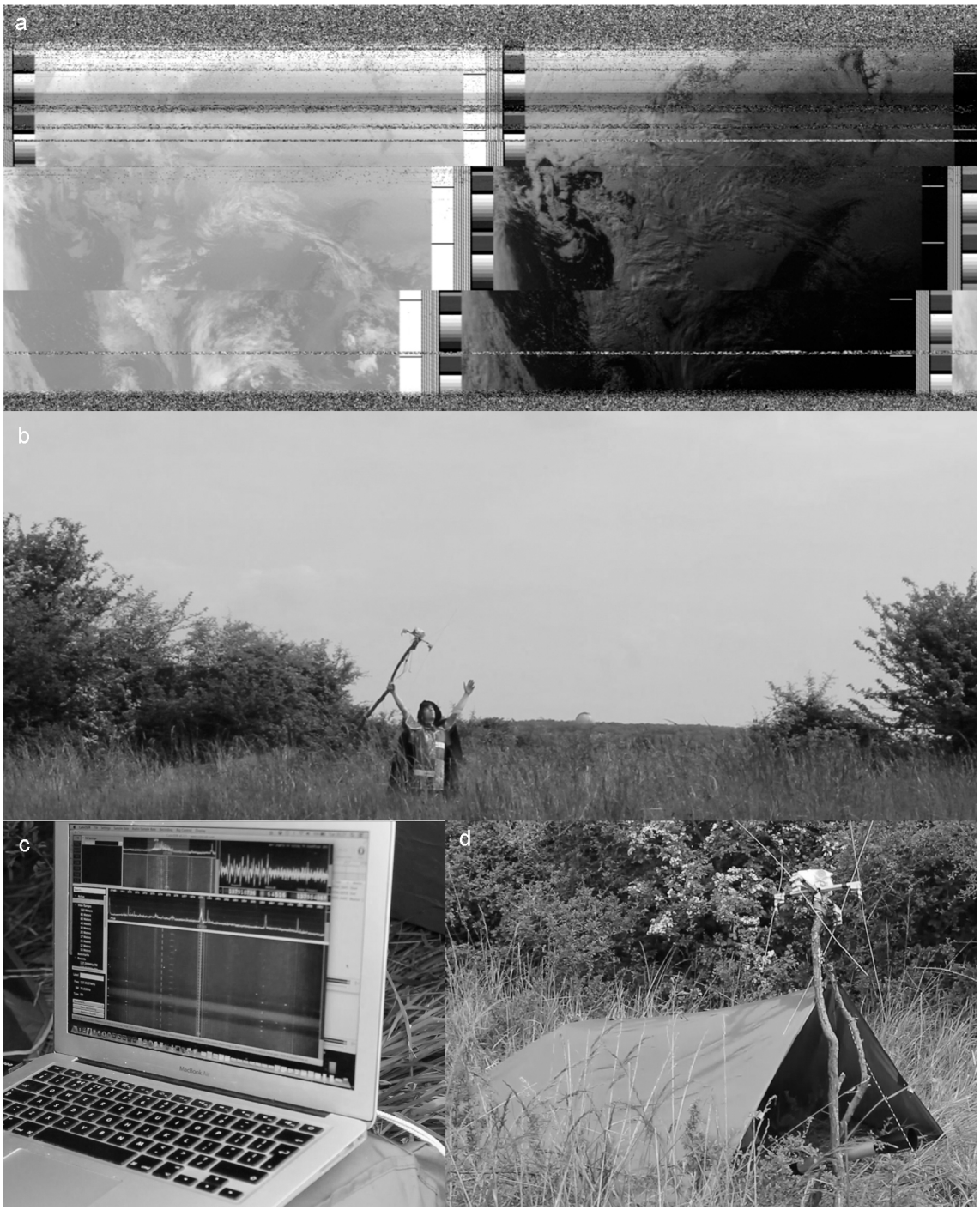


Fig 20. Clinostat Development. a) Original gimble mechanism. b) Amplified rotating platforms. c) Growing weightless peas. d) Recording the flight path. e) Pea shoot eating apparatus

5.1.3 - Satellite Ranging Hovel

A site specific work involving the creation of a satellite laser ranging station in the form of a hermitage out on Pevensey Marsh. I spent several days in character as a goliard living at the station and carrying out satellite science, including communicating with NOAA weather satellites and re-enacting visions of angels.

Fig 21. Satellite Ranging Hovel. a) Downloaded image from NOAA18 weather satellite. b) Re-enacting.



c) Receiving signal from NOAA18. d) Hovel and antenna.

5.1.4 - Interferometer

A Michelson Interferometer coupled to a sound making device that renders nanometer scale displacements of two mirrors into sound resulting in a microscope seismometer. The resultant sound immediately interferes with its own operation creating a feedback loop which is affected by macro scale phenomena.

Creating the interference patterns with a cheap laser and observing the wave like nature of light was something I had long wanted to do and so the experiment initially started as an optical one. My time at the SGF had sparked an interest in the idea of creating very accurate machines by hand, and the way in which human scale movement could be related to scales not visible to the human eye. The interferometer then was used as a kind of 'de-amplifier' to shrink human scale hand made mechanisms into the realm of the nanometer scale phenomena. This process was then further zoomed in on by adding a light to sound mechanism. As a visible phenomena the apparatus allows the operator to observe deflections of the mirror on the order of the wavelength of the light being used. By adding this sound mechanism deflections even smaller than a single wavelength are possible to observe. This playing with extreme scales was then thwarted by the object being affected by its own sound. I was interested in its ability to allow a simultaneous experience of the microscopic with the macroscopic.

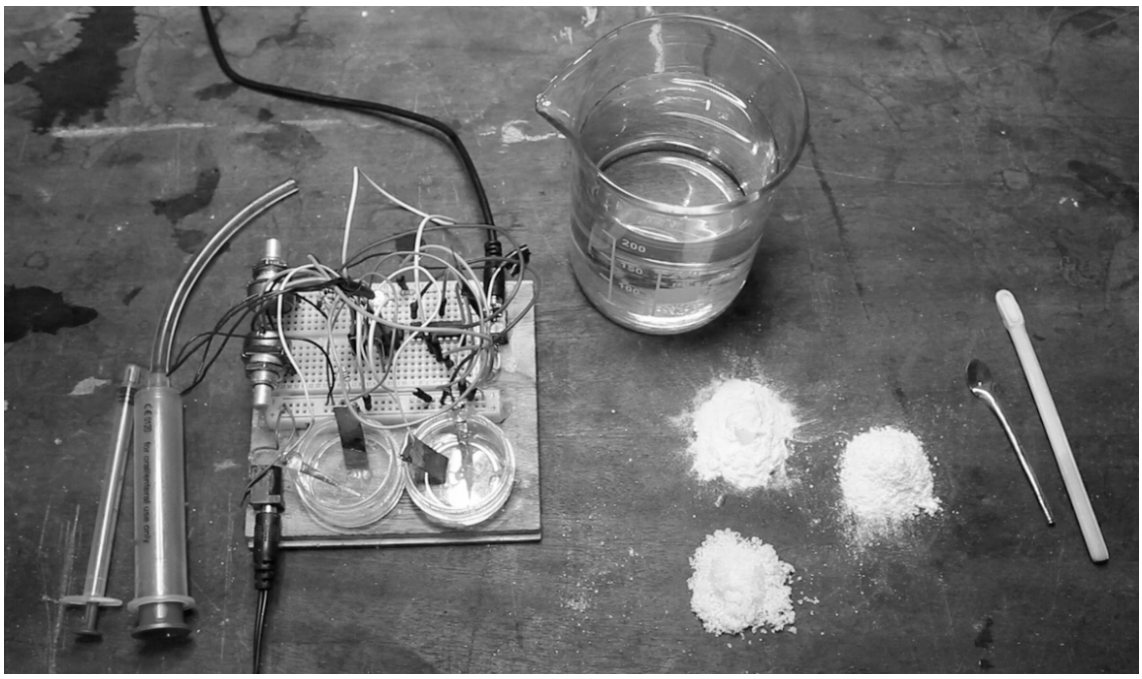
Fig 22. Initial tabletop interferometer experiment.

5.1.5 - Chemical Synth

A synthesiser controlled by chemical processes. The instrument works by constricting musical gesture to the action of stirring chemicals with tiny spoons. These processes 'uncontrol' the synthesizer's output.

This piece began when I needed some capacitors of a certain value and began looking into how to make them by hand. I had tried various methods including foil separated by a dielectric and the method of using liquid in a similar fashion. In the course of experimenting with various dielectrics in water I found that certain chemicals would result in the pot becoming more or less resistant, and holding a charge more or less effectively. I came up with the idea of trying to make a circuit whose architecture would change depending on the properties of the components being used, rather than simply changing the value of a fixed component, having a component change function as it transformed from a capacitor to a resistor. In doing so I came across some simple ways of creating oscillators using Schmitt triggers. Since creating this example I have experimented with a number of 'flexible' circuits like this.

Fig 23. Chemical Synth



5.1.6 - Mirror Signalling

A device for re-enacting holy visions. The piece uses signal mirrors transmitting sunlight several kilometres which is then picked up by a light to sound sensor. The result is a bright star in the landscape speaking in an incomprehensible language.

The initial experiment came after reading about Alexander Graham Bell's experiments with photo-phonic materials, materials that emit sound when they are subject to a changing light source. I was most struck by his account of the experiment which was presented to the Royal Society and printed in its proceedings (Bell 1881). The account stands out, with its anecdotes and tangents, as something quite different to a scientific paper. I decided to recreate the experiment first by building a mirror reflector and an electronic circuit to demodulate the light into sound. Initially I modulated the light by attaching a speaker to the mirror. During the experiment I received a phone call which I took while continuing to fire the light at the sensor some two kilometres away. When I got back to the recording I was surprised to find it had picked up my voice in the air. The angle of deflection of the sunlight becomes so great over a long distance that the tiniest movement of the mirror is amplified thousands of times. Doing this experiment on my own led me to think about the idea of communicating with a distant voice, and the difficulty of communicating with yourself and expecting to hear something you don't already know.

Fig 24. A small pony intervenes in the experiment.

Fig 25. Mirror Signalling development. a) Signal being sent. b) Mirror transmitter. c) Mirror receiver. d) Target flag

5.1.7 - Looking at Paintings

A device for playing paintings like records. Paintings are spun on two turntables making them harder to see and read with a variety of sensors. The resultant sound is then interpreted by a specially trained scientist using a variety of wind and percussion instruments. The device is also used to create paintings by enticing artists into the process.

I was asked by artist Ian Boutell who I shared a studio with, if I would come up with

something to perform at the opening of their exhibition *Hard Painting.* His piece *Tondo* had been hanging on the studio wall for some time and it reminded me of the modified records made by sound artist Graham Dunning (2009-present). I decided to find a way to spin the piece and read it using light sensors attached to various simple synthesizer circuits. Over time I developed a number of ways of reading the painting, including using light dependent resistors and LEDs and re-using the light sensor used for *Mirror Signalling.* The piece took on a number of iterations including being used for a workshop as part of the Brighton Science Festival where young people were invited to draw things to put on the turntable. This was a particularly useful developmental stage where I had the opportunity to see how people perceived the operation of the work. Similarly after a performance at the opening of the *Open House Exhibition festival launch 2018,* I had the chance to discuss the piece with the audience. In both cases the many misconceptions of what it might be doing were useful in designing further versions of the piece. For example, someone making the analogy of a record stylus inspired the development of a 'record paintbrush' which amplified vibrations of a brush in physical contact with the painting.

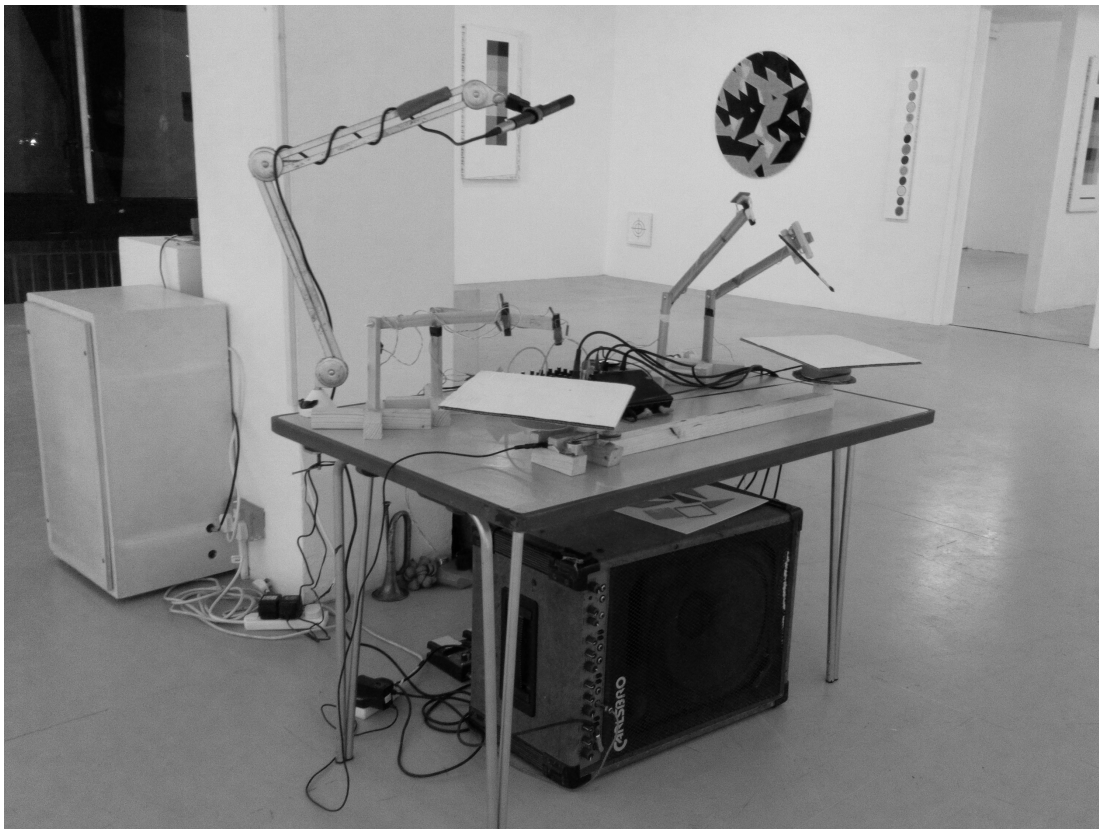


Fig 26. Looking at Paintings turntable and painting reading tools.

5.1.8 - Gravity Sword

The Gravity Sword is a pendulum able to measure gravity extremely precisely. It consists of a sword balanced on two perfectly straight edges made of agate crystal, which swings in a special frame. It is coupled wirelessly using a light source and a carefully smoked pane of glass to a synthesizer which allows measurement of its frequency and the tiniest movement of the apparatus. The sword was enchanted at the Gravimetry lab in Herstmonceux by measuring its length very accurately using the acceleration of gravity as measured by the facility's absolute gravimeter. With this known measurement the sword was then able to measure gravity in any other location.

These pieces often involve hand made processes and workarounds to make up for a lack of precision tools or certain materials, lending a particular DIY aesthetic to the work. Taking inspiration from Annie Carpenter this is played upon to stand in contrast to the high tech usually employed in such work, where often some piece of scientific equipment is presented as dazzlingly opaque and the technology becomes a 'black box' (Latour 1999) producing some magical effect. Here, in contrast, the technology is made in such a way as to make its workings as open as possible. This can also allow for a kind of misdirection where expected effects are subverted and mechanisms are made to perform in unexpected ways.

During the making of these objects sometimes great lengths would have to be gone to in order to work around problems of manufacture. Frequently the making of some part would require the making of something else first, and it would then turn out that making that preliminary part would require making something else before it and so on. In some cases, this would modify the intention of the piece. This would mean sometimes huge effort would be expended to produce apparently minimal gains, and this process was played upon as a humorous aspect of the work. As Jake Evans writes of the *1 Second Drop Tower* in the art review of the *The Verse,* Brighton University's newspaper, 'It is surely no coincidence it resembles a cardboard box: the magic transporter to mystical lands; a shiny sports car; a den.'[38]

[38] http://theverse.co.uk/all/art-review-spotlight-ed-briggs-suzanne-ohaire-phoenix-12-03-18/ accessed 19/03/18

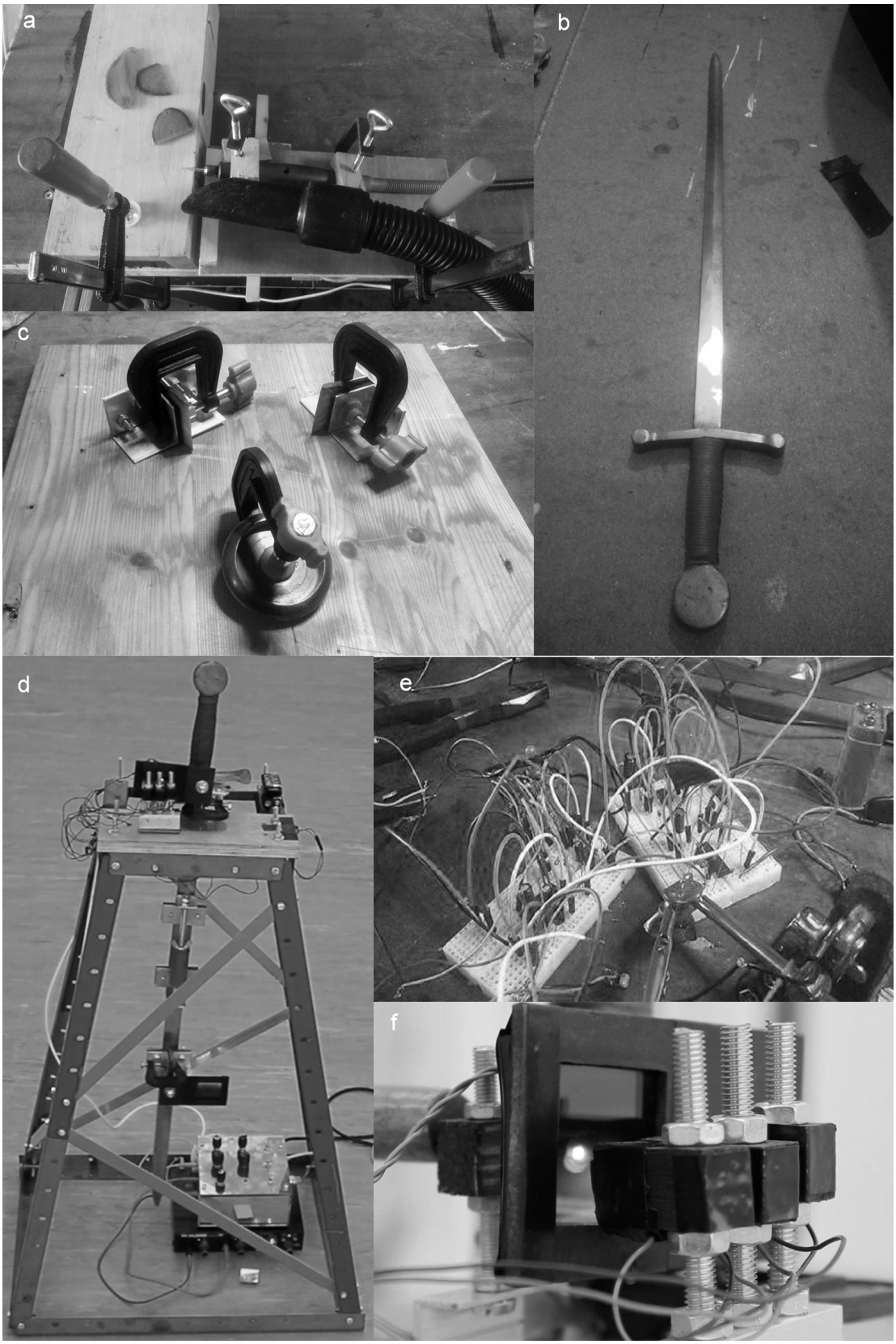


Fig 27. Gravity Sword. a) Agate edge grinding apparatus. b) Unenchanted Sword. c) Fulcra and weight d) Gravity Sword set up. e) Breadboarding synth. f) Smoked glass opto-coupling.

Fig 28. Enchanting the Gravity Sword in the Gravimetry lab

5.2 - Performing the performance objects

There are two main performances included in this body of work, a performance of experiments relating to gravity called *Weighing Almost Nothing* performed first of all at an experimental music night *Speil2* in the form of a scratch performance and then developed into a full show for the British Science Festival 2018. The second performance, *Re-enactment* was made in response to my time at the SGF and was also performed in various contexts including a music event *Ceremonial Laptop*, a theatrical setting *New Grounds* at the Old Market Theatre and also at an academic conference *Faking It* at the University of Sussex.

5.2.1 - Weighing Almost Nothing

This piece began with a semi-fictional anecdote about confusing early romantic stirrings as a child with the feeling felt when going over bridges in a car. Reflecting on

this link between emotion and bodily sensation led me to think about the link between emotion and physical processes in general. Physics, seemingly the most abstract and 'pure' of the natural sciences, is of course rooted in the physical realm with all its messy incongruities. The idea of trying to reconcile the chaotic and subjective realm of personal experience with the abstract and idealised realm of physics laid the basis for the show *Weighing Almost Nothing.*

Nahum Romero Zamora's piece *Matters of Gravity* (2015)[39] in which he led an expedition of artists onboard a parabolic weightless flight to perform art experiments was another starting point for this work. I discussed this piece with the artist who described his intention to explore the difficulty of hugging in zero gravity. He described how during the process he was overcome with 'weightlessness sickness'.Here, not only does the chaotic nature of actual physical experience interfere with idealised abstract notions of physics, but also with similarly idealised abstract notions of emotional experience. The fiction of an act, the performing of actions with a particular intention, versus the actual reality of this happening in a room with people subject to all manner of unrelated influences, and with physical objects subject to all the various conditions they are in in that moment illustrates this dynamic between abstract idea and reality.

Fig 29. Still from *Live Gravity Experiments,* scratch performance developing *Weighing Almost Nothing*

[39] https://www.artscatalyst.org/news/matters-gravity accessed 26/07/21

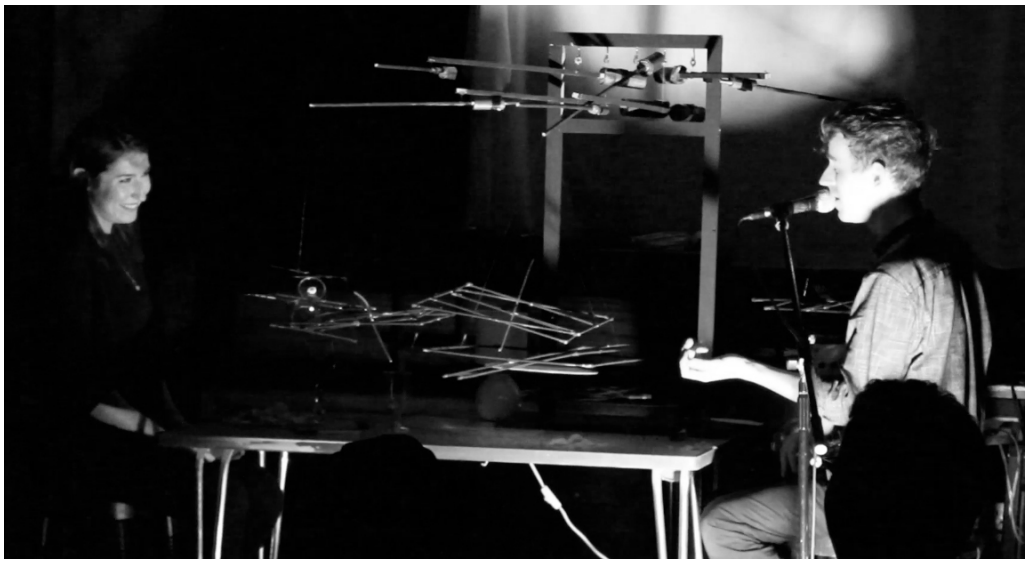


Fig 30. Still from *Weighing Almost Nothing*

5.2.2 - Re-Enactment

Re-Enactment was made after my residency at the SGF using footage from the experience. I had spent time at Herstmonceux first of all filming for part of an experiment in *Weighing Almost Nothing* and then during my time working in residency. In this time I did a lot of filming with only a vague idea of the possible outcomes in mind, mostly of the operations taking place there as well as the landscape around the facility, keeping an eye out for things that could be taken out of context or reframed.

For this piece I was interested in the idea of reportage, of making a documentary that walked a fine line between fact and fiction. The aim was to explore the idea that re-enactment is somehow at the same time 'more real' and 'more fake' than other forms of documentary. More real than a historical artefact because it is situating it in a live experience, more fake because it is a theatrical fiction.

The performance explores this ambiguity and the way the piece was scripted played with this notion. I spoke with stand up comedians Victoria Melody and performance duo Action Hero about how to do this. In the end I would aim to have certain 'checkpoints', gags or lines that were word for word scripted or had to be delivered in a very particular way. In between these was a general aim which I would follow while being responsive

to the audience in the moment. There were many parallels with how I had performed in improvisatory music groups, where there might be guiding principles, particular themes and motifs to arrive at, and material constraints to work off against to give the performance structure.

5.2.3 - Other performances

As well as these two main performances the technology was tested and developed further in a number of other events. These included an exhibition opening *Hard Painting* at Phoenix Gallery Brighton, the Open House Festival launch 2018, during an artist residency at the Rose Hill Arts Centre, as part of the public art project *Manmade* organised by Boca2Mouth at Onca gallery and the Spire, in public workshops for the Brighton Science Festival and finally during music performances with the band *Champagne Dub* in gigs at Folklore in Shoreditch and The Vortex Jazz club in Dalston. All of these events meant that the practical work for this project was developed in a live public setting and tested 'in the field' in front of an audience. These shows were used as an opportunity to demonstrate scientific principles through the re-enactment and re-imagining of scientific experiments in a staged context, participating in a rich tradition of performing experiments in a public forum.

Fig 31. Playing the 'Table Synth' and 'Laser Pipes' with free improv group *Champagne Dub.*

The pieces *Weighing Almost Nothing* and *Re-enactment* necessitated the creation of much additional work in order to provide context and present the various technologies presented in them. The formation of narratives, the creation of documentary film work and the staging of the shows themselves all constitute a significant body of work in themselves, adding to the DIY nature of the project. From lighting design to stitching costumes, everything was done with the ethos of 'going the long way round'. Both shows were scored throughout with a soundtrack entirely produced by a homemade analogue synthesizer. This involved the creation of medieval style music in which the synth was used as a hurdy gurdy[40], covers of well known tunes[41], arrangements of classical music[42], original composition and sound effects, all performed live throughout the show. The idea of 'going the long way round' was put to use literally during filming for *Mirror Signalling* where I would set up a camera and then travel to a point in the far distance of the shot to aim the mirror back at the sensor.

Part of the effect of the shows was that there was almost too much to do at once, so that the frantic attempt to keep on top of it all itself acted as a form of constraint to work off against. The stage would be crowded with apparatus so that pieces would physically impinge on one another. Their precarious nature was used to add tension to the performance with pieces working in unexpected ways or even occasionally failing to work at all.

In these performances various techniques were employed as disruptions to the idea of the science demonstration. These included for example creating an ambiguity around the origin of the tools being presented. Sometimes novel or invented techniques are spoken about as if they are common knowledge to the audience, things that are clearly inventions are referred to as commonplace items. The specific function of tools are questioned, for example they are presented as musical instruments which then

[40] The instrument in fact has many parallels with the hurdy gurdy in that it has the significant limitation of only having two oscillators, the equivalent of two strings, which are being continuosly voiced so that phrases have to be articulated by using 'crans' a technique used in bagpipes.

[41] Described in the show as a 'simulation' of music.

[42] In one perfromance the synth was used to play a Bach cello suite at 'record breaking' speed during a fast experiment, to be later revealed when live footage of the experiment was played back in slow motion.

produce visual effects rather than sound or become experimental apparatus for some other purpose entirely. Documentary footage is presented with fictitious explanation, historical processes are positioned anachronistically, fiction is frequently conflated with fact. Some mechanisms of operation are made opaque and others are unexpectedly exposed. An audience member at a performance at *Ceremonial Laptop* commented that 'there is absolutely no way of knowing which corner you're about to turn next'. The intention is to draw the audience's attention to some specific detail only to reveal it as something else.

Fig 32. Discussing *Looking at Paintings* with audience at The Old Market Theatre

5.3 – A taxonomy of creative resistances

We now come to the idea that the body of work presented here is used to develop a set of tools with more general application. The physical objects presented here will doubtlessly be deconstructed, recontextualised, atomised and reconfigured by the time the work is published. Taking a cue from Paulo De Assis the works as a whole might be regarded as '*multiplicities*, as complex conglomerates of *things* and *intensities*, containing innumerable and potentially never-ending components, which are continuously rearranged and reassembled in their specific modes of appearance throughout history' (De Assis 2018).

The enduring outcome of this work is instead the derivation of a series of principles that others might use in the future. These are the strategies developed by the project, and they take the form of a series of tools or techniques that were identified by reflecting on the creation of this work. This consitutes the 'toolkit' that illustrates the types of creative resistance at play in the performance of scientific objects.

5.3.1 – Making Backwards

The construction of these pieces involves a technique I call 'making backwards'. This is the process whereby to make a given object or to produce a particular effect some previous object or effect is required. This then in turn might require further preliminary stages which in turn require their own preliminary stages and so on. Artist and designer Thomas Thwaites demonstrated this principle excellently in his piece *The Toaster Project* (2011) where he attempted to build a toaster from scratch using pre-industrial techniques revealing the vast number of antecedent tasks required to achieve an apparently simple task. Leonard E. Read's essay *I, Pencil* (1958) which tells the story from the point of view of a pencil of the extraordinary number of processes involved in its production also demonstrates this idea, suggesting that tracing the chain of production of a given object stretches back indefinitely.

The *1 Second Drop Tower* was initially conceived after observing a handful of coins tumbling in the palm of my hand as it was moved rapidly down. To capture this I

needed to build a structure to hold both a camera and the coins so they could fall together. This in turn required another structure to control its fall with a system of pulleys. To make this I built a lathe to turn the pulley wheels. To make the lathe I modified a clutch motor from an industrial sewing machine and so on.

Each 'preceding' process in turn modifies the later stages. The normal order of production is disrupted by a kind of looping back on itself. The piece *Gravity Sword* in particular played with this idea. The piece is based on an 19th century experiment devised by Henry Kater to establish local acceleration of gravity using a pendulum. Kater's invention allowed people to precisely calculate the length of the pendulum between two crucial points, the pivot and the pendulum's centre of oscillation. Once these values, length and frequency, are known to a sufficient degree of accuracy then gravity can be calculated wherever the pendulum is swung. To further play on the idea of disrupting the order of production, the making backwards of the pendulum included several interesting anachronistic processes. I decided to make it using a replica medieval arming sword. The precession of techniques used to create the tools (that created the tools etc) to make the piece were drawn from a variety of different centuries. For example, the pendulum swings on two pivots made from a straight edge of agate stone. The perfectly straight edge was achieved using techniques borrowed from 17th century lens grinders, which in turn required the making of a lap-stone. The pendulum also used a pane of glass smoked with lamp black to create a graduated light filter, a technique borrowed from Alexander Graham Bell's experiments with photo-phonic materials (Bell 1881), which in turn necessitated the manufacture of a simple paraffin lamp. Analogue synthesis techniques were employed using circuits developed in the late 20th century[43]. The sword itself was given a hilt made using the medieval process of *cuir-bouilli* and so on.

In another example of 'making backwards' the construction of the gravity sword involved an inversion of the equation for measuring gravity using a pendulum. Having established the pivot and point of oscillation and set the agate edges accordingly,

[43] Based on designs from Forrest Mims' fantastic hand drawn and very DIY book *Optoelectronic Circuits* (1986) Radio Shack.

measuring between these two points to a satisfactory degree of precision proved very difficult. It occurred to me that if I took the pendulum to the gravimetry lab at the SGF I would be able to use their incredibly accurate measurement of g and my own measurement of the sword's frequency to solve the equation to determine the length of the sword. This idea of using their gravimetry lab as an incredibly complicated and expensive ruler amused the scientists working there and I was very kindly allowed to perform a vigil with the sword to make the measurements. When demonstrating it on stage I explained that the SGF had enchanted the sword to allow it to make this miraculous measurement, with which it could detect gold and other heavy metals, as well as discover caverns beneath the earth. While the description of the sword's enchantment is fantastical, it is also in a scientific sense strictly true.

Making Backwards then is a process of resistance to the normally teleological process of designing and building something. After my time with *Millimetre* I learned that designers and fabricators very often have to use this process of iterative problem solving, where the course of producing something might be likened to a stream of eddies and countercurrents. Here this process is allowed to double back indefinitely so that the very impetus for creating something is shifted in the process.

5.3.2 – Fictional Re-enactment

...the angel depicted is like nothing on earth. (Hacking 1983, p138)

Another form of 'temporal resistance' which is applied to the theoretical basis and origins of the apparatus presented here is the idea of 'Fictional Re-enactment'. This is also demonstrated through the production of the *Gravity Sword.* For example, in speaking to the sword-smiths at the re-enactment I discovered that much of the knowledge needed to build a Katers pendulum existed in the middle ages. It was understood that the point of oscillation was interchangeable with the pivot point of a sword, for as these two points represent harmonic nodes of the object they are the two most efficient points on a sword to transfer the maximum amount of energy to a target, namely where the hilt meets the blade (pivot) and a corresponding point on the blade

(point of oscillation). When I joke in my interview with the sword-smith 'this is the bit that does the cutting?' he understands I am referring to this point and demonstrates it by striking the sword revealing the primary node of vibration. This knowledge along with other knowledge such as timing using points of co-incidence were known to medieval people, the only thing lacking being the concept of gravity itself.

The premise for the performance *Re-Enactment* is itself an example of this technique. The piece consists of a documentary report on my time spent at the SGF. Throughout the piece footage is shown of various activities taking place. The central joke of the piece is that I have confused the activities at the SGF with the activities of the re-enactors at the castle, and so throughout I try to explain what is being shown on screen in terms of a re-enactment. Throughout the piece an inappropriate frame of reference is applied to the documenting of the SGF and in doing so the actual frame of reference is highlighted. A viewer being told that the function of the telescope dome is to guard against arrows knows that this isn't the case, and so they are invited to speculate as to what the actual function is. The SGF was described as a sort of monastery, the inhabitants of which spent their time sending and receiving messages between celestial beings, using manufactured 'holy light'.

During my time creating *Re-Enactment* I decided to develop the idea of fictional re-enactment further by setting up the *Satellite Ranging Hovel*. To do this I found a remote area on the marsh about two miles from the castle. I decided to create a character that I would reference in the show. Initialy loosely based on the idea of the 'shepherd scholar' John Dudeney of Sussex, I imagined an itinerant monk working as an outpost of the 'SGF monastery'. I spent several days camped out with a telescope, computer, a software defined radio and several homemade antenna, spending the time in character. It was a curious thing to re-enact on my own, shifting the focus from one of demonstration to introspective insight and ths is a practice I plan to explore and develop further in the future. During this time I intercepted NOAA weather satellites, downloading several images, one of which was used in the show. I also tracked visible satellites with my telescope, did some astrophotography and worked on the lute. In

between satellite tracking I used this time to read Helen Waddell's *The Wandering Scholars* (1927) which documented a class of monk, who occupied a niche somewhere between scholar and travelling entertainers, and who satirised the customs and ceremonies of the church with plays and latin lyrical comic verse. This was used to create a fictional character to be presented in *Re-Enactment.* The fictional nature of this re-enactment was given an extra strange dimension as I learned that the activities of the goliards were very similar to my own activities.

I also present some fictional medieval technology in the show, claiming that the *Mirror Signalling* was used to reproduce the effect of seeing/hearing angels so that scholars could research the phenomena by directly experiencing them. I explain that during my re-enactment I tested this technology and that it had a profound effect on me, almost as if I had actually seen an angel. In the show I explain that instead of showing the documentation of this experience I will convey it to the audience in a re-enactment of my experiment, and so I set up a scene where I have my experimental equipment ready on stage, I get into costume and project an image of the scenery in which the experiment takes place.

The joke is that the piece becomes a re-enactment (happening during the show) of a re-enactment (my re-enacting being a medieval scholar) of a re-enactment (medieval scholars re-enacting holy visions). It is suggested that shot through this nesting of re-enactment the effect of experiencing having a 'real vision' is preserved. The (fictional) medieval scholars 'actually felt' they were seeing an angel, which I actually felt when re-enacting this and tried to convey this feeling to the audience.

At the same time the experiment really *is* a re-enactment of an experiment carried out by Alexander Graham Bell in 1881 to try and come up with a method of transmitting sound using light but this original experiment is never mentioned. There is a further nesting, in that at the same time as being presented as a 'medieval research method' the activity really *is* research by being part of this project. In a sense the 'reality' of the research is projected backwards through time. Something that never really happened *then,* but it happened *then now.*

5.3.3 Instrument first composition

The technique of 'instrument first composition' involves using a piece of technology to construct compositional constraints to provoke performance in the form of structured improvisation of musical, visual or kinetic outputs. It stands in contrast to the idea of designing such a performance object with a specific outcome in mind. It is important to clarify that 'composition' in this case does not mean an event that happens 'before' the performance of the work, but instead refers to a process of constrained improvisation, a kind of composition in real time. This is where the performance object is designed to exert a form of resistance back onto the performer.

In the technique I have previously mentioned, 'making backwards' the design process itself involves this reflexive feedback, where constraints encountered during making these objects are allowed to modify the end output, and this process as a whole is presented in the final demonstration. Here I will explain this process in terms of their actual use and performance. In the pieces presented here, through the concept of 'instrument first composition' I suggest a complex interaction of constraints is used to produce the output of the performance objects. By 'pushing against' them something unexpected is created that emerges as a hybrid between the performer's intention, the materiality of the instrument and the environment it is in.

An example is with *Chemical Synth* whereby musical gesture is impeded by the fact that changes must be brought about through chemical processes. Sound can only be changed by causing various chemical reactions to occur. Not only do these processes require manual dexterity to carry out but they also take time to happen and depend on other factors such as ambient humidity and temperature. The impossibility of measuring chemicals accurately also means there is a great deal of unpredictability. The output of the instrument is abstracted from any gestural input. The audience is invited to speculate as to the relationship between the process of adding chemicals together and the sound they can hear. Instead of the usual gestural cues their attention is drawn to the performer carrying out the more abstract activity of mixing unidentified chemicals.

This instrument was used in several live improvisatory performances, first of all with guitarist Lee Westwood at an artist's residency at the Rose Hill Arts Centre in December 2018, and then at various performances with improv group *Champagne Dub* in the summer of the following year, alongside jazz musicians Max Hallett and Ruth Goller, members of the London Improvisors Orchestra Clive Bell and David Ross and the previously mentioned art/science artist and producer Nahum Romero Zamora. In all these cases the other performers were experienced improvisors and expert instrumentalists. Using the *Chemical Synth* in this context proved a significant challenge whereby being reactive and responsive required a huge amount of foresight to account for the slow nature of the synth. Also performing the necessary movements to delicately play the instrument while also being performative, expressing something of the instrument to the audience, proved very difficult. This required frequent moments of hands off reflection while the sound developed.

The table of optically controlled synth elements used *Re-Enactment* as part of the goliard's travelling equipment refered to as the *Table Synth* was also used in these improvisatory performances. The piece operates as a modular synth where each part is controlled by light sensors and in turn also produces light. The proximity of each module, how they illuminate and cast shadows on each other, as well as a few optical objects such as lenses and prisms determines how the system works. Replacing the cables that would be used in a normal modular synth with light sources and sensors introduces a complexity to the interaction of the modules. A further challenge here was its sensitivity to environmental light. In one performance stage lighting affected the sound so much that someone from the audience afterwards commented that is was amazing how in sync the lighting operator was with the music. The difficulty in using the piece is used to provoke performance, whereby attempts at creating a specific configuration are thwarted by environmental factors which are then used to provoke further configurations in an iterative process of discovery and intention.

The technique of optocoupling used here in the *Table Synth* is normally used in

scientific practice to isolate parts of a system and constrain their interaction to one degree of freedom. It is a one dimensional link creating a single changing value between two things. This might be the coupling of a voltage between two electrical items, the measurement of a position of a moving part or ranging a remote body. Here it is used to couple several parts of a system at once to make that coupling more indeterminate and chaotic. At the same time its sensors are positioned in such a way as to be 'open' to the environment. Instead of allowing the operator to constrain the interaction between parts of a system to some specific ends, it forces the operator to react to and re-arrange the parts of the system in response to an unpredictable interaction. In a similar process *Chemical Synth* uses a normally controllable process, a simple chemical reaction, to de-couple the gestural input of an operator from the output of the system. Instead of a predictable discrete process meant to yield a specific outcome it creates an instability that affects the actions of the operator, forcing them to react to the reaction.

In both cases the use of technology to determine performance demonstrates instances where practice precedes theory, where intention is shaped by a reflexive process of reaction and interaction. As an improvisor using these objects, the action necessarily starts with a particular intention. The material constraints of these objects, which are rooted in physical processes that the technology is originally designed to examine, exert a resistance on this intention. The performer then modifies their action and the system responds differently. There is a conversation between the performer acting on a set of culturally informed musical (or other aesthetic) aims, the technology as a form of transducer (Barad 2007) transforming action of one sort into outcomes of another (chemical process into sound for example) and the environment in which both the technology and performer are situated.

5.3.4 - Noising

This positioning of problems as constraints to work off against is explored again here with the concept of including noise. Noise plays an unexpected role in constructing meaning in this work. In *1 Second Drop Tower* this principle is illustrated by a series of mechanisms inside the falling box that are devised to impart forces on the objects inside. During early experiments with the box it was observed that objects by and large exhibited the same behaviour[44]. An arrangement of objects would rise at exactly the same time and their position in relation to each other would stay the same. While this was an interesting phenomenon in itself it would be easy to overlook, instead becoming so predictable that it would 'disappear' as a phenomenon altogether. Illustrating it would require creating conditions that deviated from it by introducing noise. To do so I started by putting fixed structures in the box which the objects could catch on and thus change their course. Interestingly on occasions where I have used the film of this in live settings, this action often elicits a laugh. Perhaps this is an example of a 'kinetic joke' operating on the same principle of a linguistic one, where an expectation is quickly thwarted and the mechanism is simultaneously revealed. I then developed this 'addition of noise' to the system by creating mechanisms that could let go of or flick an object at a given moment thus creating relative movement between objects. The effect was further illustrated by disrupting the path of the box as it fell. By plucking one of the strings guiding its fall a rotational force was imparted on the box. This gives the impression of the objects inside taking an irregular path, or rotating as they rise. This is most clearly observed with the set of polystyrene balls which seem to swarm like fish as the frame of reference, the box with our viewpoint attached to it rotates around them. Here, the distinction between the observed and the technology doing the

[44] An interesting exception to this rule was observed. I conducted an experiment measuring the height that different weights rose to in the box. As was expected lighter weights rose higher than heavier ones. However, to my surprise when a small weight was put in the box with a larger one, they both rose to the same height. The lighter one would only ever rise as high as the heavier one. I described this puzzle every time I demonstrated the experiment and most often people would assume that the heavier weight was exerting a force on the lighter one somehow. Because the experiment was framed as a gravity experiment various explanations involving gravitational forces were cited. Often Galileo's explanation that in a vacuum objects will fall at the same time was mentioned. In fact the illusion that the larger weight was exerting an invisible force on the smaller one was actually no illusion. The heavier weight (or more accurately the sum of weights in the box) impedes the acceleration of the box itself. The weights do indeed exert an invisible force on each other, but its invisibility is due to the fact it is transmitted through the thing doing the framing, which disappears into the background.

observing is brought into focus through the inclusion of noise.

Noise situates the information that is being conveyed in the chaotic world in which the audience views the work and in which the phenomena under investigation take place. Sculptor Nina Canell's piece *Free Space Path Loss* refers to this very process. The sculpture consists of an empty copper frame whose surface is coloured and stained by fingerprints while it was installed in the gallery. As Chris Sharp points out *'these indexical marks contain or figure nothing more than their own index...' and that '[Canell] never doubt[s] the principle or supposition that [nothing] can ever be unencumbered by matter, or perhaps better yet by media'* (Sharp 2014).

My own *Mirror Signalling* experiment is an example of the phenomenon that Canell's title references. It is originally based on Alexander Graham Bell's experiments with using light to transmit sound. *Mirror Signalling* borrows the technique of reflecting sunlight off a mirror, which in turn is being modulated with sound. This signal is projected several miles onto a sensor which then translates the varying light signal into a varying voltage driving a speaker. The light is further modulated in between the sensor and mirror by atmospheric conditions. This technique was in turn borrowed from the SGF's sun photometer and visiometer, which both use different methods to measure the density and type of aerosol gases in the atmosphere. The sound varies, fading in and out depending on the clarity of light and the stability of mirror and sensor. In Bell's original experiment the purpose was to achieve as clear a transmission of sound as possible. Nowadays remotely transmitting sound is a commonplace occurrence and so simply reproducing this with the mirror would be unremarkable. An audience might not even realise the sound is being transmitted by the mirror, instead assuming the it had been dubbed onto footage of the piece or else produced at the point of the receiver. In order to be properly observed, the effect of *Mirror Signalling* relies precisely on it's *inability* to transmit information through the environment without being eroded by it. The noise in the system is re-purposed as the signal itself.

5.3.5 - Hall of Mirrors

The 'hall of mirrors' effect refers to the act of presenting work in a way which makes the subject ambiguous. This could be by talking about one thing in terms of another, presenting a process as an outcome, or otherwise misdirecting the attention of the audience. This is a technique that is put to use in this work in a variety of ways. Both 'making backwards' and 'instrument first composition' present the problem of allowing the subject to slip under the weight of investigation, in the former through the process of constructing certain technology and in the latter through utilising constraints to determine outcomes. This effect here describes a similar mechanism that manifests in the contextualisation of such activity. This is mostly useful in understanding how the work is presented to an audience.

In *Re-Enactment* an example of this idea is given at the end of the piece. The scene is a report on the piece *Satellite Ranging Hovel.* Here a piece of data in the form of a sound recording from the work shifts meaning as it is presented in several ways. First a recording is played to the audience and it is explained that this is a marsh warbler recorded on site during the exercise. A sonogram analysis scrolls onto the screen, being produced in realtime by the chirruping, and appears as a series of vertical stripes. I then describe how I scanned the tall reeds that surrounded me to look for the source of the sound. The screen is now full of vertical marks of the sonogram scrolling by and it is suddenly apparent that they have taken on the form of the scene being described. As the description continues the sound recording gradually slows down. The high pitched chirruping becomes a strange prehistoric wailing, the sussuration of wind in the reeds becomes the slow chirping of insects. At the same time the sonogram stretches out as the sounds become slower. Eventually it resembles a line of script. I then describe that while I was watching the sonogram I realised I could suddenly read the writing of the nymph imploring me to set my radio telescope to a certain frequency.

During this scene a recording becomes bird creating an aural backdrop, then a visual representation in the form of a sonogram, then a visual depiction of scenery, then back into a sonogram as the sound transforms into an otherworldly environment, and the

sonogram transforms into 'text' now inhabited by a supernatural creature. This shifting of frame of reference and meaning is employed throughout the pieces. There is a similarity to the oulipian concept of 'pataphor' (Lopez 2005) the metaphor that extends beyond its own usefulness, shifting function as it progresses.

Another hall of mirrors is the presentation of *Clinostat.* The clinostat is first presented as a kind of musical instrument consisting of two connected resonant boards which are rotated using servos. The servos are used to create sound and are augmented by the application of two piezo transducers acting as crude contact mics. The servos both create the sound source by vibrating the boards, and at the same time rotate the boards in relation to each other, changing the harmonic content of the vibrations. The pattern of rotation is also described as a harmonic relationship. This is made explicit through the use of long exposure photography to reveal the different cymatic patterns produced by varying the oscillation of one board in relation to the other. This harmonic in turn effects how energy travels through the system as a whole, it determines harmonic content on a higher level, the partials of the system.

The piece is presented first of all in reference to these concepts relating to sound. It is then revealed that the piece 'can also be used as' a device for simulating weightlessness in germinating plants. The 'real' function of the piece is revealed, to see how some pea shoots respond to growing in a low gravity environment. An experiment is then set up where a member of the audience is asked to try a pea shoot and see if it taste any differently to a normally grown pea. They are sat at a table with the *Weightless Dinner Set* where it is explained this is to 'enhance' the weightlessness of the simulation. It becomes apparent that the scene has been arranged to resemble that of a date, and they are subjected to 'romantic' music played on a trumpet, accompanied by the clinostat, while they attempt to eat a low gravity pea shoot with a floating set of cutlery. At the end of the experiment they are asked a series of questions relating to the romantic nature of the experiment. The joke is revealed that the experiment was an extremely elaborate set up to arrange a date. As in the case of making backwards during construction and operation, during the presentation of the

piece the apparent subject of the experiment is allowed to slip. Here creative resistance takes the form of a sort of 'inverted friction'.

5.3.6 - De-translation

All the techniques described so far have worked on the premise of drawing an audience's attention away from an 'objective representation' and instead towards a process. Using obfuscatory techniques in a manner of casting shadows that make certain invisible assumptions reveal themselves. Here I discuss a process that is usually employed to create a sort of transparency through which meaning can be perceived (Polanyi 1958) that is the process of translation.

To achieve this, several pieces of work presented here engage with the idea of sonification. The most straightforward example of this can be seen in *Interferometer.* This began life as an experiment with no sound, then sound was used in its development and subsequently the technology created for this purpose was used in several other experiments. The *Interferometer* began as an attempt to make an instrument usually used for measuring nanometer scale movement, using simple hand tools. This particular type is based on the original design by Albert Abraham Michelson, where a beam of light is split using a half silvered mirror (in this case a splitter cube prism) and reflected off two mirrors and recombined creating an interference pattern. Deflection of the mirrors in relation to each other cause the interference pattern to shift and so very tiny movements on the order of fractions of the wavelength of the light used can be detected. I had gained experience in setting up such an apparatus while working at the SGF and it was through this encounter that I decided it would be possible to recreate this in my own studio. In this case, as I was less interested in making actual measurements than recreating the mechanism and detecting movement it was useful to couple the output of the device to a sound making circuit.

A simple phototransistor coupled to an amplifier was used. This circuit became central to many of the pieces presented here. It is significant for the 'directness' of its

operation. Light and dark hitting the sensor corresponds to a signal in the amplifier circuit. The more light hitting the sensor, the further forward the speaker cone and the darker the further back. This means that only dynamic changes of light are rendered audible. In the case of *Interferometer* light and dark bands of the interference pattern create sounds. Interestingly while setting up the apparatus a 'zipping' sound can be heard as the two beams line up. This can be used to fine tune this sensitive process in a way that wouldn't be possible using purely visual stimulus. Similarly deflections of the mirror that would not be visible to the eye are rendered audible. The device is then able to detect vibrations happening at a nanometer scale. Mysterious rumblings and pops can be heard with no obviously apparent source, it effectively becomes a microscope for sound.

The technology developed in *Interferometer* led to the piece *Looking At Paintings* which was commissioned for the 2018 painting exhibition *Hard Painting* featuring work from six abstract painters. The work in this exhibition was characterised by a distinctly modernist, minimal style of painting and two of the pieces in particular *Yellow Tondo* and *Falling* (Boutell, 2017) resembled the modified records used by sound artist Graham Dunning in *Mechanical Techno* (Dunning 2016). Read in this circular manner the visual rhythm of the work suggested music and so spinning the paintings seemed a natural approach. *Looking At Paintings* then became an opportunity to explore the idea of sonification in a very direct way.

A simple turntable was used to turn the paintings and various sound to light circuits were used by positioning illuminated sensors above the painting like a record stylus. One was based on the light to sound circuit mentioned above and was particularly sensitive to surface texture. Others used the varying light and dark to modify parameters of simple analogue sound circuits. Moving the sensors at random to sit above a different part of the spinning painting produced different repeating patterns. After experimenting with improvising along to these ostinati with various instruments I found that the most striking effect was created by simply recording any simple percussive loop in time with the spinning turntable. Regardless of where the beat fell it

would automatically put the sound in context and miraculously sound musical. Positioning a sensor at the corner of the square turntable created a strongly pulsed spelling of the phrase.

Once the other painters in the exhibition saw footage of the device they started to send me prints of their work to use with one painter, Patrick O' Donnell, sending me an original work. This consisted of a planet like figure in the middle of a large black canvas. The light from the sensor appeared to orbit the planet as the painting was spun, and the direct sensing method meant that the texture of the paint could be distinctly heard as if drawing a microphone across the surface. By dramatically lowering the sensor to the spinning painting the rough surface created a sound akin to rocket motors firing. In this performance gesture the idea of space travel was suggested, hanging somewhere between puppetry, instrumental performance, concrete sound, tactile sensation and of course the illustrative properties of the painting itself. During the run up to the show another of the painters, Philip Cole, approached me to find out more about how the spinner worked and decided he would make a piece specifically for it. He presented me with a collage of geometric shapes stuck in a grid on a board refining the rhythmic quality of the original spun piece by Boutell, exploiting features such as texture, wide tonal (colour) range and some thought put into the rhythmic relationships between the shapes.

There is one more version (or inversion) of sonification that I would like to address here. This relates to the use of sound *put to use* developing the science. In most common conceptions of sonification data is taken after the fact, or maybe during an experiment (but again, after the experiment has performed its function) and through some intervening technology is rendered as sound. In *Clinostat* and *1 Second Drop Tower* the process is inverted, whereby sound is used in the building of the experiment.

As has already been mentioned, the counter rotating platforms that make up *Clinostat* are controlled by two servos that oscillate by rotating 360 degrees one way and then the other. The harmonic relationship between these two is visualised by adding a light

to one corner of the inside platform. Using long exposure photography its path is traced. The various ratios of oscillation between the two servos produce cymatic patterns. This is related to a parlour trick popular in the victorian era, whereby a tine with a brightly painted bead on the end is bowed. When different harmonics of the tine are excited the bead vibrates in different patterns. The same effect can be seen on an oscilloscope with two oscillators assigned respectively to an x and y axis. This was used to determine the maximum variation of movement of the platform to evoke the effect of a low gravity atmosphere for a plant growing on the platform.

The film produced using the *1 Second Drop Tower* also exploits this ambiguity and displays another variant of this inverted sonification. What begins as seemingly 'purposeful' experimentation involving weight and scales quickly falls apart as the scales are seen to comically flail about inside the box. Eventually the piece develops into a series of short abstract movements reminiscent of the simple physics experiments performed on the international space station for popular science broadcasts. The shots are treated 'musically' as repeated motifs, the subject of each scene becoming secondary to their abstract movement and corresponding to its own internal logic.

In the making of the piece I began to think of the interactions between the objects as a kind of harmony. The movement was orchestrated using the small mechanical actuators which can be seen attached to the inside of the box. The timing of these actuators was crucial to this internal harmony. An object would either fly up with some upward momentum, float downwards or remain motionless depending on very precise timing of when it was released. A spoon is made to intersect a plane of seeds, a golden cube is made to drop then pause in its descent before continuing down. The precision of this mechanism itself was achieved through an act of translation. Thin nylon wires were passed through holes in the bottom of the box and hooked onto the triggering mechanism of the actuators. The other ends were attached to tuning pegs fixed to the bottom of the frame. The actuators are triggered when the box comes to the end of the respective nylon threads, in effect translating a spatial dimension into a temporal one.

The *1 Second Drop Tower* is thus presented as a kind of instrument, borrowing concepts from both scientific and musical uses of the term, translating musical concepts into physical ones.

De-translation then is the technique of resisting the usual readings of translation often put to use in art/science work, that in an act of translation one thing simply stands in for another. Here instead translation is seen as a mutually transformative act. Instead of using translation to decode information, instead it transforms the information itself, or even in a reflexive move modifies its own rules of translation in the process.

The practical work here has been descirbed in terms of its material arrangements, the actual work itself, as well as the principles that have been derived from this practice. These principles in themselves are examples of the Birmingham screwdriver. All of them in some way constitute a use of the 'wrong tool' – 'progressing' backwards, using anachronism and fiction as a tool of enquiry, letting technology determine its own function, utilising noise, misleading, deferring meaning. In each case these 'problems' are shown to work as forms of creative resistance that are hugely productive. The following chapter is an analysis of the epistemological implications of the work, which will help to illustrate how this process can be understood as a method of generating knowledge *alongside* and *through* scientific activity.

CHAPTER 6
EPISTEMIC COMPLEXITY

In this chapter the techniques previously described as methods of making work are examined in reference to the ways in which friction is exerted between the artistic practice itself and the science that it draws on. It presents the practice as a 'golden hammer' that treats science as if it were art and vice versa in the hope that through the resistance encountered in this exercise something of the way both practices operate as methods of making knowledge is revealed.

6.1 - Thinking Forwards: The antegenesis of ideas.

'Every new scientific object sheds a “recurrent light” on those by which it was preceded' (Rheinberger 1997, p33). The concept of making backwards demonstrates the complex and sophisticated tasks that can be achieved through a kind of backwards problem solving. It in effect constitutes a form of doing before knowing at odds with the notion that experiment produces knowledge by starting with theory and is only then tested through practice. This view tends to position practice as subordinate to theory, for example saying someone is 'good with their hands' implies an intellectual deficiency, vocational education is often described in opposition to academic etc. Gilbert Ryle's 1945 address to the Aristotelean Society challenges this distinction, saying that it implies some intermediary act that would somehow have to 'unite in itself the allegedly incompatible properties of being kith to theory and kin to practice' (Ryle 1945, p2). He goes on to critique the notion of entirely rational theorizing stating 'the rationality of any given performance [would have to be credited to] the rational execution of some anterior performance and so on until it becomes impossible to start' (ibid.) suggesting instead that knowing *how* precedes knowing *that.*

'Making backwards' plays with this idea allowing the process of production to 'run backwards' in a chain of anterior performance. Methods of production are folded in to the 'outcomes' of the experiment. A piece might include stories, fictional or otherwise, of

its history and context. It will use the processes involved in its construction to determine constraints against which the piece will operate. Its history is brought to bear directly on its function. By presenting the constituent elements of the piece in parallel with their 'outcome' they are allowed to influence each other in a causal fashion. I argue that this constitutes a kind of productive misuse of the work's history. 'Making Backwards' projects future possibilities into a kind of 'meta-past' of the work. It demonstrates the synchronic nature of 'apparatuses...materializing in intra-action with other material-discursive apparatuses' (Barad 1998, p102) in which 'preceding' processes seem to unfold forwards in time, sometimes 'overtaking' their own chain of production.

This 'flattening out' of the temporal relationship between knowing and doing, exposes the artificiality of such a cut. Instead I suggest doing is an act of knowing (Clark & Chalmers 2002, Rorsch et al. 1992). As Polanyi states 'the arts of doing and knowing...are thus seen to be only different aspects of the act of extending our person into the subsidiary awareness of particulars which compose a whole" (Polanyi 1966, p67).

'Making backwards' also illustrates the problem in 'cordoning off' of a set of processes as belonging to the production of some particular artefact, in finding where this regress of anterior performances stops (or perhaps more accurately, starts). It could also be argued that earlier processes become less relevant as they are involved in other activities, the lathe built in the production of the *1 Second Drop Tower* will be useful in lots of circumstances for example. But this distinction can only be made in hindsight, when those other uses become apparent. It begs the question put by Barad 'what precisely constitutes the limits of the apparatus that gives meaning to certain concepts at the exclusion of others?' (Barad 1998, p98).

Making backwards is the ability to resist the teleology normally ascribed to the process of experiment. Instead, production emerges from a rhizomatic network of activities. The origin of a piece of knowledge, as in the origins of a piece of technology, stretch back in this manner, until they are lost in a blurring of a vast network of related activities. So too

the potential applications and implications of a piece of knowledge stretch forward and diffuse into a vast network of consequences in the future, 'never a completed process, and therefore…always before the event' (Feyerabend 1975 p15). A piece at any given moment (its demonstration, documentation, conception, production etc) is only the temporary crystallisation of a series of related concepts and processes. Involving scientific practices in this process reverse engineers the artefact, the origins of its production and its possible future applications by engaging them simultaneously in a process of parallel development. Through this treatment, the scientific object is re-invigorated with the possibility of a kind of slippage that makes room for further epistemic excess to emerge. It demonstrates the 'overreaching' that Polanyi describes as being "*less* than knowledge, for it is a guess; but it is *more* than knowledge, for it is a foreknowledge of things yet unknown and at present perhaps inconceivable." (Polanyi: 1966 p143).

6.2 - Made up realities

Given that the aim of science is to discover *new* knowledge it would seem counterintuitive to relate it to re-enactment. Re-enactment might be viewed precisely as a representation of what is already known. Of course re-enactment might also be viewed as a method of creating potential for unpredicted insights. By embodying historical knowledge a re-enactor might gain insight through affective response to their experience. By situating historical knowledge in a real life environment material realities that might otherwise be difficult to infer from historical records become apparent. These insights emerge as unexpected epistemic things and are often characterised by disruption. The passage of an aeroplane over a medieval re-enactment inviting the re-enactors to consider the soundscape of the middle ages. The laser at Herstmonceux was just such a disruptor, incongruously scything above the tents of a medieval encampment.

This juxtaposition led me to consider the science that was going on there as *part* of the re-enactment and there is a sense in which science itself is *always* a re-enactment.

Each time an experiment is carried out it draws on historical occurrences of the whole or parts of other experiments. It is 'a complex and heterogeneous historical process which contains vague and incoherent anticipations of future ideologies side by side with highly sophisticated theoretical systems and ancient petrified forms of thought' (Feyerabend 1975, p106). It can be regarded as a sort of re-enactment which must nevertheless move beyond itself to produce something new, a process which is characterised by disruption. Of scientific experiment Rheinberger states 'the generation of differences becomes the reproductive driving force of the whole experimental machinery' (Rheinberger 1997 p75). Perhaps at times the medieval setting of the site offers just such disruptive insights to the scientists there.

However, the Birmingham screwdriver being put to use here is not simply the incongruity of re-enactment, which as we have seen is already integral to scientific practice. The disruption here comes in the way re-enactment operates differently in scientific and artistic contexts. Schwab talks about Walker Evans' use of the term 'documentary-style' to distinguish it from true documentary (Schwab 2015) describing a shift in the frame of reference that positions the artist as a 'virtual witness' (Shapin 1984, Schwab 2015). The audience is invited to notice the *act* of a self-conscious pointing towards the traces left by a historical event rather than the traces themselves. In '*fictional* re-enactment' no such indexical marks exist, the audience is virtual witness to an already virtual act.

The work here then might be considered re-enactment-*style.* In the manner of the document being contained 'one frame in' inside documentary-style art there is a similar process of nesting happening here. Re-enactment-*style* art is already a re-enactment within a re-enactment. In setting up the scene with a backdrop of the Herstmonceux landscape along with the technology I was using, here my activities as a re-enactor are 're-re-enacted' on stage for the audience. Another layer 'back' is created by claiming that the original goliards (who I am re-enacting here) were themselves re-enacting the experience of having a holy vision. Here we have a re-enactment (of an encounter with a celestial 'speaking' light) within a re-enactment (of my activities in a field in

Hertsmonceux) within a re-enactment (on stage at various performances). This layering extends 'in the other direction' too. The character that is being played in *Re-Enactment* is based on Helen Waddel's account of the medieval goliardic tradition.

The work of these itinerant scholars often involved music, conjuring and other performative devices and the humour in these works was often self referential and relied on meta-layers of language (Waddell: 1927). This same style of joke is being made here, where I present myself as a scholar whose work reflects on and parodies the scholarly work of a historian and scientist. The same meta-layers of humour are being employed, so that in pretending to be a re-enactor of a goliard I am *in fact* participating in a goliardic tradition. In a parallel move, *Mirror Signalling* is a re-enactment within a larger history of free space optics (Bell 1887) which itself extends into the activities detailed here. Below is a diagram of the multiple nesting involved in this piece.

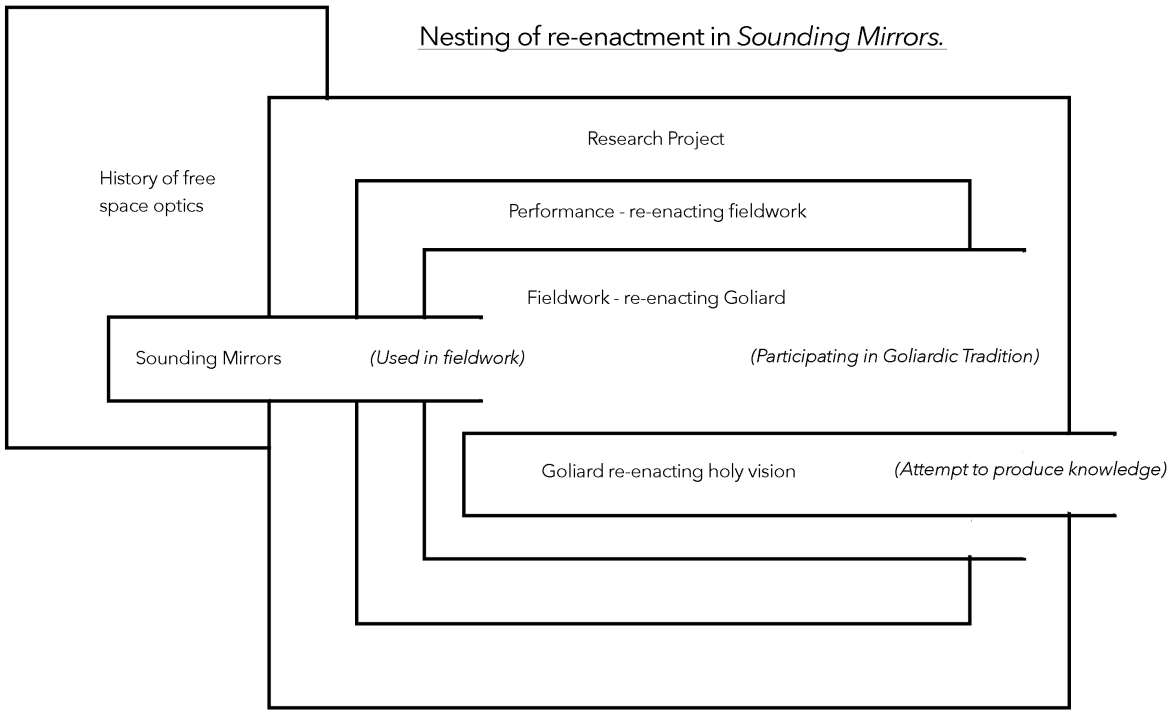


Fig 34. Diagram of nesting of re-enactment

The use of *fictional* re-enactment being brought to bear on scientific practice here allows for a kind of permeability, for example the act of producing knowledge crosses

over from medieval scholars interpreting holy visions to my own attempts at an original contribution to knowledge. There is a sense in which science in art is always a kind of re-enactment within a re-enactment. Fictions from one layer are brought to bear on realities of the layers in which they are nested and there is a leakage of ideas that allow unexpected knowledge to arise.

6.3 – Inter-functional constraints

Instrument first composition is a technique that occurs frequently in experimental performance often utilising novel and homemade technologies (see the work of Graham Dunning, Alistair Strachan or Sarah Angliss for excellent examples). In particular it is used as a method of structuring improvisation through technologically determined constraints in a form of 'comprovisation' (Dudas 2010). Although traditional instrumental technology does of course inform its own performance outcomes, the technology is able to disappear behind tradition as the various possibilities a given instrument offers become formalised. Extended technique, which is most often employed in experimental forms, brings this dynamic back into the fore (Norman 2013). In a similar fashion with custom made performance objects with less or no formal tradition to draw on it is inevitable that in a live setting technology itself has a significant influence on the work that is produced. This is discussed in reference to musical artefacts in Norman's account of creative resistance (ibid.), or in terms of digital musical systems as 'performative agency' (Brown, Eldridge and McCormack 2009) emphasising the ability of software to influence performance outcomes. The dynamic is also discussed with reference to scientific instruments as the interplay between human and non-human agents in the 'real time dialectic of resistance and accommodation' in Pickering's *Mangle of Practice* (Pickering 1993, p568), or the 'material-discursive phenomena' in Barad's account of intra-activity (Barad 2007, p203).

In all these accounts the performative outcome is guided by the interplay of constraints. Thor Magnusson (2010) shows how this process differs from simple static readings of technological determinism by also acknowledging in addition to the *objective*

constraints of the technology, the effect of *subjective* and *cultural* constraints at play at the same time. Here my analysis of the instrument first compositional approach considers that not only do certain constraints reside in either subjective, objective or cultural contexts, but in fact each one presents a face in each of these spheres, and the interaction between them is where meaning arises. Furthermore when the performance object is a piece of scientific apparatus some of the constraints from that use are 'borrowed over'. This results in a fourth class of constraint that I call 'inter-functional' constraints, as those in which resistance is encountered when the object is simultaneously put to use as a performance object and an instrument for investigating some part of nature. Inter-functional constraints operate across objective, cultural and subjective constraints at the same time.

An example of this interplay is in the operation of the *Table Synth* used in *Re-Enactment.* Here an 'inter-functional constraint' is the fact that light moves in a straight line, exploited to create an optoelectronic mechanism in both *Table Synth* and the absolute gravimeters at the SGF. In objective terms in the gravimeter the predictability of the light-in-a-straight-line constraint allows a particular measurement to be made. In the *Table Synth* this predictability must be worked off against to create a dynamic system to perform with. In subjective terms the constraint interacts with the theoretical background of the physicist to allow conclusions to be inferred about something else (i.e. the gravitational field the experiment is designed to measure). In its use in the *Table Synth* the performers theoretical background allows it to be exploited to bring about a particular aesthetic effect. In cultural terms, for the scientist the universality of the light-in-a-straight-line constraint means the output of its use reliable and useful to the wider physics community. In the case of the performer it does not relate to the wider cultural context in which it is being used because it has no (or very little) historical precedent.[45]

The 'light-in-a-straight-line' constraint is inter-functional because it exerts friction

[45] The use of optical links such as this do in fact have a long history in analogue synthesizer design. Referred to as a 'vactrol' this combination of led and photo-resistor used as a voltage controlled resistor results in a distinctive 'rounding off' of dynamic change owing to the performance characteristics of the photo-resister. A vactrol is however a sealed unit specifically in order to exclude environmental effects. In the case of the *Table Synth* this convention is bucked to create a 'free space optical link' in the same way as the piece *Mirror Signalling.*

between its use in scientific practice and its use here, between being a fixed point against which something can be *measured* to one against which something is *articulated* (Hayles 1993), between generating *matters of fact* and generating *phenomena* (Hacking 1983), and between referring to *universal* implications and referring to *specific* instances. It is the tension between these two modes of operation that allows the technology to act as 'differential constructs that may but need not “decay” into representation' (Schwab 2018, p15). Instead there is a reflexive process where the scientific tool is brought to bear on artistic practice and vice versa. This is the same reflexivity Polanyi mentions when he describes the focal awareness on a nail and the subsidiary awareness of the sensation of the handle in our hand when hammering (Polanyi 1966), or in Barad's account of the piezo transducer being both the emitter and receiver of sound waves in ultrasound imaging (Barad 2007). Instrument first composition in this case is subject not only to the resistance encountered between performer and technology, but between the performer and the scientific and artistic contexts in which the technology is used.

6.4 - Noise, signal, figure and ground

There is a complex relationship between conceptions of noise in different fields and its application here draws on both artistic and scientific conceptions of the term. Michael Schwab discusses noise in reference to the extraneous information recorded in a photograph. He explains that it is 'what is unnecessary or superfluous for the representation of an idea that makes an image real...what appears is in excess of our knowledge; we accept it as real on the basis of the promise of possible knowledge and not on knowledge already had.' (Schwab, 2015 pp124-125). Similarly in *Semiconductor's* inclusion of noise in the form of the rawness of data being used it comes to signify unmediated reality. By virtue of its chaotic nature, its homogeneity and pervasiveness it represents reality outside the realm of human construction. It somehow evades our knowledge yet gives rise to the things our knowledge is about, it is something 'before the object' we are trying to see.

In scientific practice the distinction between signal and noise is fundamental in

ascertaining results from an experiment (Walker 2011) Quality of data is determined by the extent to which it reflects the phenomena under investigation to the exclusion of anything else. Noise then is anything in the data that impedes this exclusion, extraneous artefacts or evidence of the observer and their technology. It can refer to the distortion of data, the skewing of a statistic by an outlier, a human error of calculation, a lens flare or the hiss of electronics. Hacking writes about Penzias and Wilson's discovery of cosmic background radiation which was only made the object of investigation after (or because of) repeated failed attempts to eradicate it as an artefact of the technology (Hacking 1983). The phenomenon Penzias and Wilson observed was considered noise firstly because it wasn't yet the object of their investigation and secondly because its (literal) universality across the sky indicated that it had no single identifiable source.

The relationship of noise to universality has a long history, from the Lucretius' *clinamen* (Lucretius ii 216) the random swerve of atoms that were thought to give rise to all interaction, to quantum fluctuations posited as the cause of the emergence of all structure during the universe's rapid inflation. Noise here is the chance encounter necessary for anything to exist at all. It is the force by which a thing is made differentiable. Where noise isn't understood as a deviation from a signal it is instead related to the universal, to the primordial conditions of the universe, the palette from which order is created. Noise is problematic when related to a specific thing under investigation but is instead made sense of as the ground against which the figure is made. The signal is itself already included in noise, made of the same stuff, and some boundary must be drawn to differentiate the two.

In the case of the *Mirror Signalling* noise permeating this boundary between background and figure is precisely what signified it as a 'real experiment'. The constraint operating here is the limit on the efficacy of a signal to travel through space unimpeded by the environment. It is the erosion of the signal by the environment it is placed in which situates the piece in a real space. Similarly extraneous environmental

noise in *Table Synth* is what situates it in the room distinct from an equivalent digital synthesiser, which could be made to simulate the functionality of the instrument in every way, its analogue physical presence is what gives rise to its radical contingencies. If *Semiconductor's* use of noise in scientific data is to bring a scientific reading of noise into artistic representations of that practice, here 'noising' represents a sort of inversion of this process. Instead a conception of noise borrowed from artistic practice - noise as that which contains the potential for knowledge - and is brought to bear on scientific experiments by situating them once again in the a chaotic and unpredictable landscape. In 'misapplying' noise in this way it transforms its problematic quality, its obscuring of the thing under investigation, into the potential for revealing new things to investigate. Its being 'before the knowledge' carries with it the possibility of precipitating *new* knowledge.

6.5 - Mirror frames of reference

If instrument first composition describes a process of exploiting tension and constraints embedded in an experimental system to provoke artistic output then the technique I call 'hall of mirrors' might describe a similar challenge posed to the audience. By presenting work in an ambiguous or misleading way, fictionalising documentary and factual material, the audience is required to perform a similar action as the performer in working against constraints to produce meaning.

This was one of the principle ways the work created humour. As in the case of any linguistic joke an expectation is set up only to be thwarted in an unexpected way. This might be through changing the apparent subject of the experiment as in the case of *Clinostat*. The audience are led to believe that the experiment is looking at a particular subject until it becomes clear that it has shifted. The aim was to make this shift invisible taking the audience as far as possible down a winding conceptual path only to look back and realise the absurdity of the distance travelled. Often this would involve a conceptual portmanteau where meaning slides from one thing into another as in the case of the sonogram image becoming scenery then script, so that it is impossible to

tell where the slippage has taken place.

A concept useful in understanding this technique is *frame of reference*. In physics this is the abstract set of co-ordinates characterised by its state of motion relative to some material body of the universe (Kumar 2003). Whenever a value is mentioned, for example velocity, the frame of reference defines what this value is measured with respect to. The SGF in Herstmonceux for example is involved in defining the terrestrial frame of reference which is used for making measurements on the surface of earth. This perspective is played with in *Semiconductor's* film *Heliocentric* (Jarman & Gerhardt 2010)[46] in which a camera is arranged to track the sun keeping it at the centre of the frame. The fixed nature of our earth bound perspective is revealed by abandoning it as our frame of reference, here the literal frame of the camera is fixed on the sun. This simultaneous abandoning and fixing on a frame of reference was described by Matt Wilson in my interview with him at the SGF. He mentions that in order to make measurements of the earth it is necessary to take a perspective away from the earth and look back on it. This is done in literal terms using satellites, the measurements made of the earth are made with tools orbiting the earth from afar. These then in turn establish co-ordinates by which measurements of things on earth can be made.

The difficulty in making measurements using the very thing you are measuring can be described as 'opening a box with the crowbar that was inside' (Pratchett 1992). One way to achieve this would be to shake the box vigorously and allow the inertia of the crowbar to crash the box open. This method was both figuratively and literally explored with the piece *1 Second Drop Tower* where the rapid movement of the frame of reference (the camera inside a box) mean that objects inside appeared to levitate and move around. Interestingly the forces at play here are referred to in physics as 'fictional forces'. A further play on frames of reference was made by first showing the drop tower operating from the outside. The claim of weightlessness appears to be a reference to the box jumping in the air. Only when it is presented through the moving frame of

[46] Jarman, R, Gerhardt, J (2010)*Heliocentric ,* https://semiconductorfilms.com/art/heliocentric/ accessed 5/12/19

reference of the internal camera do they see the inversion - that the falling box creates the weightless state. Similarly, describing the footage of the SGF as that of a group of re-enactors creates a new frame of reference through which meaning is continually shifted.

The comparison between this and 'instrument first composition' can be made whereby in instrument first composition the outcome of the piece is created by the tension exerted between the experimental apparatus and the performer's effort to create a particular effect. The synthesis of these two forces gives rise to a new artistic and scientific readings of the effect at hand. This process is framed in terms of the goals of the performer which themselves are 'understood in terms of contingently formulated accommodations to temporally emergent resistance' (Pickering 1996, p580).

A particular inversion of this process happens here by virtue of the fact the process is being brought into the artistic realm. In Pickering's discussion of the emergence of goals in scientific practice the tensions at play are between the (scientific) performer and the material arrangements with which they are grappling. In the example here there is a third party - the audience. Hall of mirrors refers to the play of tensions between the (artistic) performer, the material arrangements and the audience as interpreters. The shifting frame of reference here is not just a shifting of the co-ordinates against which a phenomena is measured, but a shifting of co-ordinates against which it is communicated. This evasive technique attempts to keep the possibilities for new meaning open as it is produced. As Michael Schwab states 'Not knowing what a thing precisely is may offer better access to understanding its complexities than fixing it in a reductionist notion of identity.' (Schwab 2018).

6.6 - Found in translation: New approaches to sonification

The term 'art/science collaboration' itself denotes an exchange of some sort between these spheres. This process inevitably involves a degree of translation whether this be the translation of terminology, themes, techniques or insights. As in any translation meaning can be modified, lost or created in this process. A common method in this field of expressing this exchange is by using the technique of 'sonification'. Some problems inherent to this have already been touched on earlier in this writing, issues such as the manipulation of data into pre-determined aesthetic forms. Often data is 'massaged' in such a way that it fits a musical system so that an audience understands little of the original. The translation from a scientific language into a readily perceptible musical language sometimes works on the premise that there can be some kind of direct correlation between the two. Work of this kind often confuses cultural and naturalistic assumptions, drawing on classical ideas of consonance and underlying order in both science and art. On the other hand a pre-occupation with veracity at the expense of creative expression can lead to instances where the translation has to presume prior knowledge on the part of the audience or else require a supplementary explanation and thus fall short of illuminating the phenomena at hand.

Schwab talks instead of *transpositions* which 'need not “decay” into representations, that is, conventional forms of knowledge... [instead] tend[ing] towards a continuing suspension of representation proposing new and more complex epistemic objects” (Schwab 2018, p15). Here an attempt has been made to offer a critical take on the act of sonification and instead to treat it as a process of 'de-translation'. Instead of a fixed lens through which data is transformed it becomes a process whereby the mechanisms for making such a transformation are able to feedback on themselves and modify those same mechanisms. In this sense the instruments of de-translation are more akin to transducers. Barad employs the example of the piezoelectric transducer used in ultrasonography, to describe an instrument which acts simultaneously as a transmitter and receiver, and consequently through which 'not simply signals but discourses operate' (Barad 2007, p191) extending this reading to the operation of the apparatus itself. De-translation acknowledges the material-discursivity involved in such a process.

In the piece *Interferometer* a feedback process was brought into play that in fact modified the functionality of the technology. The piece has an interesting limitation relating to its title, in that it is so sensitive to sound that listening to the device almost always causes feedback. It was demonstrated at a performance *'Against Talent'* at the Phoenix Gallery, where this feedback was so sensitive that the movement of the audience, doors being opened in the building and other environmental factors would affect the feedback loop. In effect this enabled it to measure macroscopic phenomena. The act of translation between light and sound was initially intended to aid its original function as a measuring device, and became an act of de-translation when in the end its 'failure to perform as intended' meant that a new function emerged.

In *Looking at Paintings* de-translation operated in a number of ways. The artists whose work was initially the subject of *Looking At Paintings*, began to make work where *Looking At Paintings* was its own subject. The paintings then became part of the overall machine, and in effect stopped being paintings. The piece begs the question, 'where is the thing being translated in all of this?' It is rendered harder to see by the attempt to do just that. In being spun round and lit with small points the machine imposes a temporal dimension on the paintings and forces a particular kind of viewing. The technology was modified to reliably produce an approximately musical effect. In trying to render the sound more 'musical' objects were added to the paintings obscuring them further.

Chemical Synth also played with the ambiguity between the subject and the machine operating on it. I was asked at a performance exactly what bit of the chemical process was being 'made into sound'. I found it was quite difficult to explain that no bit of the process was being made into sound, it comprised in and of itself the circuit. An analogy would be to ask 'which bit of wood gets translated into sound in a violin?'. It might be possible to answer this question at a stretch, 'the tension created by the fibrous structure of the wood gets translated into the resonant properties of the violin'. Here the question asked of the *Chemical Synth* is even harder to answer. It might be hazarded

'the delay caused by the time it takes to build a charge across the electrodes in the sodium bicarbonate to a certain threshold gets *made into* the frequency of the oscillation when the process is fed back into itself and allowed to repeat'. But in a similar way that the object of the painting spinner gives the appearance of an objective translation, here the physical process that can be seen in the mixing of chemicals gives the impression that something is 'physically translated' into sound.

De-translation also plays on the traditional hierarchy involved in sonification, that the sound is in some way subordinate to the process that is being sonified. In *Clinostat* de-translation occurs where its ultimate operation is determined by rendering it as a sonic relationship. In using the Lissajous patterns created by the *Clinosat* to determine how to set up the experiment the process of sonification here effectively happens 'in reverse'. This process was then further 'fed back' into itself when the piece was presented as a musical instrument. The different harmonic relationships between the platforms do indeed result in different patterns of sound. While this fact is presented as the original purpose of the platforms it is in fact a result of the use of sound to develop its function as a plant growing clinostat.

In *1 Second Drop Tower* various de-translations take place in order to operate the experiment. The internal set up of the objects are treated in a musical way in order to compose movements in each experiment. The object borrows from musical instrument design in order to function. Part of the mechanism relies on a translation of space (length of trigger wires) into time (when events inside the box are triggered). In these cases, sound and musical concepts are 'de-sonified' into scientific experiment.

Scientific apparatus are all in some way involved in the production of traces (Rheinberger, 1997). Sonification as a process adjunct to scientific practice attempts to mimic this process but in doing so often fails to take into account the material reality such practice is rooted in, instead treating data as disembodied artefacts that possess an aura of the method that produced them. De-translation attempts to modify this practice first of all by including the mechanisms that produce the data in the system

itself. Its use in an artistic setting here also allows the data to be positioned in such a way that it can modify the mechanism itself, revealing the true material-discursive nature of the systems that it draws on. It treats the production of data in a way that resists the attempt to create a 'true' image. Instead it results in something more useful, the potential for new epistemic objects to emerge.

CHAPTER 7
OPEN ENDINGS

7.1 - Overview

This project began with questions that arose during an ongoing practice regarding the use of art as a research method. In particular the apparent paradox involved in idea of 'learning something about reality by making something up'. The Birmingham Screwdriver was a starting image to try and explore the process of finding a way to proceed without already knowing the way forward, the state of learning something new. The image of the golden hammer was meant to invoke the idea that learning something new, doing research, creating knowledge all might be viewed as a process of making, of 'making something up' because this is the only tool we have to hand before we know. Rheinberger (1997), Schwab (2015) and others described this as the emergence of epistemic things. I wanted to explore this idea, but rather than through the image of an expert virtuosically manipulating an experimental system, I wanted to shift focus onto other strategies such as improvisation, problem creating and solving, creative friction and resistance, in diving headlong into unknowing.

A way to explore this process was to invoke it by immersing myself into a situation where as an outsider I was forced to use the Birmingham screwdriver as a heuristic. The position of the artist working in science is one where this outsider status is frequently encountered, challenged, put to use and struggled with and so it seemed like a good place to begin. This experience was navigated through making and performing, through chance encounters, and through the generous exchanges of a variety of experts resulting in a body of practical work. This work is then presented here and examined in an academic context, for the academy itself represents a scientific institution, where all researchers are to some extent involved outsiders venturing into unknown territory. It is also a place for chance encounters, collegiate generosity, and for intellectual exchange between different sorts of expert.

So there has been a nesting of analogy, where the use of art as research in this project and more generally as a form of enquiry became an analogy for making art about science, and where this in turn was an analogy for this rather abstract statement about using the wrong tools to try and explain the state of fruitful unknowing essential to any learning situation, including the learning situation I found myself in at the start of this project and which I continue to work through. It is hard to say which was the starting point here, instead here it is presented as a kind of historial ensemble of ideas, because that is in reality how these epistemic things emerged.

I started with a review of art and science collaborative work attended at the initial stages of this project and several issues were identified with this exchange. I speculated that possibly due to a re-invigoration of anxieties after the 'science wars' it seemed like practitioners outside of science were under pressure to present an accurate and authentic representation of science. For artists to gain access to science institutions such as in the artist residency certain power dynamics and relationships had to be upheld. This resulted in artists often having to play the role of 'science communicator' in exchange for privileged access to specialist knowledge, with the expectation that they would have little to add to science itself. Artists engagement with the outputs of scientific activity were explored here in reference to the concept of sonification and several problems were identified with this practice. Namely that in this work data was often treated either as 'raw' with the presumption that it retained an aura of its origins that would automatically be transmitted to an audience, or else it was shaped into consonant aesthetic forms in which case its origins became arbitrary.

At the same time that art practice is under pressure to assume this illustrative role in science practice, it is increasingly being put to scientific use by being accepted as a method of research in its own right. This rift in the role of art in knowledge making activities was illustrated by the continuing struggle to define exactly how art functions as a method of enquiry. This has prompted calls from various theorists, notably Michael Schwab, Henk Borgdorf, Andy McNiff and others, to formulate proper understandings of how art generates knowledge. Edward Wilson's theory of consilience was touched

upon as an example of how art could be positioned within a larger epistemological framework.

As an alternative to consilience, the very problems that may have caused the current pre-occupation with veracity and authenticity, the misappropriation and misuse of science, were put to use as a strategy to discover how art might engage with science constructively. Using the poetic phrase 'the Birmingham screwdriver is a golden hammer' notions of catachresis, wrong tool use and a kind of comic playful approach were explored as a kind of creative resistance. A comparison was made between the use of creative resistance as a strategy for making new artwork and uses of resistance as a driver of scientific practice. In the end the project proposed a diffractive reading of these two interpretations identifying two particular sites of exchange in which this might take place. First of all in the context of the artist in residence whereby art practice is imported into a scientific context and secondly through the creation of a series of original artworks where scientific objects are brought into an art practice. In this concluding chapter I will reflect on these points of exchange and try to unpick some of the insights gained through this project, as well as suggest future avenues for exploration.

7.2 - Semiconductor

In Chapter 2 I reported on a detailed case study on artist duo *Semiconductor* who generously gave their time to discuss their work and offer advice on this project. As well as studio visits I attended several talks given by the duo, and eventually ended up working on the fabrication of one of their pieces *Halo.* .

First of all their background in computer art and discussions around the translatability of data offered an alternative approach to the previous encounters with data being sonified. Their description of data as being a co-producer of the work offered an alternative reading of how it might be used, introducing me to the idea of a kind of shared agency between an artist and their work. Their use of noise and the artefacts of

scientific instruments being regarded as the signature of man opened up avenues of enquiry which were explored in my own work, in particular the idea that noise is inextricably linked to any process of investigation and that any form of research or enquiry will bear the traces of the tools and practitioner.

I was able to discuss their experiences working with scientists and some of the tools and techniques they employed to do this. Of particular interest was their position as outsiders, and how they brought a very different set of specialisms to bear on a normally impenetrable world. Through a review of their piece *Earthworks* I looked at how the various stakeholders in a large scale art piece had an influence on the work and I was impressed with their ability to hold their position and maintain integrity in the face of various outside pressures. This tongue in cheek bravery, exemplified by their film *DoYou Think Science* was a key insight into how to work in scientific contexts. They described the process of managing expectations, gaining trust, communicating effectively and retaining control over their work when engaging with institutions, stakeholders and eminent experts in fields other to their own.

Finally, I was lucky enough to be directly involved in the production of one of their pieces *Halo.* I was given insight into how such a large scale project gets put together, the compromises and problem solving involved. In particular I was fascinated with the collaborative nature of the piece, from its origins at CERN's *Collide* residency at the LHC where it worked as a kind of analog to the processes happening there, to its conception and the collaborative efforts of both artists, through to its production at an advanced fabrication company and finally its exhibition. Future collaborations have also been speculated with the possibility that composers might have the opportunity to work with the machine. It was interesting to learn how this both mirrored and differed from the large scale collaborative efforts at the LHC itself.

In the end I was inspired by *Semiconductor* to carry out my own residency and they offered invaluable advice on setting it up and carrying it out successfully. Without this input it is unlikely that I would have even tried, and so their effect on this project has

been significant. I continue to stay in contact with them and will be taking part in helping to get *Halo* up and running for exhibition in 2021.

7.3 - Residency

In chapter 3 I reported on a residency I undertook at the Space Geodesy Facility at Herstmonceux which followed as a result of the work with *Semiconductor*. First hand observations were made about the workings of a lab and my own position in it as a visiting artist. Through the concept of dissonance (as a form of creative resistance) attention was paid to ideas of specific place and time vs universality, the body and physicality vs abstract measurement, and the historical and contemporary cultural influences on the lab. Finally, I reflected on my own position as an outsider, the particular nature of acceptance I received and the opportunities I was granted to contribute, transform and create anew within the lab.

I began this chapter by reflecting on the framing of this activity, namely the idea of re-enactment at the site. A comparison was drawn with the phenomenological reduction (Husserl 1912) and Latour and Woolgar's viewing of the lab as a place of inscription (Latour & Woolgar 1979). This framing both conditioned my time there and also my reflection of it and later would become the starting point for the performance *Re-Enactment*. Differences between Latour and Woolgar's approach and my own were highlighted. Where their analogy of the lab as a place of literary inscription worked predominantly through a sympathetic resonance, my own analogy as a re-enactor worked through a kind of dissonance.

I reflected on the site itself as being both integral and alien to the landscape it was in. Its relationship to the landscape was considered in reference to its primary function as a facility for measuring the environment it was situated in. The building and landscape were both extremely evocative and this seemed somehow to be at odds with the idea of a scientific institution making universal measurements and dealing with abstract concepts. Instead, the sense of presence and location were both striking.

I then spoke about the operations that happened there. I was particularly struck by the number of processes that were done by hand, the craft skills that were brought to bear on high precision mechanisms, and the translation of bodily gestures into unimaginably huge or infinitesimally small scales. I was made aware of the reflexivity of inscription, where physical measurements were defined by bodily physicality, and how in turn those measurements put physical constraints on the bodies doing the measuring

I also reflected on the people at the facility and the social aspect of the place. I found everyone to be incredibly generous with their time and interested in the work I was doing. I had initially been very concerned that as an outsider I would be treated with suspicion but in fact I was very quickly accepted. I was intrigued by their sense of the political, historical and cultural importance of the work happening there. All the members of the team had an interest in and valued the arts. There was a general atmosphere of playfulness and creativity which extended from moments of social 'downtime' into the work taking place there.

I concluded by tracing my own trajectory from newcomer observing the lab, to participant assisting in the lab and I proposed a further stage – 'initiate' - playing on the idea of 'one who is accepted into an institution' and 'one who starts'. My own involvement was also a reflexive process where my activities in response to the lab and its participants began to involve the lab itself and the people working there. In the end my work there felt like an exchange and this was carried through to the performances based on this experience, whereby rather than an outsider making a report, I presented as a kind of fictionalised representative of the SGF. My initial attempt to engage with the experience through the concept of 'dissonance' was frequently thwarted, where my expectations of the place were proven wrong. Many times when I thought my activities and inputs would be dissonant I found them to be entirely consonant with the activities and people there.

7.4 Performing scientific objects

The second point of exchange consisted of the creation of a public facing body of original artwork. If the work at the SGF was a repositioning of an artist from their usual context then the following work, the creation of performance objects and their use in performances, was a mirror of this process where artefacts of science were repositioned in an artistic context. This practice began to answer the question 'How can the application of the 'Birmingham screwdriver' help to understand the types of creative resistance involved in performing scientific objects?' To explore the dynamics of this process I identified several themes and techniques at play in the work. This analysis was presented in two parts drawing on Subrata Dasgupta's theory of complexity, in particular the distinction between systemic and epistemic complexity (Dasgupta 1996 quoted in De Assis 2013).

Chapter 5 gave an account of the practical component of this project by tracing its systemic complexity defined as the 'quantitive characteristics and … intricate operational behaviours' (ibid. p154). This consisted of a description of the material arrangements that made up the work. It described the processes that went into the construction of several instruments and their use in performance. From these processes general principles that were employed in making the work were identified. These are presented as a set of tools or techniques that might be put to use in making further work and are summarized below. Chapter 6 then dealt with the epistemic complexity of the work in terms of 'the artefact's capacity for producing unexpected behaviour; and the amount, variety, and novelty of the knowledge embedded in it.' (De Assis 2018, p154). This part of the analysis examines ways in which these tools might be put to (mis-)use to produce new knowledge.

7.5 - Mis-making

'Making Backwards' described resistance being applied to the normally teleological process of creating an artefact. In his description of systemic complexity De Assis, citing biologist Kovac likens the progressive unfolding (or perhaps more accurately an

accumulative folding in) of complexity in biological evolution to a similar process involved in the creative invention of an artefact (ibid. p152) Here this process was consciously subverted whereby creative invention was allowed to 'progress backwards' with an artefact being created in a kind of parallel alongside its antecedents. The normal unfolding of complexity can be seen here to operate 'in both directions' through time. Notions of 'end goals' or even 'intention' or 'purpose' were resisted in favour of a sprawling productivity that opens up the possibility for unexpected directions of creation.

Next re-enactment, a process suggesting repetition or reproduction, was put to 'misuse' as a strategy for producing invention. New technology was produced through the idea of re-enacting fictional processes. These imagined histories gave rise to new technology based on re-workings and interpretations of actual historical experiments, for example Bell's experiments with photophonics were re-imagined as medieval apparatus in *Mirror Signalling* resulting in an entirely new instrument.

'Instrument first composition' described how the work used technology normally used to investigate some part of nature and positioned this effect as a compositional constraint to generate work. Creative resistance here was the pushing against the performer's intention created by the physical system 'meeting the universe halfway' (Barad 2007). It constituted an inversion of the function of experimental apparatus used to investigate nature instead exerting its effect back onto the experimenter. The material-discursive effects of the apparatus were used not only to tell the user something about the aspect of nature it operated on, as in a piece of scientific instrumentation, but instead used this effect to provoke new artistic outputs.

'Noising' represented an attempt to turn attention onto the experimental apparatus itself. Normally an impediment to the observation of a signal here noise was put to use in highlighting the ground against which a signal could be produced. By resisting clarity and specificity, the technique of 'noising' opened up the possibility of unanticipated signals. Noise here was used to signify that which 'is unnecessary or superfluous for

the representation of an idea that makes an image real' (Schwab 2015, p124) situating the instrument in a real and 'materially accessible' (ibid) context.

The 'hall of mirrors' was descriptive of the intentional shifting of context underneath the feet of the piece of work being presented. This misuse of frame of reference was employed for example in the creation of *Clinostat* whereby the device was conceived as both a device for producing sound and also in it's traditional use as a device for simulating low gravity environments for plants. This slippage of context was put to use when harmonic relationships derived from its sonic application were allowed to bleed into the design of the rotating platforms.

Finally 'de-translation' was employed here as a response to the technique of sonification. Various methods were employed to render particular effects as sound. Instead of using translation to render the data from an experiment somehow 'more readily accessible', instead it was used to question the relationship between an instrument and its output. In the case of *Looking at Paintings* for example the translation was allowed to have an effect on the original input, even going so far as to produce entirely *new* output.

This first part of the analysis largely concerned itself with instances of resistance between artistic output and the constraints that the instrumentation is subject to. 'Making backwards' and 'Instrument first composition' described working with and off against material constraints to produce instruments and put them to use to provoke performance. 'Fictional Re-enactment' and 'Hall of Mirrors' described techniques of re-working historical and contextual constraints to (re-)produce an artefact or performative act. 'Noising' and 'de-translation' are both methods of reflecting back and creating friction with the output of the apparatus itself. 'Unmaking', fictionalising, mistranslating and obfuscating, have all been demonstrated as useful strategies for making new work. Representing forms of creative resistance they have all been put to use in creating some 'friction' with reality and thus creating work both in the sense of 'creative output' and also in the sense of 'movement'.

An unexpected outcome of this practice was the extent to which these processes echoed reflexively throughout the work. To begin with the actual tools themselves were drawn from sources 'outside' the practice. These borrowings ranged in scale from mechanisms such as opto-coupling, to whole apparatus such as the clinostat, to larger scale practices such as gravimetry or satellite ranging. Once these elements had been re-situated in this way they would become embedded in the practice only to be re-contextualised again, in effect 're-borrowed' from the practice itself. The instruments were frequently 'unmade' where parts would then become a new node in the process of creating some new technology. Practices developed for one piece would be re-contextualised for another. The histories and origins of a piece would be fictionalised or inverted to illustrate some other process and the purpose or intent of a technology would be recast into a new context. The output of a technology might be reused as the input to some other part. Different cuts 'through' the work were made to reveal different strata at different scales, for example a piece might be presented as the output of an object, the object itself, or the particular use of the object. The relationship between these 'cuts' was kept purposefully ambiguous. Creative resistance then is demonstrated not only as a process of resistance between materials and artistic outcomes, but as internal tensions and frictions of the artistic work itself.

7.6 - Mis-thinking.

So far the descriptions of how these themes are put to use have been positioned 'along the lines' of their operation and the actual process of creating the work. There is another sense in which resistance is put to use here. Norman states that

> *Resistance suggests a state or act that is energetically loaded with respect to the context in which it is manifest, i.e. the force that it withstands. In other words, since resistance presupposes and arises at the interface of a given and an opposing—albeit emerging - state, it creates an energy differential.*
> (Norman 2013, p279)

This opposition suggests a kind of directionality, a resistance *in respect to* a particular opposing force. In the previous section resistance was shown along a particular axis between the artist and the constraints used to produce work. But there is another manifestation of creative misuse and resistance here which runs along a perpendicular one. That is between the differences in scientific and artistic ways of making knowledge that the work draws on. In order to begin to answer how art might generate knowledge *alongside* scientific activity it is useful to consider the work at the crossing points of these lines.

Chapter 6 examined this mechanism, dealing with the work's epistemic complexity. Here I will summarize this in reference to Rheinberger's concept of the 'experimental system' (Rheinberger 1997). In his analysis Rheinberger states that experimental systems are (1) units of research within localised settings in which specific practices are developed, (2) that they produce insight through '*differential repetition',* (3) that they are graphematic, that is they are spaces of representation and inscription and (4) that they form networks with other experimental systems (ibid pp2-3). The practice presented here represents a kind of artistic experimental system which while comparable has key differences in how it operates. As the work here plays simultaneously on both scientific and artistic manifestations of experiment, the tensions this creates constitutes this 'other dimension' of creative resistance at play here.

7.6.1 - Units of research

Experimental systems are described as units of research in which scientific objects (epistemic things) and material arrangements (technical objects) that lead to their production are inextricably linked (ibid.) Rheinberger explains this distinction is mutable and ever changing as epistemic things become technical objects in further developments of experimentation. This relationship is negotiated through the familiarization of procedures and techniques that amount to a kind of virtuosity (ibid. 24). Technical objects of the experimental system are described as playing out their own "intrinsic capacities... [then] become independent of the researchers' wishes just

because he or she has shaped it with all possible skill' (ibid).

Drawing scientific (technical) objects into an artistic context resulted in an interesting bifurcation. Each instrument served a double function at the same time having a scientific goal and an artistic one. The constraints by which the scientific instrument operated were also put to use as constraints by which artwork was made. Similarly the constraints of using them as artwork exerted tension on their use as scientific instruments. As instruments borrowed from scientific practice, the pieces presented here are indeed analogous to technical objects, however their relationship to the notion of virtuosity is altogether different. Rather than becoming fully independent from the researcher's wishes, they are continually pressured by artistic intention. Their dual status as both objects for producing phenomena and instruments for producing artistic output means that they are held in tension, the epistemic thing acting as a compositional constraint. Output is provoked through creative resistance and in this way virtuosity is always evaded.

By shifting contexts and frames of reference the epistemic thing itself is shifted under the feet of the experiment. Frames of reference are normally employed as co-ordinates against which measurements can be made. Meaning is derived by having these points of reference fixed in relation to the instrument (or theory). These fixed points (and freedom to articulate the instrument against them) 'faces' the scientist. Here in an artistic context these co-ordinates now face both the scientist (or performer) and an audience at the same time. This added perspective creates a 'double jointedness' to the frames of reference, where they can be used as set co-ordinates for a measurement and at the same time to be articulated against the 'fixed' perspective of the audience.

7.6.2 - Differential Repetition

Rheinberger describes experimental systems as operating through 'differential repetition' (ibid. p180) comparing this to the use of the term in evolutionary contexts. He borrows Derrida's term 'historiality' to describe how rather than this happening across a

universal scientific history instead each experimental system evolves within its own temporal locus, collectively resulting in a 'historial ensemble' (ibid. p181). The positioning of scientific practice in an artistic experimental system here modifies how this process of differential repetition unfolds.

First of all in the manner in which this evolution is driven changes. In *The Mangle of Practice* Pickering describes the negotiation of forces between the scientist's intention and the material and cultural resistance out of which emerge particular goals (Pickering 1996). In the practice presented here rather than progressing in a linear fashion through time this happens through a series of parallel processes. Instead of technological artefacts being 'packed into one another' Rheinberger's epistemic things becoming 'technical objects' for use in other experimental systems (Rheinberger 1997), instead technology is unpacked into constituent parts, each becoming a mycelial fragment with its own potential to spread rhizomatically outwards.

Secondly, history is treated here in such a way that the individual experimental system itself constitutes such a historial ensemble. Through the adding of fiction and by playing with notions of anachronism these 'differential repetitions' not only occurred across successive events, but instead were inverted and nested into one another. The 'extinctions and reinforcements, interferences and intercalations' (ibid 182) occurred as parallel, mutually informing processes happening across simultaneous frames of reference.

7.6.3 - Spaces of representation

Rheinberger's description of experimental systems as essentially graphematic includes the interesting notion that 'the scientific object itself is shaped and manipulated “as” a traceable conformation. Temporally and spatially, the object *is* a bundle of inscriptions' (ibid p111.) Here these ideas where explored through the concept of signal and noise. Earlier I mentioned that *Semiconductor* used noise as a method to pull focus onto the instrumentation itself. At the other end of this 'focal plain' is the conception of noise as the background conditions from which the signal emerges. Here there was an attempt

to 'increase the focal depth' to consider both the 'wide angle' and 'close up' readings of noise as an intrinsic part of the signal at the same time. Rather than differentiate between instrument as a man made artefact and the nature it looks at instead the attempt was made to regard the instrument and its operator as inextricably linked to the environment in which they operated. This was further explored by allowing the traces of the experimental apparatus to modify the means of their own production. Rather than treat data as simply an output it was regarded as part of a feedback loop where it is able to modify its own method of production. As a result the instrument isn't put to use creating a 'true impression' of nature, but instead presents its traces in a way that avoids collapsing into representation and leaves their meaning open. If the work of the scientist might be to read these traces as a kind of text, this work has demonstrated that such a text might be read poetically.

7.7 - Experimental Cultures

To see how the project has addressed the question 'how might art practice be understood as a simultaneous process of generating knowledge, not only as an activity adjunct to scientific practice but one that works through it?' I consider the interactions between myself as a practitioner, the work and the scientific institutions it has been positioned in. The final defining feature of experimental system that Rheinberger describes is its capacity to form links with other experimental systems, to diverge into separate systems and in the formation and breaking of these links precipitate an experimental culture (ibid. p3). These bifurcations and conjunctures are described here in relation to the act of positioning this artistic experimental system into other research contexts to yield insights about how this work has worked *through* scientific practice to make its own epistemic gains.

7.7.1 - In the lab

Contrary to my initial concerns, while interacting with scientists at the SGF and even with representatives from the British Geological Survey, I felt under no obligation to put my work 'in scientific terms'. In the course of this study I encountered a willingness on the part of the scientists I met to engage in the poetic use of their work. The work was

understood on its own terms, and my own specialisms and expertise were acknowledged as a valid contribution. Outreach, communication, critical engagement, development of ideas are all accepted as important roles for artists in a greater 'experimental culture'.

The tension, or perhaps even mistrust, that I expected to encounter as an artist getting involved in science was almost entirely absent. This antagonism directed at the 'misuse of science' cited at the start of this writing almost always refers to theoretical discourse. However as a *practitioners* both the scientists and myself shared a common understanding of the forms of 'misuse' necessary when dealing with epistemic unknowns. Both practices rely on forms of tacit and embodied knowledge in relation to using instruments. Both involve the adaptation of craft skills across different contexts. Both involve improvisation and dealing with aleatoric processes and happenstance. They also both involve the challenge of articulating such practices within predominantly language based cultures. My experience was less of a dissonance here than a sympathetic resonance. I had thought that using the 'Birmingham screwdriver' would mean putting to use the tension between my practice and that of the scientists, but instead I came to find that they employ many similar techniques of 'misuse' themselves.

7.7.2 - In public

In the end it was 'facing out' from the science institution in the context of science festivals and other public performances that I found the dissonance or friction that I set out to explore to be most useful. The act of science outreach might immediately suggest that it is the role of the artist to *illustrate* science in some way and my initial intent was to try and move beyond this role. This was based on my critique of sonification and the suggestion was that in striving for 'accurate representations' the work failed to add anything new to the data being used. Through working with concepts such as frames of reference and the relationship between signal and noise I came to realise that illustration is rarely a passive process and in fact cannot fail to modify its subject.

This realisation helped me reframe my critique. Sonification was problematic not simply because it represented data, but because it did so in a closed way. This can be understood with reference to Ian Hacking's description of likeness whereby 'Likeness stands alone, it is not a relation. It creates the terms in a relation. There is first of all likeness, and then likeness to something or other.' (Hacking 1983 p139). A unique mechanism by which art can make knowledge is to create these stand alone likenesses which remain open to terms of relation as context shifts around them. Some attempts to represent science do so in a way that makes a 'likeness of a likeness' and so already assume the terms of relation between the work and science it draws on.

Instead, indicative of this ability to recognise 'likeness before the likeness *of* something' I found there was a willingness to accept the strangeness of the representations that the work produced. An experiment could be presented with all manner of random swerves of context and meaning, no matter how far along a path of absurd conclusions and misunderstandings it went it would be accepted on its own terms. The experiments I presented were not testing any one thing in particular, the representations they made were always diverging from the practices they drew on. Instead, through representations that engage in fictionalising, or adding noise, shift contexts or evade definitive outputs, the work becomes a 'standalone likeness' leaving open the potential for as yet unknown relations.

The kind of knowledge that this activity creates in the public realm is usually understood as the dissemination of scientific 'matters of fact' to a lay audience who may have varying degrees of pre-existing understanding. Traditionally the work is expected to fill in the gaps in an audience's knowledge by demonstrating the 'correct' science. This project has explored a different mechanism at play. Rather than corrrect misconceptions the work uses them instrumentally, inviting the audience to examine their existing knowledge and test what they already know. The audience is presented with the friction of the Birmingham screwdriver which they are encouraged to grasp and put to use themselves. Rather than simply communicate science, work of this sort

might be more effectively put to use in deconstructing knowledge, opening up potential for new understanding.

7.7.3 - In the academy

First and foremost, I am a maker and artist, and as such I began by feeling very much on the outside of the academy which has nonetheless generously granted access by way of acknowledging art practice as a possible methodology. A review conducted by the AHRC into practice led research states 'we have come to the conclusion that conventional ideas of contribution to knowledge or understanding might not be serving us well' (Rust et al. 2007, p4.) and so this project aimed to actively participate in the negotiation and exploration of unconventional ideas of knowledge and understanding – in this case by exploring the creative resistance as a productive force of 'un-knowing'. The AHRC describes the possible outcomes of practice as research stating they 'may include for example, monographs, editions or articles, electronic data, including sound or images; performances, films or broadcasts; or exhibitions'[47] While the activity of making art as research in the university is supported and encouraged, it suggested to me another question - is it permissible to be an artist and to use research as a method of making art?

I began to answer this by examining my time and how it resembled my experience of an arts residency. In the same approach I would later come to use in my residency at the SGF, I spent my first days as a researcher re-learning the necessary language, asking the other scientists what they were doing and trying to ask pertinent questions. Even in this very early phase of the project I practiced 'making backwards' as my reading spread out rhizomatically in all directions. I enrolled in various courses to audit before I knew the precise direction I would be going in. I went almost at random to various lectures, at one point using the university's online room booking system like a menu, so that I could sit in a lecture theatre all day and attend various lectures on all manner of unrelated subjects.[48]

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[47] AHRC, *Definition of Research* - https://ahrc.ukri.org/funding/research/researchfundingguide/introduction/definitionofresearch/ accessed 06/02/19

[48] During this period of haphazard immersion I stumbled upon an interesting sounding informatics

Later on, towards the end of my research I was asked to present some work, in this case an abridged version of *Re-Enactment* at the Sussex University conference 'Faking It', the call out for which stated 'the distinctions between the original and the inauthentic, the actual and the seeming or the experienced and the imagined are becoming less and less distinguishable'[49] and posed the question 'Has the 'truth' always been solely a matter for discourse?' (Farkas & Schou 2018). The show fitted the issues being addressed by the conference well and was received warmly. In the afternoon a 'live peer review' took place with groups being assigned the task of commenting on and critiquing the work being presented. My work was conspicuously left off the list. Was this in and off itself a kind of peer review? Had I been 'faking it' too authentically? Perhaps I had shifted the frame of reference against which that measurement could be made underneath my own feet, beginning my presentation paper in hand in front of a powerpoint and ending in cloak and tabard wielding a staff.

On other occasions I had attended conferences where practice-based researchers were required to perform while attendees ate their lunch or at evening social events. This is not to suggest that social functions or moments of entertainment are not legitimate parts of a conference. But it is clear that this kind of work while readily accepted into research programmes still must find an unconventional position in between the delivery of papers and outside of lecture theatres. On reflection I feel that being an artist in the academy embodies this unstable 'in-between' position. Perhaps the role of art in the science institution is to always be debated and questioned, holding open the space of debate around the production of knowledge in general.

To generate knowledge through art practice alongside the largely scientific institution of the university is to be granted a kind of precarious license. The liminal space the artist-researcher will often occupy is one in which grants certain freedoms. To be able to use humour in earnest, to give voice to the inarticulable through movement, image or

lecture on 'search optimisation heuristics'. The lecture had barely a handful of people and being thus exposed I was asked if I was sure I wanted to be there. At the time I didn't really know, I was applying my own search optimisation heuristic and subsequently used what I learned there to pick my lectures more pertinently.

[49] Call out for *Faking It* conference University of Sussex 2019

sound. Perhaps then it is not the place of the artist-researcher to seek legitimacy but instead to actively negotiate it. To speculate what might in fact count as research and to challenge what a contribution to knowledge might actually be.

7.8 - In closing

Where an academic is granted the access of an expert, perhaps the artist is granted the access of the professional amateur (from the latin *amare* – to love) in a state of open minded epoché to observe, participate and initiate. The proximity-in-difference (Schwab 2012) between scientific and artistic research is perhaps one that is arbitrarily constructed but if it is a fiction then it is a useful one, a fictional re-enactment of an idea that has oscillated back and forth through history. Rheinberger states of the distinction between theory and practice 'Why then construct a division whose only effect is that it permanently has to be undone? The answer is: because it helps to assess the game of innovation, to understand the occurrence of unprecedented events and with that, the essence of research' (Rheinberger 1997, p31).

Borgdorff notes art research constitutes 'an activity undertaken in the borderland between the art world and the academic world' and that 'the crux of the matter is whether a phenomenon like research in the arts exists' (Borgdorff 2010, p31). If to take this question to it's logical extreme such a project shows that art in fact *cannot* constitute research in the traditional sense then in a way by coming to such a conclusion it *does* in fact continue to function as research. This circularity again represents something of the bootstrapping problem explored throughout the project, the dilemma of trying to learn something new given only the resources at hand which are by definition inadequate for the task. As Schwab states 'As much as we seek to understand better what artistic research might be, it can only be in a register of knowledge that is proposed by artistic research' (Schwab 2012, p244). Perhaps then the Birmingham screwdriver offers a method to accommodate this circularity. Through acts of creative resistance, problematising and improvisation provoked through the use of the wrong tool it represents a way of creating knowledge about something by

resisting and transforming it. Distinct, perhaps even opposing, epistemological activities can be taken together, exerting diastolic and systolic pressure respectively. The conscious application of creative resistance created through the techniques outlined above represent ways of exerting this pressure, creating friction with some part of reality, to catch upon it and ultimately to move it.

The contribution to knowledge that this project makes takes the form of the artworks it has produced. These pieces re-ask the question that the project explores, the problem of the Birmingham screwdriver, an example of an artist generating knowledge by harnessing the friction of creative resistance. Or course, these pieces do not claim to cover all the ways in which art practice can generate knowedge. Rather, they offer a view onto some pathways and hopefully invite further exploration. The development of a taxonomy of creative resistance is similarly not meant to be comprehenisve, but rather, it serves to introduce some of the ways this process might be articulated.

This written thesis began with a parsing of the title and I will end in a similar fashion by unpicking the phrase 'original contribution to knowledge'. I am confident that this work is novel and of sufficient complexity both in its construction and conceptual basis to be deemed 'original'. Part of its intellectual value is embedded in the many skilfully applied (and misapplied) techniques and processes that have gone into its production. Where its multiplicity and polysemic nature leaves it open to criticism of lacking the rigour of some traditional methods of study it makes up for in liveliness, ludic humour and creativity that I hope are proven to be valuable and valid aspects of practice as research. This work has contributed in many contexts. It has been live and active both in and outside of the academy. It has engaged audiences, artists and professionals as a live artefact and will continue to be exhibited, transformed and created anew. This leads me then to knowledge. This project has been wildly productive for me, and I leave it in some ways knowing less than I knew when I started. Adopting the techniques of mis-appropriation, misapplication, fictionalising, destabilising all represent techniques to open spaces of un-knowing into which new knowledge can rush.

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