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Airspace – Zones of Fidelity and Failure

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Declaration

I declare that the work presented in this thesis is my own.

Signed

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Abstract

Given our increasing reliance on air travel to function in all aspects of society, it seems imperative to expand our knowledge of airspace and the social relations that air travel enhances and makes possible. My thesis offers a critical analysis of the technical safety systems that support air travel. It finds fissures in the rationality that underlines our belief in the safety and sustainability of air travel and leaves open the question of whether our confidence in this system can be sustained only by the claim that it is inherently rational.

According to anthropologists Geoffrey Bowker and Susan Leigh Star, one of the defining characteristics of technological systems that achieve the cultural status of ‘infrastructure’, is that they ‘become visible upon breakdown’. (Bowker and Star 2000, 335) Two real world events - a commercial airliner’s (Air New Zealand 901) collision with an Antarctic volcano, killing 257 people in 1979 and the closure of European airspace due to the presence of volcanic ash (eruption of Eyjafjallajökull, Iceland in 2010) expose the fragility of the infrastructural systems supporting air travel. As conditions of exceptionality, these events pose a challenge to aspects of our spatial imaginary, allowing us to understand the contradictory interdependence of trust and risk.

Working across media, using video, sound, object making and print, my practice is concerned with the ‘breaking down’ of space. My work reflects my increasing interest in the precariousness of empirically grounded monolithic systems that aspire towards comprehensive totality and stability through their own set of formal logics and structural parameters.

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List of Abbreviations

ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAD	Civil Aviation Division
CDA	Continuous Descent Approach
CEATS	Central European Air Traffic Services
CFMU	Central Flow Management Unit
CIA	Central Intelligence Agency
CVFR	Controlled Visual Flight Rules
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
EU	European Union
FUA	Flexible Use of Airspace
GPS	Global Positioning Systems
GPWS	Ground Proximity Warning System
HACANClearskies	Heathrow Airport Campaign Group
ICAO	International Civil Aviation Organisation
iFACTS	Interim Future Area Control Tools
MAC Centre	McMurdo Air Traffic Control (Antarctica)
MET	Meteorological (Office)
NATO	North Atlantic Treaty Organisation
NATS	National Air Traffic Services
NOTAM	Notice to Airmen

NZALPA	New Zealand Pilots Association
NZDT	New Zealand Daylight Time
PR-NAV	Precision Navigation
RVSM	Reduced Vertical Separation Minima
SES	Single European Sky
SSE	Stop Stansted Expansion
TACAN	Tactical Air Navigation System
TCAS	Traffic Alert and Collision System Avoidance System
VAAC	Volcanic Ash Advisory Centre – MET Office
VFR	Visual Flight Rules
VHF	Very High Frequency (range of radio frequency)
VMC	Visual Meteorological Conditions

Chapter One

Introduction

> Up there in air-space, in that soft, imperceptible field which had been made possible by the century and which, thereafter, made the century possible, becoming one of its defining locations, the place of movement and of war, the planet-shrinker and power-vacuum, most insecure and transitory of zones, illusory, discontinuous, metamorphic, - because when you throw everything up in the air anything becomes possible.
>
> (Rushdie 1988,5)

The rise of a culture of air travel means more of us live greater proportions of our lives in airspaces (between airports, aircraft, flight paths and the social worlds they connect. (Cwerner et al. 2009,4) While the air transportation of people has created a more attenuated relationship with place that expands our spatial imaginary, aviation has also revolutionised the mobility of information, goods, cultural artifacts, letters and much more. (Cwerner et al. 2009,10) Redefining the scale of human geography by reducing the cost of distance in time and money, air travel continues to grow so long as current environmental, safety and security concerns are managed satisfactorily.

The aviation industry consists of a well-developed material infrastructure, specifically designed to facilitate rapid and efficient transport of people, goods and data. This infrastructure consists of airports, planes, air traffic control, air routes, information technology systems, data networks and so on. Given our increasing reliance on air travel to function in all aspects of society, it seems imperative to expand our knowledge of airspace and the social relations that air travel enhances and make possible. I trained as an Air Traffic Controller and so have first hand knowledge of how one very important part of the air travel system works. My thesis offers a critical analysis of the technical systems that support air travel. It finds fissures in the rationality that underlines our belief in the safety and sustainability of air travel and leaves open the question of whether our confidence in this system can be sustained only by the claim that it is inherently rational.

The word ‘infrastructure’ originated in military parlance, referring to fixed facilities such as air bases. (Edwards 2003,186) Today it has become a slippery term, often used to mean the basic structures (e.g. buildings, banking/finance, roads, transportation, power supplies) needed for the operation of a society or organisation. It is essentially any important, widely shared, human-constructed resource. According to anthropologists Geoffrey Bowker and Susan Leigh Star, one of the defining characteristics of technological systems that achieve the cultural status of ‘infrastructure’, is that they ‘become visible upon breakdown’. (Bowker and Star 2000,335)

We tend to think of technological systems as having autonomy from the society that produces them. In any kind of system when there is a breakdown, the tendency is to look for human error allowing an assignment of blame, or for technical failure, rather than at the system itself being inherently flawed. In the modern history of the air traffic system there has been a tendency to lay blame on individuals, as if they were somehow independent from the structure of the systems they are part of. Although most breakdowns would in fact be better explained by complex relationships between operators, systems, natural conditions, and social expectations, social causes are rarely invoked. For instance, when volcanic ash from the eruption of Eyjafjallajökull in 2010 led to the largest closure of European airspace since World War 2, the cancellation of hundreds of flights caused most of us to think only about grounded planes and restrictions imposed by regulators, rather than to question our society’s construction of and dependency on air travel.

Focusing on our increasing dependency on air travel, I examine what happens when the normal infrastructural flows and circulation break down, forcing the user to see beyond the veneer of safety, to the various systems and people behind the working service. The infrastructural underpinnings of air travel are largely opaque to the people who use them, such that interruptions and breakdowns test their confidence in agencies and technologies involved in the production of air travel.

Throughout the twentieth century, increasingly sophisticated aeronautical technologies have co-evolved alongside cultures of aeronautical safety, to minimise known potential risks and make air travel statistically one of the safest forms of transportation. (Budd et al. 2011,8) Trusting not only human experts, but also the technology sustaining air travel, such as automation and decision-aiding systems raises important questions. These automated systems are very much a part of the infrastructural systems underpinning air travel today. (Urry 2009,29) Although engineered to be highly reliable for many known conditions, unpredictable natural processes causing unplanned variations in operating conditions, unexpected or erratic behavior of system components or human operators, system malfunctions, etc. means that there will always be a set of conditions under which the automation will reach an incorrect decision. None of which is consistent with a rational decision to choose to travel by air.

In order to analyse the air transport system as a mobility system in terms of the moment it breaks down, I have developed a methodology combining art and a branch of social science called mobility studies. As an artist and someone who has worked within the air traffic system, moments of systemic break down or exceptions to the norm, are the points that seem to me the most interesting and telling. Drawing upon my experience as an air traffic controller, I introduce through my art practice a subjective, real-time visual and audio interpretation of events that while being informed by social scientific methods are not determined by them. The artworks I have constructed as part of this project introduce a poetic, aesthetic and highly subjective account of the interior of the infrastructural systems supporting air travel. In attempting to situate these art works within the broader objective analysis of how these systems work I am led inevitably to moments of break down, as this seems to be where the two are most co-dependent or configured.

The social science literature I refer to has been inspired and influenced by a paradigm of thought which first became identified with a ‘mobilities turn’ (Hannam et al. 2006) or ‘new mobilities paradigm’. (Sheller and Urry 2006)

Mobility studies encompasses research on the spatial mobility of humans, non-humans and objects; the circulation of information, images and capital; as well as the study of the physical means for movement such as infrastructures, vehicles and software systems that enable travel and communication to take place. (Sheller 2011)

In relation to air travel, adopting a research methodology grounded in the mobilities paradigm offers the opportunity to focus on the practiced and performative dimensions of aerial lives. (Adey 2011) Calling attention to the methodological shortcomings in attending solely to the representations of flight, geographer Peter Adey focuses not only the way aerial life is portrayed, but *done* and lived. (Adey 2011,9) Rather than discarding representation or ignoring the power of the imagination, Adey suggests that the visualisation and imagination of an aerially mobile subject is bound up in the production of aerial subjectivities, in the production of aerial life itself. (Adey 2011,10)

The imagination and visualisation Adey identifies, is a starting point for my artistic work, exploring the production of aerial subjectivities through moments when the various processes and systems that produce these subjectivities break down. These moments of break down become fissures, allowing a glimpse into how these subjectivities are constituted. As an artist I have created a series of artworks that provide an insight into the interior of the system – both through the fissures created by disaster and through the normal functioning of the system, in terms of its resilience and the capacity demands placed upon it. Using mediums such as video and sound, I draw upon the subjective experience of those working within the system, offering poetic, emotive and aesthetic representations that enable us to visualise and further understand the production of aerial life.

The inclusion of artworks in my project contribute to our broad understanding of the social phenomena of air mobility, by providing a sense of visuality to the system in operation, which is somehow different from looking at a plane. In addition, these artworks introduce a level of subjectivity and identification with the people administering the system. While these contributions should be seen as perspectives that engage with many of the same issues and questions raised within social science research, they also provoke alternative responses and reflections. The artworks allow the viewer to generate knowledge and gain experience of how the air traffic system works, by feeding elements back, both in the kind of experiences one has in relation to them and in the way they make this phenomena more immediate. They contribute to the overall project by enabling the viewer to reflect through this immediacy on the systems supporting air travel and the meaning of mobility.

In the late 1980s pioneering research into commercial air traffic control and the real-time management of the airspace occupied by commercial flights was conducted by a team of sociologists and computer scientists, based at Lancaster University in the UK. (Hughes et al. 1988,1992) This study included ethnographic (observational) field work, which looked at the actual practice of air traffic control as it occurred and unfolded, moment-by-moment, day to day, and as it was executed and experienced by the air traffic controllers themselves. Ethnography, with its emphasis on the in situ observation of interactions within their natural settings, seemed to lend itself to bringing a social perspective to bear on system design. (Crabtree et. al 2000) The main virtue of ethnography lies in its ability to make visible the real-world sociality of a setting. (Hughes et. al 1993) The Lancaster study focused on the work of the controllers and their use of the paper 'flight progress strip' - a strip of card measuring about 20 cm by 3 cm containing formatted information about a particular flight - with the objective of contributing to the design of an electronic equivalent.

A key virtue of ethnographic studies when directed toward system use and design is that they place an emphasis on studying the functionalities of a technological system, as they evolve from their incorporation into the socially organised work activities of those who use them; rather than, as in many cases, functionalities as the system's designers might imagine them to be. (Hughes et. al 1988,1992) One obvious thing one can say about air traffic control is that it is done by air traffic controllers and it happens in air traffic control centres. The point is that work happens in a place, and the practical activity that is the object of investigation cannot be separated from the environment or setting in which it is carried out. While these studies did not result in the design and deployment of a new air traffic control system they were crucial in demonstrating the possibilities of sociologists and computer scientists working together in a fruitful manner, as well as the possibilities for using field study findings for design.

Following the air traffic control studies conducted at Lancaster, further studies were carried out by anthropologist Lucy Suchman. Suchman's seminal research on control rooms and office systems, (Suchman 1987,1999, 2007) observed workers in their environment over a period of several months, in order to gain a deep understanding of the actual rather than the formal working practices. Through a project initiated in the late 1980s, Suchman explored in detail the constitution of a technology-intensive mulitactivity workplace, choosing the operations room of a local airport as a study site.

Suchman was interested in developing new ways of theorising both the social and material orgainsation of everyday practice. (Suchman et al. 1999) The study found that it is through the infrastructural details that the texture of our technology-infused society is woven. Ethnographies of the social world, work across the grain of categories and distinctions—cultural and technical, real and virtual—to recover just how the social/material specificities they describe are assembled together to comprise our everyday experience. Critical studies, ethnographies of technologies-in-use, and design interventions are all forms of engagement with the production and re-figuration of that experience. (Suchman et al. 1999)

In Lury and Wakefield's inventory of methods (2012), Suchman raises the question of how humans and machines are configured together in contemporary technological discourse and practices, and how they might be reconfigured, or figured together differently. Suchman introduces configuration as a tool to think about the work of drawing the boundaries that reflexively delineate technological objects, and as a conceptual frame for recovering the heterogeneous relations that technologies fold together. (Suchman 2012,48)
As Suchman explains, configuration has two broad uses:

> First as an aid to delineating the composition and bounds of an object of analysis, in part through the acknowledgement that doing so is integral not

> only to the study of technologies, but to their very existence as objects. And second in drawing our analytical attention to the ways in which technologies materialise cultural imaginaries [1], just as imaginaries narrate the significance of technical artefacts. Configuration in this sense is a device for studying technologies with particular attention to the imaginaries and materialities that they join together, an orientation that resonates as well with the term's common usage to refer to the conjoining of diverse elements in practices of systems design and engineering.
>
> (Suchman 2012,48)

As a practice of figuring things together, Suchman suggests we might consider configuration as one form of what sociologist John Law has named a 'method assemblage'. (Law 2004 in Suchman 2012,55) Law argues that 'methods', are enactments that make relations between what is present (including knowledges, representations, subjects and objects, and what is absent or part of the latter's 'hinterland' (both manifestly, for example in the form of things articulated as 'context' for what is present, and othered, in the form of an open-ended horizon of the unremarkable and/or repressed). (Law 2004 in Suchman 2012,55) Suchman argues that 'it is in this sense that the method assemblage of configuration can be understood as a device for articulating the relation between the "insides" of a socio-technical system and its constitutive "outsides", including all of those things that disappear in the system's figuration as an object'. (Suchman 2012,55)

Feeding into a social scientific paradigm, my own artistic research methodology is closet to the methodology used by Suchman. Objects, videos, sound recordings, images and text all participate in the processes of figuring, drawing attention to particular features of the system, reproducing the conventions of scientific/technical practice and creating a series of representations that are the focus of social discourse. Constructing these representations of an aspect of the air travel system, involves my own position as someone that has worked in

[1] The word 'imaginary' is a term of art in recent cultural studies (see Marcus 1995, Verran 1998). It shares the nice quality with the more colloquial term 'imagination' of evoking both vision and fantasy. In addition, however, it is used to reference the ways in which how we see and what we imagine the world to be is shaped not only by our individual experiences but by the specific cultural and historical resources that the world makes available to us, based on our particular location within it. The general location of the imaginary I am citing here are the circulating information and communication networks of what we might call the hyper-developed countries of Europe and North America. (Suchman 2003)

the system. Such a position and the knowledge it brings, bears upon the relation to what is seen, as much as any meaning inherent within the artworks themselves.

My artworks use various approaches to draw attention to the ways in which the air traffic system's deterministic functionalism dominates as a rational system that excludes alternative forms. Outwardly the system is efficient, cost effective and safe, however subjective judgement, experience and error also play a role. Knowing how it works, understanding it's underlying form as the regulations and scientific principles that govern it, one can reconstruct the decision-making process that made the system (or rather that allowed it to make and sustain itself). This is the imagined socio-technical artefact – the air transport system within the cultural imaginary.

While the written element of my project is an analysis of this dimension in relation to an objective analysis of the system as a system itself, the artworks draw upon the subjective experience of those working within it. They become a way of looking at how the system as an object is inherently not foolproof, largely because of its human dimension. It is this emotive, poetic, subjective view that offers an opening into the system, which becomes particularly visible when the system fails. During such moments, the objective language of the system fails - further fracturing into the people involved thus affirming the significance of the subjective dimension of mobility. This is seen most acutely in *the Antarctic experience* (2011), an installation comprising video, photography, objects and text. The work reveals how a configuration of ideas and imaginaries about the sublime, the Antarctic and technology come together to produce a disaster. To understand disaster, the failure of the system in this case, requires a re-configuration of the human experience involved in it.

Experienced through the prism of the Erebus disaster, *the Antarctic experience* installation allows us to see what the limitations of the system are and how the imaginaries that constitute it can also destroy/undermine it. The debris and pathos of disaster combines with victims, those held responsible and those leading the accident investigation. Here we see an attempt to use the objective language of a complex socio-technical expert system [2] as a way of explaining the cause. However this attempt fails. It is through the artworks, emphasising a subjective dimension of mobility that we gain an understanding of how this objective language fails.

Using configuration as a methodology means acknowledging the enacted rather than the given nature of delineations of 'inside' and 'outside' with respect both to object and to subject boundaries. In utilising the possibilities that video and voice recordings provide, artworks *Heathrow Director* (2013) and *Swanwick* (2013) draw attention to the role of information and communication technologies in relation to the air traffic control room setting. Both works reanimate the time critical nature of a controller's work revealing the extent to which the system affords different solutions to problems it has itself created. In a process of (re) configuration the artworks test the tension that exists in airspace, by appealing to and expanding our imaginary construction of how the air traffic control system works.

The artworks also draw attention to the ways in which technology materialises cultural imaginaries, just as imaginaries narrate the significance of technical artefacts and sustain certain configurations of them. Configuration in this sense is a device for studying technologies with particular attention to the imaginaries and materialities that they join together, an orientation that resonates as well with the terms common usage to refer to the conjoining of diverse elements in practices of system design and engineering. (Suchman 2012,48)

Past experience working in air traffic control allowed me to gain access to the strictly secured control room at the UK's main Air Traffic Control Centre in Swanwick, Hampshire. While in the control room I recorded an informal conversation with three off-duty air traffic controllers (*Swanwick* 2013). The casual and humorous exchange between the controllers and myself is edited together with a moving grid composed of consecutive frames captured from a short 'behind the scenes' video (BBC Visits Swanwick Air Traffic Control 2010). The casual chatter, while standing around a workstation reveals tacit knowledge

[2] Expert systems (Giddens 2008) are ways to organize and manage social environments or large amount of material. Expert knowledge is integrated into society so that it is continuous and ever present

about the system, not usually expressed except on the occasions when the 'normal and routine' break down. As the still frames move up the screen to the sound recording of our informal discussion, two layers implicit within the system are revealed. Firstly the formal public portrayal of the air traffic control centre and secondly the underlying interior of the system expressed through the telling of anecdotes and stories by the controllers. In bringing the two layers together, I attempt to reanimate the figure (in this case the air traffic system).

Heathrow Director (2013) focuses on the temporal and spatial elements of the air traffic system by tracing the sequential movement of flight progress strips. While radar provides a dynamic real-time view of moving aircraft in space, flight progress strips are the material through which the patterns on the screen and thus patterns in the sky are organised to create a 3-dimensional picture. The handling and placement of flight progress strips, is part of the real time recording of what is happening in the sky at that moment, which becomes crucial if the radar breaks down. To make this work I used online simulation games and the scanning of radio frequencies used by pilots and air traffic controllers found on plane spotting sites. Scanning the sky, as if replicating the eye of the controller, rehearsed dialogue and movement in space highlight an abstract and coded language that contributes to an imagined construction of planes choreographed in airspace. *Swanwick* continues this dialogue as an unscripted piece set in a control room, where we hear actual air traffic controllers speak about aircraft occupying a structure in a sky we never see. In both video works, the material content is forced to fold into the formal structure of the system.

Socio-technical artefacts, (such as the air traffic system and planes) are imagined as made. They are fixed within design and engineering discourses precisely not as already existing and independently agential, but as emerging from and dependent upon the actions of their (human) makers. (Suchman 2012,55) Suchman argues that in this sense, configuration as a critical device calls for a kind of alternate re-specification to discovery; a recognition of the historical anteriority of even the most innovative objects; and the material agencies that shape their design. (Suchman 2012,55)

In two of my works, *Luft* (2014) (a split screen video work) and *Descent 111* (2014) (a sound work), the figure of the engineered object – an aircraft engine, is reanimated. *Luft* combines an acoustic reverberation, captured from inside a wind tunnel (a tool used in aerodynamic research), with a passenger's video recording of the aircraft's engine during flight, while *Descent 111* combines the wind tunnel reverberation with a sound recording taken from the ground underneath the flight path towards Heathrow. These recordings and moving images probe a material imaginary, providing ways of entering into and thinking about being in the air and airspace itself. Referring to how humans and machines are figured together – or configured together, these works explore the variety of reconfigurations in play at any one moment of sociomaterial engagement.

According to Suchman, configuration is a practice enacted always from within, in other words, however much its objects may be figured as 'out there' and its concerns focused on how to delineate their relations and boundaries. We are always already inside the worlds that we take as the objects of our actions. (Suchman 2012,57) As Suchman notes:

> Like the scientist enfolded within the apparatus, 'we' (whether positioned as designers or users) are internal to the technologies that engage us and with which we engage. An orientation to configuration reminds us to reanimate the figures that populate our socio-material imaginaries and practices, to examine the relations that they hold in place and the labours that sustain them, and to articulate the material semiotic reconfigurations required for their transformation.
>
> (Suchman 2012,57-58)

The relationship between the air travel system and the kind of cultural imaginaries, which both produce and support air travel are relevant to the way people experience it. Public confidence in the safety of air travel depends on trusting experts, their knowledge (air traffic controller's, engineers, pilots, meteorologists, etc.) and underlying expert systems, designed to eliminate as much risk as possible. Confidence as defined means trust or full belief, coming from the Latin verb 'Fido' meaning 'I trust' or put confidence in. Far from retaining universal meaning, trust is comprised of an aggregation of factors, including delegation of responsibility, investment of faith, informational credibility, accountability and confidence to perform.

In order to gain a greater understanding of what it is that we trust, it is my contention that we need a state of exception or a condition of exceptionality in relation to the norm. Further speculating on the hidden relationship between the systems governing air travel and the larger role air travel plays in society, I refer to states of exception (exceptions to the norm), which reveal underlying tensions existing beneath the infrastructural system supporting air travel. It is important to note that my use of the term ‘state of exception’, in the context of my thesis is distinct from the philosopher Giorgio Agamben’s use of the phrase. Agamben’s use of the term ‘state of exception’ describes the increase of power structures governments employ in supposed times of crisis. Investigating how the suspension of laws within a state of emergency or crisis can become a prolonged state of being, Agamben cites the circumstances of the 9/11 attacks and the detention by the Bush administration of non-citizens suspected of terrorist activities. (Murray 2010,62)

Although terrorist acts are not included in my research, there is no doubt that this threat has been made more difficult to stop by the speed and pervasiveness of the air transport system. While terrorism is a threat to the rule-governed nature of the airspace imaginary, the prospect of willful acts of sabotage targeting the airline industry, is now built into the defences of the air travel system - not substantially different from the normal routine maintenance of technical equipment and the updating of procedures. According to Adey, ‘the increasingly central role of air transport mobility to our society has led to a distinctive kind of mobile society, a “life on the move” - that the aeroplane has worked to imagine, define and mould’. At the same time, Adey argues, ‘the aeroplane threatens to destroy that life and other non-aerial forms of existence’. (Adey 2010,8)

While the cultural history of flight has been well documented, our knowledge of airspaces and the social relations they enhance and make possible have received scant attention. However, the last decade has witnessed a surging and unprecedented interest in aviation and air travel within the social sciences, in part as a result of the ‘mobility turn’ and a new mobility paradigm that has yielded a more systematic interest in physical travel and its relationship with other mobilities, networks and systems. (Cwerner et al. 2009) With air travel being such a significant dimension of contemporary mobility practice, there has been a greater focus on the social and cultural geographies of *aeromobility* – a term used to describe the dominance of flying as a normal mode of international travel, (in much the same way that *automobility* refers to the dominance of the motor car as a means of personal transport). (Beckmann 2001 in Adey et al. 2007).

According to social scientist Saul Cwerner, ‘aeromobilities are now even more important because they have become routine, matter-of-fact, effectively banal’. (Cwerner 2009,6) The fact that air travel has become normalised and continues to be associated with all number of bodily pleasures and excitements – as well as anxieties- suggests aeromobility demands to be theorised as a complex set of social representations, imaginations and practices as much as the outcome of technological advances. (Adey et al. 2007)

Philosopher Charles Taylor throws some light on new practices and institutional forms (science, technology, industrial production, urbanisation), of new ways of living (individualism, secularisation, instrumental rationality): and of new forms of malaise (alienation, meaninglessness, a sense of impending social dissolution). Claiming that modernity is inseparable from a social imaginary, Taylor sketches an account of the forms of social imaginary that have underpinned the rise of Western modernity. (Taylor 2004,2) In describing a ‘social imaginary’, Taylor claims that it is ‘in the ways people imagine their social existence, how they fit together with others, how things go between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlie these expectations’. (Taylor 2004,23)

The social construction of air travel is underpinned by a social imaginary, which incorporates a sense of the normal expectations we have of each other, the kind of common understanding that enable us to carry out the collective practices that make up our social life. (Taylor 2004,24) Both factual and normative, our social imaginary gives us a sense of how things usually go, but this is interwoven with an idea of how they ought to go and what mis-steps would invalidate the practice. (Taylor 2004,24)

Airspace is commonly understood as an efficient, highly technical and rational, rule-governed space produced as an extension of a ground based civil society. However, what Taylor refers to as a social imaginary, extends beyond an immediate background understanding that makes sense of a particular practice. As part of the social imaginary in which people ‘imagine’ their social surroundings, airspace may be expressed as a vast void - an empty transportation zone, not expressed in theoretical terms, but carried in images and stories. Simplifying the most complex of subjects, the creative force of the social imaginary can make mysterious subjects and situations more palatable to the common person.

The complexity and tightness of the various systems that enable air travel produce distinctive environments of risk. Large technical systems, such as airports and the global aviation industry, are sites of riskiness since planes ventured into the sky a century ago. (Urry 2009,28) Flight is risky for those flying, those organising and managing those flights, and for those on the ground as viewers or innocent bystanders. (Urry 2009,28) While a wide array of expert systems have been developed to deal with the riskiness and contingency of air travel, the tight coupling of such interactively complex systems, makes airlines and airports especially vulnerable to small disruptions that produce cascading and positive feedback effects when things go slightly wrong. (Urry 2009,29)

Ordinarily, the complex, largely invisible, aerial infrastructure of flightpaths, control zones and airways, which facilitates this routine aeromobility, is taken-for granted and the only time passengers hear about airspace is when flights are delayed, diverted, or cancelled owing to adverse weather conditions, computer failure, terrorist activity, or industrial action. (Budd 2011) Two real world events, the closure of European airspace due to the presence of volcanic ash (eruption of Eyjafjallajökull, Iceland in 2010) and a commercial airliner’s (Air New Zealand 901) collision with an Antarctic volcano on a sightseeing flight in 1979, reveal the fragility of the infrastructural systems supporting air travel. The volcanic ash cloud event and the Air New Zealand crash (Erebus disaster) can be characterised as exceptions to the norm, which expose a fissure in our belief in the monolithic safety regime of the air travel system, bringing limits of air safety into sharp relief. Posing a challenge to aspects of our airspace imaginary, these states of exception allow us to see what we are trusting in, both it's strengths and limitations. These case studies also show how the sublime is implicit within any attempt to examine aerial life through the prism of break down or disaster.

Positioning us is in the midst of the aerial and entangling us with airspace in a very material sense, these events also evoke a terrible awe-inspiring sublime. The aesthetic category of the sublime defined by philosopher's Edmund Burke and Immanuel Kant, is that area of experience and speculation in which the mind is brought into disconcerting proximity with what exceeds its conceptual power. Discussing a work of art in each of the chapters, I reflect on the sublime and environmental intrusions, which remind us that airspace is never entirely a socially or techno-socially constructed space. It is always premised on an 'earthly' outside, which can never be wholly absorbed into the system.

The ash cloud event resulting from the volcanic eruption of Eyjafjallajökull and the Air New Zealand airliner colliding with a volcano (Erebus) in Antarctica, evoke the sublime in different ways. As an instance of the natural sublime, the volcanic eruption overwhelmed the system, leading to a decision by regulators to shut the airspace system down in the interests of safety. In contrast the Air New Zealand Antarctic sightseeing flights evoked a yearning for the sublime – a sublime wilderness as it operates within culture. However, in this case those operating and regulating the system underestimated the potential risk. The Erebus disaster can be seen as a parable of hubris – a cautionary tale, warning of the consequences of not paying adequate respect to the inherent dangers to which these flights were exposed. In these cases, particularly the Air New Zealand crash, the sublime becomes an important aesthetic property of disaster.

In Chapter Two I discuss the construction of airspace. I begin by examining the development of international airspace legislation from the early twentieth century to the present day, identifying key moments in the formation of airspace and the aeroplane's involvement in the configuration of airspace. For those not involved in the production of airspace, the largely hidden spatial practices of air traffic controllers and pilots is inexplicable. I raise the question of how to describe, explain, interpret and /or represent airspace, as an architecture of movement, informing identities, sensations and emotions, shaped in part by the projected imaginations of all those that comply with it.

As an extension of social space, airspace has a strategic function, utilising codes, data and specialised language to mobilise, assemble and contain airborne objects. Within this space, a complex set of social representations, imaginations and practices combine technology with social engagement. Mediated by different users and agencies, and imbued with meanings, values and significance, airspace is simultaneously produced 'from above' by pilots and controllers, and challenged by people on the ground whom oppose its use. (Budd 2009,132) The requirement to provide sufficient capacity, that is, to enable aircraft to fly through the airspace on request, is defined by the available runway capacity at the airport. The expansion plans of airport facilities and runways often become the focus of intense public debate and resistance.

Expanding upon the impact of airports and flight paths upon neighbouring communities, I discuss the sound-film *Ki-atsu: the sound of the sky being torn* (2011) by Angus Carlyle and Rupert Cox. The work is part of an installation *Air Pressure* (2011), which explores the clash between traditional farming life in Japan and the technology and economy of an international airport through the sound generated by daily life. The project is based on a protest against the expansion of Narita Airport, Tokyo, Japan in 1966 by a farming community living and working on the airports perimeter. Two remaining farming families living at the end of runway 'B' at Narita airport are engaged in a way of life that is tied to the fertile volcanic soil lying on the edges of Mt Fuji. Penned in by international commerce, travel and delivery, the families mark a sharp contrast between the apparent global-shrinking phenomenon of modern mechanics and place-hopping, whilst their own working patterns remain resolutely rooted, grounded, clinging to their small stretch of land. The forces of nature and catastrophe only, arrest the resolute determinacy of the farmers rooted in the earth and the air travellers in the aerial topographies above.

When in March-May 2010, an eruption of the volcano Eyjafjallajökull in Iceland sent a plume of volcanic ash and debris over 30,000 feet into the sky, UK Air Traffic Control took the unprecedented step of closing national airspace to all commercial traffic, a move followed quickly by other European governments bringing international, transatlantic and European air travel to a standstill. The many people stranded in the wake of Eyjafjallajökull found themselves shifting from the routine of unhindered mobility to an involuntary exile, both an absence of choices or alternatives to the situation … and an inability to grab such alternatives even if they presented themselves. Thus, in this type of crisis, widespread systemic stability quickly worked against individuals, rendering them victims. As systemic complexity was brought to a standstill, choices were reduced to a stunning simplicity: fight, flight, or 'wait'. (Birtchnell and Buscher 2011,5)

Chapter Three delves deeper into the closure of European airspace as a consequence of the eruption of Eyjafjallajökull and the decision to stop air travel due to the perceived threat to aircraft safety. The recurrent closure of much of UK and Northern European airspace from 14 April 2010, following the eruption, disrupted the travel plans of 10.5 million passengers, and cost the airline industry in excess of $1.7 billion in lost revenue. (Budd et al. 2011) With the normalised rhythms of industrialised air travel becoming disjointed, the infrastructural systems supporting air travel were exposed. The volcanic eruption not only unsettled our cultural understanding of air travel as a 'safe and normal' activity, but also raised a series of questions about the air traffic control system, the way airspace is imagined and the integration of air travel with the global economy.

As a state of exception created by natural event, the volcanic eruption of Eyjafjallajökull confronted us with a material experience of the natural world that surprised and resisted human desire and ambition. With the culture of mobility particularly ill-prepared for this unexpected force of nature, the Eyjafjallajökull eruption impacted on the very heart of modern (post-) industrial society and disrupted its slick yet fragile order. (Lund and Benediktsson 2011,9) I examine the level of preparedness in place by regulatory authorities to anticipate and react to the volcanic eruption. Taking the fact that volcanic ash clouds happen from time to time all over the world, it can be argued that the potential for the ash cloud to surprise was not because its occurrence could not be subjected to calculations of probabilistic risk, but because its status as an event was determined by how it disrupted – or threatened to disrupt – the networks, infrastructures and systems through which life is organised.

I shall also discuss the artwork and score *4'33"* (1952) by John Cage. The title of the piece refers to the total length in minutes and seconds of a given performance. Timed to conform to the industry standard of Muzak pieces, four minutes and thirty-three seconds was the total length of the work's first public performance. (Pritchett 1993,59) Cage offers us a work, which critiques the commercial expectations of a short piece of music, in which the musical content is emptied and we are left with the outlines of rhythmic structure. Serving as a point of departure for reflecting on the eruption of the Eyjafjallajökull volcano and the suspension of air travel, I discuss the way in which Cage suspends the `normal' performing of a musical/auditory space, permitting the 'outside' noises or the environmental intrusions 'in'. As the audience sat and 'listened' to *4'33"*, Cage reminds us that this 'outside' is always present and is perhaps the very condition of possibility of every musical/artistic performance.

The inability to comprehend a work like *4'33"* other than 'silence' or 'not what music is' produces a moment that while unsettling may also be productive. One could argue that the expectations of the audience of Cage's *4'33"* performance were challenged because the piece was so abstract in it's silence that the audience did not know how to respond. There was an unsettling of the assumptions we bring to the social sphere, in this case art, which a work like *4'33"* is produced in. Indeed during the period of the first closure of UK airspace, when disruption was at its most widespread, silence was used as a narrative framing device in some of the more reflective media commentaries on the event (e.g. see Jeffries, 2010 and Naughtie, 2010 on the ambience of the areas underneath the Heathrow flight paths during this weekend). (Martin 2011,87) There is a sense in which the sudden shutdown of the air traffic control system, allowed our perceptual attention to be redirected towards the natural world. Much like the sublime evoked in a powerful work of art such as *4'33"* shifts the mind to a different register of experience, the ash cloud forced us to step outside of the utilitarian way we live our lives and face the self's relation to something greater.

Chapter Four has a personal connection with my life. Just after 8 am on the 28th November 1979, while working as an air traffic control assistant in the Air Traffic Control Tower at Auckland Airport, New Zealand, an Air New Zealand DC-10 aircraft with call sign [3] TE 901, radioed Auckland Tower requesting route clearance to Antarctica. The flight was a scheduled eleven-hour sightseeing flight with 257 people on board, leaving Auckland in the morning to spend a few hours flying over Antarctica, before returning to Auckland in the evening. What I did not know as I listened to the controller's routing instructions to the crew of the taxiing aircraft, was that the last and final transmission from the aircraft would be four hours later.

The last transmission received from TE 901 was a request to the United States Navy Air Traffic Control Centre in McMurdo, Antarctica for permission to descend. A short time later, after McMurdo allowed a descent to 10,000 feet (3000 metres) and continue visually, radio contact with the aircraft was lost. It was many hours later, after an extensive aerial search that it was established the aircraft had collided with Mount Erebus, Antarctica's tallest volcano (12,448 feet, 3794 metres), killing all on board. The cause of the crash, also known as the 'Erebus disaster', was initially found to be pilot error. However, the accident report was later refuted by a Royal Commission of Inquiry, presided over by Justice Peter Mahon, which went beyond it's terms of reference, blaming the crash instead on the unanticipated interaction of multiple systemic failures.

In the early 1970s wide-bodied 'jumbo' jets heralded a new age of cheaper and faster international travel. After the deregulation of the airline industry in the United States in 1978, questions of cost efficiency, operating profitability and competitive behavior became the dominant issues facing airline management. Key to the expansion of air travel over the last thirty or so years has been the

[3] A call sign is a pronounceable word(s), sometimes with suffix number, serving to identify a communications station (such as an aircraft). Civil aircraft ** are ICAO phonetic letters and numbers derived from international registration; ground station ** are name of airport followed by type of station (tower, departure, clearance delivery, etc). (Gunston 2009)

changing nature of the regulatory framework for air travel, particularly the deregulation and liberalisation that begun in the late 1970s. Airline liberalisation has boosted the will to fly and led to a radicalisation of time/space compression and the obliteration of more territorial boundaries with new regions and localities brought into systems of aeromobility. Deregulation, liberalisation and the new aviation regime have been particularly crucial for the tourism industry world-wide. (Cwerner 2009,7)

The Air New Zealand case is a powerful reminder of the intimate connection between air safety and the commercialisation of air travel. Pointing to a phenomenon much more common within the realm of air travel, that of a tragic air disaster, the Air New Zealand accident was brought about by organisational failure setting the preconditions for human failure. Despite data showing that air travel is among the safest forms of travel, high-profile accidents have always conjured up images of risk and danger that accompany aviation to this very day of mass air travel. (Cwerner 2009,8)

Compared with the existential issues raised during the volcanic eruption in Iceland however, an air accident is a specific autonomous event that inclines towards rational analysis. Air accidents rarely disrupt the functioning of the air travel system. Instead, the air travel system is swiftly returned to confidence in part by rational analysis and in part by an enduring imaginary (Taylor 2004) where there is only a safe, rational, ‘perfect’ system.

I shall further develop the notion of the ‘airspace imaginary’ as a set of shared understandings that imply on one hand an efficiently rule-governed social space and on the other hand an empty place. Moments of breakdown challenge peoples understanding of airspace and aspects of an imaginary aligned with a ‘blind leap of faith’ in the systems infallibility. However, in the case of the Air New Zealand disaster, protections afforded from within the system itself broke down, creating a fissure in a genuinely held belief that air travel is safe and the systems that support it will work perfectly. Revealing what people already know - that systems fail, nothing is foolproof and humans make mistakes, the Air New Zealand crash exposed an aspect of the imaginary being at odds with the way it actually is.

The conflicting reports into what caused an Air New Zealand DC-10 to collide with Mount Erebus, suggested complex systems designed to eradicate failure, produced behaviours that caused a catastrophic disaster. Mining the Antarctic sublime, Air New Zealand exceeded air traffic regulations and systems guarding safety, in order to meet the commercial expectations of a sightseeing flight. The fatal decision to fly below the minimum safe altitude by the crew (later found to be encouraged by the airline) made relevant the latent failures from within Air New Zealand's organisational system and the external danger of the weather phenomenon 'whiteout'.

A Royal Commission of Inquiry into the accident conducted by Justice Peter Mahon, found the original air accident report entirely missed the importance of a flight plan change and the rare meteorological conditions of Antarctica. Justice Mahon's report was notable for it's groundbreaking allocation of culpability to organisational failure, providing enormous insight into human behavior in aviation environments, human-machine interaction and management systems.

The construction of airspace drew heavily on the 17th and18th centuries' exploration of the ocean, with the vast resource of the sky promising to be another realm within which goods and people could move. I shall discuss *The Forgotten Space* (2010), an essayistic documentary film by Allan Sekula and Noel Burch, which focuses on the sea, to make apparent the extent to which the spatialisation of the world is tightly linked to global transport industries. Just as the aeroplane has guaranteed social and geographic mobility along with the promise of economic growth, Sekula and Burch identify the container ship as a visual organiser and a microcosm of the way capital and space relate. We are reminded in *The Forgotten Space* that we are all implicated in keeping the flow of global capital on the move. In the opening prologue of the film we hear the voice of Allan Sekula narrating:

> Of all the forgotten spaces, the sea in its ancient terribleness is the most forgotten. Even though nine tenths of the worlds commerce travels in this way the sea is only remembered when maritime disaster strikes or the black tide rolls in – some of the oil is recovered and burned polluting twice over and then we forget again.

(Sekula and Burch 2010)

While Sekula and Burch 'make visible' the abstraction of commerce through the prism of the container ship, they call attention to the sea as a dominated space transformed and mediated by technology and practice, implemented by standardised systems that strip the sea of its tempestuous determinacy. The ship stacked high with containers, is a contradiction of ubiquity and invisibility, beautifully illustrated by an image of a container stack's shadow cast on the mobile ocean waves. Powerful ships glide effortlessly on a linear course, propelled by fuel kept flowing by distant wars, toward homogenous automated ports dispersing goods to mass, anonymous markets. Sekula and Burch make apparent the underlying forces of society and the invisible base that allows its visible superstructure. Drawing upon this work, I shall further explore the way technological mobility in the form of ships, (trains) and later planes have not only included more people in the experience of travel, but has led to new constructions of space and time that has functionalised and rationalised everyday life.

1a. Art Practice in the Context of Mobilities Research

Research into *mobilities* within the social sciences has opened up possibilities for describing and understanding questions of travel, exploring how ways of imagining place, space and movement inform habits of action and thought in ideological ways. Such geographical imagination often constitutes an unconscious background shaping the construction of knowledge in a wide array of professional and disciplinary contexts, creating silent, unexpected links between seemingly differentiated realms of natural, social and political life.

In addition to my own artistic research, I have situated my project within a body of engagements with arts practice and mobility research to examine a range of methodologies for understanding the ephemeral, embodied and affective dimension of mobility. Research in this field provides various methods to engage with the subjective dimensions of mobility and an analysis of the way these ideas are conveyed through a diverse array of representational strategies. Of particular interest to me is research that recognises the importance of the practised and performative dimensions of aerial life (Adey 2010, Cresswell 2006), which further tease out the sensuous qualities of being airborne and provide a counterpoint to existing research concerned only with commercial aviation in terms of its economic and functioning rationality.

Furthermore, mobilities theory also builds on a range of philosophical perspectives to more radically rethink the relation between bodies, movement and space. Encompassing both the embodied practice of movement and the representations, ideologies and meanings attached to movement and stillness, mobility research has provided analysis and reflexive accounts of the disruption triggered by the eruption of Eyjafjallajokul. Globally impactful events like the ash cloud generate new forms of control and new mobile imaginaries. These are reminders that the power to 'orchestrate' and 'engineer' the environment can be crushed by nature and the cascading effects triggered in our systems. (Birtchnell and Buscher 2011,6)

Situated within a 'mobilities paradigm', geographer Tim Cresswell traces the productive intersections of the social sciences, arts and humanities in understanding mobility. (Cresswell 2006) Cresswell not only draws attention to the material fact of movement but also to the ideas attached to that movement – the embodied social practices with which a physical displacement is always indissolubly entwined. Physical movement such as moving your hand, walking, dancing, exercising, driving to work, moving home, going on holiday, marching, running away, immigrating, travelling, exploring, attending conferences. All of these are forms of mobility but rarely enter each other's orbit in social and cultural enquiry. (Cresswell 2006,1)

According to Cresswell, mobility is central to what makes us human, providing a rich terrain from which narratives and ideologies can be and have been constructed. In making an analytical distinction between movement and mobility, Cresswell discusses the distinction between 'location' and 'place'. Location, he observes, is abstracted space emptied of history and ideology, an unspecified dot in a map. (Cresswell 2006,3) By contrast, place is a meaningful portion of space, location instilled with meaning and ideology. Drawing on this distinction, Cresswell proposes that movement is the dynamic equivalent of location while mobility is the dynamic equivalent of place. (Cresswell 2006,3) Movement is then mobility abstracted from practical contexts of meaning and power. Mobility, by contrast, is movement loaded with social and cultural significance – an amalgam of the brute fact of physical movement, ideas of mobility and embodied practices. (Cresswell 2006,4)

In his book '*On the Move*' (2006), Cresswell examines the interface between mobile physical bodies on the one hand, and the represented mobilities on the other. (Cresswell 2006, 4) Cresswell argues that 'how we experience mobility and the way we move, is intimately connected to meanings given to mobility through representation'. (Cresswell 2006,4) Similarly representations of mobility are based on the ways in which mobility is practiced and embodied. As Cresswell notes:

> To understand mobility without recourse to representation on the one hand or the material corporeality on the other is…to miss the point. Specific forms of imagining mobility may confer legitimacy to common practices and pursuits, such as air travel and imbue them in a normative structure.
>
> (Cresswell 2006,4)

In addressing how the fact of movement becomes mobility, Cresswell traces cultural, social and historical readings of bodily mobility, (including nineteenth photography, physiology, factory-based motion studies and their implications for domestic practices, the regulation of ballroom dancing and the airport as a site for the production of mobilities. (Cresswell 2006,21) This last case study weaves together, the analyses of photographic techniques, migration and citizenship to discuss the regulation of human mobilities at Amsterdam Schiphol airport.

Focusing on the way in which movement becomes intelligible, Cresswell studied a series of photographs by Eadweard Muybridge. Cresswell's invocation of photographer Eadweard Muybridge as a figure of significance in the development of mobility studies, is of particular interest to me as an artist. Cresswell draws attention to Muybridge's painstaking re-enactments of a range of mobile embodied practices in the late nineteenth century, illustrating the significance of visual representation in the analysis of movement. These images were considered to be one of the first attempts to 'capture' the 'truth' of humans and non-human movement in photographic form. (Cresswell 2006)

Muybridge's sequential series of photographs map out bodily movements against a gridded backdrop. As a series of fragments, Muybridge's bodies with their dynamics of projection and repetition, prefigure experiments in film editing techniques as seen by filmmakers such as Stan Brakhage, through to visual art, contemporary digital art, music and in choreography. The deployment of fragments often forms the focus of distinctly obsessive artistic processes, but it always pivots on a delicate, precarious sense of accumulation and projection, since the fragment without its embedding into movement, disintegrates into chaos. (Barber 2012, 24)

Taking motion as the object of his study and excluding everything else, Muybridge's work produced a graphic representation of all the antecedents involved in the genesis of movement. The gridded backdrop in Muybridge's photographs revealed any changes or variations in relation to the 'normal', in other words an index of both function and dysfunction. Cresswell goes on to suggest that Muybridge's use of the grid symbolises rationality and modernity - the ability to quantify and know. As well as playing a role in establishing a modern aesthetic of order, the grid metaphorically evoked the production of space under capitalism. (Cresswell 2006,62) This includes airspace, which had to be constructed as a grid to become commercially exploitable.

Temporalities of slowness, stillness, waiting and pauses are all part of a wider sensuous geography of movement and dwelling in which human navigation of embodied, kinesthetic and sensory environments are crucial. (Sheller 2011) Developments in social research reflect the need to gather new empirical sensitivities, analytical orientations and methods to examine social phenomena that are especially important in the contemporary world with many living 'mobile lives' or at least being affected by the mobile lives of others. These include attempts to move with, and to be moved by, the fleeting, distributed, multiple, non-causal, sensory, emotional and the kinaesthetic. (Busher, Urry and Witchger 2011,6)

As a ‘moving’ (physically, virtually and analytically) form of inquiry, *mobile methods* capture, track, simulate, mimic, parallel and ‘go along with’ the kinds of moving systems and experiences that seem to characterise the contemporary world. (Busher, Urry and Witchger 2011,6) Doing so on the move, such as observing through shadowing, stalking, walk-alongs, ride-alongs, participatory interventions and biographies enable questions about sensory experience, embodiment, emplacement, about what changes and what stays the same, and about the configuration and reconfiguration of assemblies of objects, spaces people, ideas and information.

Thus studies of movement, blocked movement, potential movement and immobility, dwelling and place-making not only illuminate important phenomena but provide compelling new modes of knowing. Through fostering engagement with multiple perspectives, practices and experiences, *mobile methods* provide novel analytical purchase on distributed, connected, fleeting phenomena; complex lived practices of mobility and (im)mobilisation at different scales and their sensory or affective dimensions. (Busher, Urry and Witchger 2011,13)

Sociologist Mimi Sheller has contributed important work towards ways of framing research in the social sciences, revolving around the study of the interdependent movements of people, information, images and objects. Sheller (2013) has adopted an analytical approach for investigating interaction and mobility that emphasis’s attention to actual data of social life, of real people’s activities in real social situations, of how they talk and act relative to emerging contingencies in real time. This provides an opportunity to examine what practices, actions and understandings people use for being mobile, and how these are deployed moment-to-moment in sequentially unfolding interaction.

Methods include ethnographies of micro-interactions of co-presence, participant observation and interviewing of people on the move, ‘time-space’ diaries, ethnographies of virtual and imaginative mobilities of the Internet, methods to research the ‘atmosphere’ or ‘feelings’ of places, use of photographs and objects to recreate memories of meetings and places, tracing the circulation of objects (’follow the thing’) physically or through tracking technologies and methods to research the spatial and temporal dynamics of transfer points such as airports and train stations.

Art critic and historian, Hal Foster, identified an ethnographic turn in contemporary art in the 1990s, following which artists have applied the scientific strategies of anthropology and sociology. Due on the one hand, to the growing interest by sociology and anthropology in visual representations and in image-based research, as well as an artistic adoption and examination of ethnographic methods on the other hand, the relationships between these two disciplinary fields have become consolidated and the number of interfaces has multiplied. Besides a strong imagery, such works of art frequently work with written sources and text-based forms of research. However, these do not constitute the basis for a scientific analysis and evaluation, but stand on an equal footing alongside the image as an additional source of information, or enter into a synthesis with the image. These are part of a complex image-text arrangement – an open, sensuous structure that first requires the viewer's interpretation and has no interest in supplying scientifically verifiably results. (Witzgall 2013,9)

Allan Sekula was amongst those artists whose work contributed to an 'ethnographic turn' (Foster 1996) towards the investigation of given social and cultural contexts beyond the art world. My methodology in this project draws heavily on Sekula's approach. Sekula enters into subject fields often dominated by social sciences and provides a series of representations with textual analysis, revealing a different understanding and perspective. Within my thesis I discuss *The Forgotten Space* (2010), a cine-essay by Allan Sekula and Noel Burch, which uses the statistic that 90% of cargoes today are carried by ship as its cue to develop a wide-ranging thesis about containerisation, globalisation and invisible labour.

Sekula and Burch use a range of materials to move between different contexts, technologies and people: descriptive documentary, interviews, archive stills and footage, clips from old movies. The methods Sekula and Burch use in *The Forgotten Space* provide an insight into the mundane 'happening' of movement by following container ships, barges, trains and trucks, listening to people, engineers, planners, politicians and those marginalised by the global transport system. A combination of poetic connections and factual commentary makes *The Forgotten Space* a multi-layered film essay, creating meanings through the reverberation between disparate scenes, visual metaphors, and suggestive narration.

Sekula's sustained exploration of the ocean as a key space of globalisation, has produced images that explore carefully and critically, the maritime industry setting. In questioning who made this place, how they did so, why and in whose interests, Sekula creates subtle interactions between images and texts, treating the facts of the matter as occasions for low key, direct and persistent probing, as if words and pictures searched always for the truth at hand, knowing that neither would find it, but that their interplay might at least suggest it. Using these methods Sekula scans the systems that support this world, asking how is it held up, is it being adequately maintained, how might it be improved? Image after image, Sekula makes visible the world's larger processes - as they unfold right before our eyes, in this particular place and time - existing as facts about things and as the irreducible constituents of individual experience.

Many contemporary artists have engaged with airspace through their art practices. Examples of these were included in the exhibition, *Flight and the Artistic Imagination* at Compton Verney (2012). The exhibition explored artists' creative responses to flight, through a combination of paintings, sculpture, photographs, drawings, prints and video, including works by Leonardo da Vinci, José Francisco de Goya y Lucientes, Paul Nash, Hiraki Sawa, Layla Curtis, Robert Smithson and James Turrell. Also, the *Arts Catalysts International Artists Airshow* (2004) extended the relationship between art and science, engaging with issues or problems beyond scientific reach or excluded/overlooked by a conventional scientific approach using the deserted Aeronautical research facility at Farnborough as a creative resource. As previously mentioned, two of my own works *Luft* (2014) and *Descent 111* (2014) incorporate the acoustic profile of one of the abandoned wind tunnels at Farnborough. In these works, I attempt to recover scientific/engineering practices to draw attention to the histories and encounters through which the aircraft is figured into existence.

Artists such as Robert Smithson and James Turrell have used their experience as pilots and their collaborations with scientists and engineers, to develop a set of ideas that became integral to their artistic practices. Both Smithson and Turrell were invited to take part in the Los Angeles County Museum of Arts, *Art and Technology Program* (1967-1971) that paired artists with corporations to collaborate with company scientists and engineers. Turrell collaborated with Dr. Edward Wortz,, a perceptual psychologist at Garrett Aerospace Corporation. At the time, Wortz was investigating the perceptual consequences of space travel for NASA. (Tuchman 1971) Though nothing concrete materialised from their collaboration, the experience encouraged Turrell to further explore perceptual deprivation and the 'ganzfeld effect' – a phenomenon of perception caused by exposure to an unstructured, uniform field. The effect can be compared to the natural visual phenomena of 'whiteout'. In making use of the basic interrelationship that exists between light and space, Turrell's 'ganzfelds' have been successfully realised as a series of immersive, atmospheric light installations.

Similarly in 1969 Robert Smithson was invited to tour Kaiser Steel and American Cement (two of the sponsors of the program), where Smithson directed his attention to the raw materials and processes used in the making of steel. Smithson also visited a limestone mine, which shaped his intention to execute a work in one of the vast abandoned caverns inside the mine. After submitting several project drawings to American Cement they responded saying they had just experienced an upheaval in corporate management and were no longer likely to take any artist-in-residence. Kaiser also indicated a lack of interest in Smithson's proposals. (Tuchman 1971)

In the same year Smithson was hired as an artist consultant to the New York - based architecture and engineering firm Tippetts, Abbett, McCarthy, Stratton (TAMS) to develop plans for the Dallas - Fort Worth Regional Airport. The initial work of TAM's was to conduct intensive land surveys and air-space simulation studies. Their concept was to design an airport from the air down. The resulting reams of abstract materials of aerial photographs, topological maps and computer data interested Smithson. Various phases of this plan for the

airport and the broader relationship between art and the aerial were laid out as drawings and two essays, produced during his year-long tenure as artist consultant. Beginning to conceive of a notion of aerial art, or works visible from airplanes ascending from and descending into the terminal, Smithson planned to locate his sculptures in the clear zones, or the areas surrounding the runways with the greatest accident potential. (Smithson 1996,116)
Although the collaboration had no tangible impact on TAM's plan for the airport, the experience was the critical impetus to Smithson's idea of the non-site and the development of earthworks, including one of his most important works *Spiral Jetty* (1970).

Situated between art and architecture, works by Smithson and Turrell display a spatial imagination freed from the questions of utility and economy.
In creating 'natural formations' (Smithson's *Spiral Jetty* or Turrell's *Roden Crater* (1974) (an extinct volcano the artist has been transforming into a celestial observatory for the past thirty years), Smithson's and Turrell's artistic processes are resonant with scientific/engineering knowledge. However, rather than illustrating scientific principles, their work expresses a certain consciousness and 'knowing' that is distinct from the kinds of activities a scientists/engineers might undertake. There is a sense in which both of these artists question intellectual authority by re-claiming science in their attempt to reshape our artistic experience, turning it into an experience in orientation (including an orientation of vision suggested by air travel).

Turrell and Smithson were primarily concerned with using the aerial view as a way of denying normalised points of view to purposefully disorient the viewer. Artwork's by Smithson and Turrell invite its viewers to look for new ways of approaching them; by negating vision they present the viewer with an unprecedented problem: how is one to experience the work? The viewer must reorient his/her gaze to confront the very question of what it means to be looking at art. (Rigaud 2012) For Smithson and Turrell the experience made available through art would potentially expand the definition of what art could be.

In contrast, my project expands upon the experiential knowledge and expectation formed by the way air mobility is represented in the cultural imaginary, through a series of representations and textual analysis aligned with subjective experience (when we are no longer contained within the structure). In relation to the exhibitions and artists I have mentioned, my work is most closely positioned to that of Allan Sekula, particularly in the way in which social science and art are used together to further explore relations between work, technology and organisation.

As Sam Smiles, the curator of the *Flight and the Artistic Imagination* exhibition reminds us, the sky as a by-product of aerial warfare became a tablet on which was impressed the traces of flight. (Smiles 2005,85) These traces range from the spectacle of searchlights to the tracks of the high-flying aircraft of the Second World War, enhanced by the vapour trails produced at high altitudes. Nowadays we take the sight of aircraft for granted, only noticing their ubiquity when the skies are clear - as in the wake of the 9/11 attacks or the shutdown of European airspace during the Eyjafjallajokull volcanic eruption of April 2010. (Smiles 2005,85)

In the next chapter, I explain how practices of ordering, controlling, navigating and contesting the sky are all implicated in the production of the various geographies of airspace. I take a closer look at how airspace is structured and managed, examining the development of international airspace legislation from the early twentieth century to the present day, identifying key moments in the formation of airspace and the aeroplane's involvement in reinforcing container-like definitions of territory and citizenship.

Chapter Two

The Nuts and Bolts of Airspace

> One tube drains into another, the conduits getting narrower and narrower, until finally the passenger is injected into the most enclosed and air-conditioned tube of all, the aeroplane itself. Where the chimney merely reaches into the sky, aircraft turn the open and disorderly meteorology of the air into a grid of tunnels and chimneys bored through what we call airspace, the newest of our architectures.
>
> (Connor 2004)

Evoking the hollowed out space in Gaston Bachelard's *The Poetics of Space* (1994), airspace seems to have qualities of a burrow formed from the body's own shape and the track of its movements, spun from the inside outwards. Bachelard insists on the participative dynamism, which always accompanies the imaginative entering into air, treating the air as a space for expansion, stimulating the desire for flight. (Bachelard 1943 cited in Connor 2003) The air is all space - or, rather, we should say, room - and is evoked in terms that express the easy overcoming of air, or unobstructed passage through it. Back on the ground at National Air Traffic Services (NATS) in Swanwick, an Air Traffic Controller describes the way he stacks airplanes in order to meet the available capacity requirements at Heathrow airport; 'they are all geared to arrive one after the other like a sausage machine….it is standardised and intense, with no time to be distracted'. (Boulton 2011)

Shaped by an act of mapping and perceived as a grid of intelligibility, airspace is part of an intensely developed infrastructure specifically designed to facilitate rapid and efficient transport of people, goods and data, mediated by the practices of the largely hidden aeronautical technology and spatial practices of Air Traffic Control (ATC) and the piloting of aircraft. The commencement of flying by fixed wing aircraft at the very beginning of the twentieth century, marked by the Wright brothers' first flight in 1903, meant that airspace became an actual space. However, airspace seemed to be a volume without visible limits or definition, and therefore from the 'conception of boundaries' as a 'lateral description', it was difficult to grasp mentally. (Adey 2010,70) The air needed to be organised to meet the urgency of the present moment leading to the development of navigable airspace – a largely invisible, interlocking aerial geography of command and control. Transcending the physical two-dimensional limits of land-based movement, the advent of flight meant embracing a third (aerial) dimension, organised into a spatial system of air routes and corridors traversed by aircraft.

A generally accepted view early in the last century, was that airspace as a road of the air is a free and universal thoroughfare for all humankind and is almost everywhere navigable, unhampered by barriers obstacles and limitations. Countries with developing aviation interests, including the UK and US, advocated complete freedom of the skies, cautioning against any bureaucratic intervention (other than that which helped secure their aerial hegemony). An English aeronautical engineer and conservative party politician from 1922-1929, Sir Charles Dennistoun Burney, designer of the British airship prototype HM Airship 100 [1] argued:

> The road of the air is a free and universal thoroughfare for all mankind. As wide as the world, and almost everywhere navigable, it is unhampered by any barrier, obstacle or limitation….Any restriction to its usage will be an arbitrary restriction imposed by the will of man.
>
> (Burney 1929,169)

The air at the beginning of the last century, looked boundless to the ordinary observer, but not to lawyers, who knew that Anglo-American law drew invisible property lines in the sky. (Banner 2008,16) A nation's right to cordon off its own airspace raised questions - was national defence paramount or did commercial

[1] HM Airship R100 was a privately designed and built rigid airship made as part of a two-ship competition to develop new techniques for a projected larger commercial airship for use on British empire routes. The other airship, R101was built by the UK Air Ministry. One goal was to eventually offer a regular and comfortable trans-Atlantic service, akin to that eventually offered by the German Graf Zeppelin. (BBC 2009)

and travel interests prevail? The question was not new in regard to the sky as it had been subject to a famous debate three centuries earlier with respect to the ocean, which was to the 17th century, something like the atmosphere was to the 20th – vast resource newly opened up for exploitation. The 17th century debate was between Dutch lawyer Hugo Grotius arguing '*Mare Liberum*', no nation could claim exclusive rights over the ocean and English lawyer John Seldon, responding with '*Mare Clausum'*, arguing nations could exercise control over water just like they did over land. Seldon insisted that the ocean could be possessed asserting that there was nothing in the nature of the water that rendered it incapable of being possessed, as was demonstrated by the common undisputed possession of lakes and rivers. Grotius claimed that the ocean was too big and too fluid to be owned by individuals, therefore that which cannot be occupied, or which has never been occupied, cannot be the property of any one, because all property has arisen from occupation.

Aerial sovereignty drew heavily from the argument between Grotius and Seldon with Grotius's views prevailing, as International law would come to allow nations to exercise sovereignty only in the immediate vicinity of their coasts, while the rest of the ocean was open to all. (Banner 2008,46) Trade via the ocean had so enriched the world by the early twentieth century that it was hard to imagine life without it. The air promised to be another ocean, another realm within which goods and people could move from one nation to another, for the benefit of all. (Banner 2008,52)

The next question raised was whether airplanes had the same freedom of navigation in the air that ships had in the ocean. In 1901, Paul Fauchille a leading French scholar of international law analysed the air in much the same way as Grotius had analysed the problem of the ocean three centuries earlier. The conclusion was that it was physically and materially impossible for a people to exercise over the air an effective grasp, to mark it with the seal of its authority. As this was in the days before the invention of the airplane it was thought that the only way to occupy it was to launch balloons into it. However on the expectation that there would be airships capable of hovering in a single location, further reasoning seemed to suggest that they would not be capable of marking out a portion of the air. Appropriation by this method, if it were possible, would only give the State a confined possession, limited to the volume of the airship. (Banner 2008,49)

In the summer of 1900, New York newspapers reported the experiments of the retired German general Ferdinand Graf von Zeppelin, who flew a 420-foot hydrogen-filled dirigible for eighteen minutes above Lake Constance in Friedrichshafen, Germany. Where most viewers would see the potential in aviation, an American lawyer, Charles Moore saw a potential problem. Moore pointed out that under principles of Anglo-American common law, the owner of land also owned the space above the land, with no height limit. As the ancient maxim put it, *cujus est solum ejus est usque ad coelum*—he who owns the soil owns up to the sky. From property law, the maxim proposed territory, with three dimensional or volumetric properties. If commercial air travel ever became technically feasible, surely it would be possible to overcome the objections of the people who owned the land beneath. 'Free as air' is a common saying, but when one desires to use another man's air he finds that, like many other common sayings, this one is only partly true. It is a principle of law that he who owns the land owns it up to the skies, and may forbid trespass in the air above as well as in the earth beneath. (Banner 2008,12) With virtually all land owned by someone, where could an airship fly? It would be trespassing everywhere it went. Would every landowner along an aerial route be entitled to damages for trespass? (Banner 2008,12)

The world's first airline, a government subsidised German airline – DELAG, began operating Zeppelin airships in 1909 on a regular scheduled passenger service across the Atlantic. (Grossman 2012) In Europe, where nation states were geographically linked within a smaller space, development of international aviation law was being drawn up from debates over aerial sovereignty. It followed that a sovereign could allocate rights in the air. However there were difficulties in trying to obtain unanimous agreement on the use and regulation of airspace between different aerial nations. There were subsequently many socio-legal debates to be had over geographical airspace before the convening of the 1910 International Air Navigation conference in Paris to discuss international air law code.

The British in particular, were concerned over the views of some foreign countries on the question of the administration of airships, as it closely affected important national interests. (Adey 2010,71) While praising the freedom and emancipation that powered flight afforded, the reconfiguration of space and territory had a political dimension, concerning the combined military and commercial threat aircraft posed. Territorial integrity of individual states, led to nation-states seeking to cede as little and seize control of as much airspace as possible, manipulating international agreements governing economic regulation for their own commercial advantage while retaining control over their borders for reasons of defence and national security. (Petzinger 1995, cited in Budd 2009,116)

In 1916, during the First World War, the first British fixed wing airline began operating regular relief flights between Folkstone and Ghent, carrying essential food and supplies to Belgium. In 1919, the first scheduled passenger flight commenced between England and France, just as the production and control of global airspace was becoming a matter of intense political concern. While the British Aerial Navigation Act of 1911 had declared that Britain's airspace (including that of her colonies and dominions) was sovereign territory and inviolable, national control over airspace was not formally enshrined in international law until the Paris Convention of 13th October 1919. (Budd 2007,2)

The right of self-protection was limited to the lower parts of the airspace, just like the nation's sovereignty was limited to the parts of the ocean closest to the shore. This meant that a zone or belt of atmosphere, corresponded to a belt of territorial waters, and an upper region of the air—the supra-territorial atmosphere corresponded with the open sea. (Banner 2008,51) With the technological developments of the mid-19th and early-20th centuries, not only did ships become more powerful, technology allowed humanity to exploit ocean resources that had never before been envisioned. Fishermen, once limited to areas near their own coasts, were now equipped with vessels that could allow them to stay at sea for months at a time and capture fish harvests that were far from their native waters.

Evolving technology also allowed for the exploitation of previously inaccessible offshore resources, most notably oil and precious metals. Defined by the 1982 United Nations Convention on the Law of the Sea, the sovereign territory of a state is protected by its ‘territorial sea’, stretching 12 nautical miles from its coastline, including the airspace above. Within the boundaries of UK sovereign airspace today, security stretches 12 nautical miles from the coast, otherwise airspace legislation regarding the high seas and military operations can take due regard. The agreement addresses a myriad of issues including navigational rights of ships and aircraft, limits on the extension of national sovereignty over the oceans, environmental protection of the oceans, conservation of living resources and mining rights.

Contemporary airspace has historically developed from military airspace emerging from the significance of air power and the huge military advantage that is accorded to those who control the air. In 1934, as one of his first commissions for the Nazi party, architect Albert Speer famously used anti-aircraft searchlights pointed skywards, as a replacement for stone pillars at Nuremberg. The beams merged into a general glow several miles up and formed a giant canopy generating the effect of a rectangle of light in the night sky. From the clouds, Adolf Hitler would descend upon Nuremberg in his airplane while a band played the Nazi party’s anthem: *Hoest Wessel Song,* also known by it’s opening words, Die Fahne hoch *(‘The Flag on High’*).

The combination of Speer’s light and the plane, was a form of propaganda that relied upon the manipulation of contrasts, both visual and sonic: light and shadow, earth and sky, man and heavens, the solitary face and the mass rally, human beauty and inanimate nature, music and blackness. But these pairs were not simply presented as opposites. Always hovering at the limits of these contrasts was the presence of mist, cloud, shimmering light, dust, haze, the fluttering of flags—anything to prevent the emergence of reflexivity or critical resolution. (Power 2007) Speer’s architectural light projection reflected the Nazi party’s swelling sense of territory, inscribing the sky in a gesture that connected the air to the metaphysics of political power. Effecting a spatial and political connection, the pillars of light extending 25,000 feet into the sky were a perfect blending of technology and ideology that would overwhelm the masses with the paradigmatic employment of sublime effects.

During some of the Nazi rallies the gigantism of the Zeppelin, a new generation of airships developed from derigibles by Count von Zeppelin, fitted perfectly into the Nazi cultural scheme to manipulate the masses. Aside from the Nazis co-opting the airship symbol, Zeppelins were making regular trans-Atlantic crossings from Europe to North and South America. Marketed using brochures explaining how simple and fascinating travel really was, the Zeppelin offered a first class standard of service and comfort that became the epitome of elite travel. However the Zeppelins trans-Atlantic flights came to an abrupt halt after the Zeppelin ‘Hindenburg’ caught fire and was destroyed while attempting to dock at its mooring mast in Lakehurst, New Jersey in 1937, shattering public confidence in the airship as a mode of air transportation.

During an interview with a surviving member of the Hindenburg’s crew, Werner Franz [2], aged 14 at the time of it’s catastrophic explosion was asked, ‘Werner, what was your most unforgettable moment of Zeppelin life, other than May 6, 1937?’ Werner thought for a moment, nodded and spoke of one particular flight to South America when the Hindenburg and her sister ship Graf Zeppelin met in mid-air - ‘the two massive Zeppelins circled one another like porpoises, a sight which was seen by nobody other than the ships crew and their astounded, elated passengers. “That moment” Werner said, “was just for us”.’ (Russell 2005) Werner’s metaphorical porpoises circling in mid-air evoked the ‘freedom of the sea’, recounting a moment when the incredible size and sophistication of the Zeppelin created a vision of the technological that could transfix the imagination.

In the aftermath of the Second World War the skies were opened up to mass air transport, with the appearance of the first set of aerial navigation charts designed specifically for commercial use. These early airspaces were relatively easy to map, but as aircraft began flying progressively faster, longer and higher,

[2] Werner Franz was a cabin boy on the Hindenburg on May 6,1937. His recollection of working life aboard the Hindenburg Zeppelin was noted in an interview with Patrick Russell in 2004 (Russell 2005) when Franz was 82 years old during a dedication ceremony at the Hindenburg-Zeppelin museum in Germany.

new universal classification systems had to be devised. (Budd 2009,124) The sky was parcelled out between nations and subdivided into a number of discrete 'blocks' that were subject to different rules and regulations. (Budd 2009,117) With the development of the jet engine, invented in Britain and Germany in the 1930s by Frank Whittle and Hans von Ohain, came greater speeds and payloads, offering the promise of much higher productivity, lower airfares and a bigger transportation market. (Bowen 2010,22)

The convention of international civil aviation (known as the Chicago Convention) signed by 52 states on the 7th December 1944, established the rules of airspace, aircraft registration and safety. Bilateral and multilateral air service agreements stipulated which airlines could fly, which airports and airspace they could use, how frequently the services could operate and the airfares they could charge. (Budd 2009,117)

Within Europe, airlines such as British Airways and Lufthansa operated in a highly protected market, insulated from any form of effective competition. However a few years later in 1978 a federal law was passed in the United States - the Airline Deregulation Act, removing government control over fares, routes and market entry. In Europe it wasn't until the late 1980s, with increased public dissatisfaction with high airfares, combined with the rise of neo-liberal economic ideologies and pressures on public spending that European governments were encouraged to embark on a programme of air transport liberalisation. (Balfour 1994, cited in Budd 2009,117) The advent of the commercial jet slashed the cost of distance, both in terms of time and money and has been instrumental to the expansion of tourism, especially long distance tourism.

The removal of anti-competitive legislation, through three progressive packages of liberalisation measures in the 1990s, has revolutionised the industry and allowed new airlines to enter the marketplace for the first time resulting in slashing the cost of distance, both in terms of time and money. (Budd 2009,117) Lower airfares have stimulated passenger demand, creating a dramatic rise in passenger numbers and an increase in flights, presenting enormous challenges for Air Traffic Control. The existing airspace structure, while able to handle mid-twentieth century traffic volumes, was not able to accommodate this additional traffic so new areas of controlled airspace have been ‘bolted on’ to existing sectors, to handle the increased numbers of aircraft. While these measures have offered a short-term solution to the problem, it has made the airspace structure even more complicated, (Budd 2007,3) which I will discuss more fully in the second half of this chapter.

More of us fly now than ever before. The historical drive towards a virtual ‘open skies’ regulatory framework has led to time/space compression - a process that has caused the relative distance between places to contract. International tourism is made possible by charter and scheduled aircraft flying between cities and continents. Geographical proximity in most countries no longer shapes social relationships and this is in part due to people being able to fly rapidly from, over and past spatial proximities, forming new time - distanciated proximities. The rapid growth and advancement of air travel is also changing risks and the development of intersecting expert systems that make movement through the air contingently possible. (Urry 2007,135) Even more significant as the planes themselves, are the systems that enable the space *above* the ground to be regularly, safely and predictably moved through by very large numbers of travellers. (Urry 2007,136)

According to sociologist Anthony Giddens, in order to understand the intimate connections between modernity and the transformation of time and space, we have to start by drawing some contrasts with time-space relations in the pre-modern world. (Giddens 1990,17) Until the eighteenth century, the fixed position of most human beings in a geographic locality - so closely related to their fixed position in the social order - was accepted as an inevitable part of human destiny. Time reckoning, which formed the basis of day-to-day life for the majority of the population linked time with place – usually imprecise and variable. Reference to socio-spatial markers: ‘when’ was universally either connected to ‘where’ or identified by regular natural occurrences. In the late eighteenth century it was the invention of the mechanical clock and its diffusion to virtually all members of the population that marked the separation of time from space. (Giddens 1990,17)

Giddens claims that the separation of time and space is crucial to the extreme dynamism of modernity as it is the prime condition of what he refers to as a process of *disembedding*. He describes this process as 'the lifting out' of social relations from local contexts of interaction and their restructuring across spans of time-space. (Giddens 1990,21) The two types of *disembedding* mechanisms intrinsically involved in the development of modern institutions are the creation of symbolic tokens (money) and the establishment of expert systems (systems of technical accomplishment and professional expertise that organise large areas of the material and social environment). (Giddens 1990,22)

The time and space distanciation Giddens describes, refers to the tendency for modern relationships to be increasingly distant. In such a system, trust becomes necessary because we no longer have full information about social phenomena. Trust is therefore involved in a fundamental way with the institutions of modernity. Trust here is vested, not in individuals, but in abstract capacities. Both enabling and constraining, these systems overcome distanciation, (which Giddens defines as 'simply a measure of the degree to which friction of space has been overcome to accommodate social interaction') and simultaneously commits the user to the discipline of the grid. Once the choice has been made, one is constrained to use the system as it has been organised. (Giddens 1984,222)

Looking closely at the systems in which the knowledge of experts is integrated, influences many aspects of what we do in a continuous way. This involves trusting their competence, as in the authenticity of the expert knowledge, which they apply. (Giddens 1990,27) In the case of the air traffic system - everyone knows there is the risk of an accident when flying, but we all accept that risk, relying on the aforesaid expertise to guarantee that it is minimised as far as possible. When one boards a plane, one enters an expert system, of which our technical knowledge is at best rudimentary.

Giddens argues that risk and trust intertwine, with trust normally serving to reduce or minimise the dangers to which particular types of activity are subject. In all trust settings, acceptable risk falls under the heading of 'weak inductive knowledge' and there is virtually always a balance between trust and the calculation of risk in this sense. What is seen as 'acceptable' risk – the minimising of danger – varies in different contexts, but is usually central in sustaining trust. Thus traveling by air might seem an inherently dangerous activity, given that aircraft appear to defy the laws of gravity. Those concerned with running airlines counter this by demonstrating statistically how low the risks of air travel are, as measured by the number of deaths per passenger mile. (Giddens 1990,35)

Some four decades ago, Henri Lefebvre agued that space is a medium inextricably linked with the expansion of capitalism. Investment in space, such as highways, airports, and other infrastructural elements, extend the concept of fixed (constant) capital confined in its connotation to equipment, premises and raw materials. (Lefebvre 1991,345) Using the example of radar networks and their use in designating airways, Lefebvre reconsidered the concept of fixed capital to include transportation grids that in his view exemplified productive consumption because they serve to move people and things through circuits of exchange and secondly because they constitute a worldwide investment of knowledge in social reality. Lefebre's insight into the centrality of reorganising and controlling space for capitalism led to a 'spatial turn' [3], emphasising the systemic impact of geometrical representation and territoriality, influencing everything from social constructions to the phenomenological experience of lifeworlds. The 'spatial turn', at its most basic level, includes a rejection of some of the grand narratives of the twentieth century and the recognition of the ways that the social worlds we live in are impacted by spatial differences.

Discussing the social production of spaces, Lefebvre describes the transition from pre-modern *Absolute space* (variously including anything divinely authorised or primordially cohesive) to 'modern' abstract space (systematically rationalised). (Lefebvre 1991,47) According to Lefebvre social space is underpinned by the bedrock of *Absolute space* – at once civil and religious preserving and incorporating bloodlines, family, unmediated relationships, but it

[3]The spatial turn (Warf and Arias, 2009) involves a reworking of the notion and significance of spatiality to offer a perspective in which space is every bit as important as time in the unfolding of human affairs, a view in which geography is not recognised to an afterthought of social relations, but is intimately involved in their construction. Geography matters, not for the simplistic and overly used reasons that everything happens in space, but because where things happens is crucial to knowing how and why they happen.

transposed them to the city, the political state founded on the town. (Lefebvre 1991, 48) The invisible fullness of political space (the space of the town-state's nucleus or 'city') set up its rule in the emptiness of a natural space confiscated from nature. *Absolute space* becomes relativised: its naturalness is smashed by the forces of history, and 'upon it's ruins [are] established the space of accumulation (wealth and resources: knowledge, technology, money, precious objects, works of art, symbols), which Lefebvre calls "historical space".' (Lefebvre 1991,49) This tendency appears in the late imperial or the medieval period, a secularised version of the political and social space of Rome. Exchange value becomes general through the circulation of gold and silver. Relational networks of markets and communication systems are established in historical space, a process that, according to Lefebvre, promotes increased social differentiation and a growing abstraction of daily life. (Dimendberg 1998,23)

Picking up on Lefebvre's understanding of spatiality in terms of human practices, geographer David Harvey draws attention to Lefebvre's tripartite division of material space – space as experienced through our sense perception, the representation of space (space conceived), and spaces of representation (space as lived). Material space is for us humans, the world of our sense perceptions (hear, feel, smell and infer the nature of space from those experiences), as they arise out of the material circumstances of our lives. We use abstract representations (words, graphs, maps, diagrams, pictures, geometry and other mathematical formulations) to represent space as we perceive it and in so doing deploy concepts, codes and abstractions.

According to Harvey the correspondence between the material space of perceptions and representation is always open to question and frequently fraught with dangerous illusions. Harvey points out that Lefebvre insists that we also have imaginations, fears, emotions, psychologies, fantasies and dreams, implying that spaces of representation refers to the way humans live-physically, affectively and emotionally - in and through spaces we encounter. (Harvey 2009,142) On further developing Lefebvre's theory of the production of space, Harvey draws attention to the political economy of space. Offering a comprehensive critique of contemporary capitalism, Harvey claims 'the emergence of the capitalist system initiated a long-term investment in the conquest of space'. (Harvey 1989,264)

If capitalism has been the history of the conquest of space, globalisation is the conquest of space by time. As Harvey explains 'the first great surge of modernism took domination of nature/space as a necessary precondition. The rise of globalisation has enabled the domination of space by time.' (Harvey 1989,227) According to Harvey, 'Marx foresaw this eventuality when he described the search for profits as the search for "moments"— the whole economic edifice ultimately reduces itself to an "economy of time".' (Harvey 1989,227)

Harvey claims that the expansion of tourism, made possible by the jet and the creation and re-creation of ever-newer space relations for human interactions, was one of capitalism's most signal achievements. (Harvey 2010,189) In the early years this activity was generally conceptualised in terms of a triumphalism manifested by the human domination over nature (partly offset by aesthetic sentiments that romanticised the relation to nature). Harvey argues that the dramatic reorganisation of the geographical landscape of production, exchange and consumption with changing space relations, is not only a dramatic illustration of capitalism's penchant for the annihilation of space through time, but it also entails fierce bouts of creative destruction - for example the jet engine complements and even supplants the internal combustion engine as a primary means to define spatial accessibilities. (Harvey 2010,189,190)

On December 7 1972, the Apollo 17 crew took a photograph of earth that became known as 'The Blue Marble' because of the whirling clouds above the continents. Knowledge of the provisional and contingent sustenance of earth, adrift from the biosphere and looking back at it, deeply intensified the spatial vertigo of these images and their implications. One of the powerful effects of the Apollo images was to prompt reflection on the interrelationship between and interconnectedness of the planet's inhabitants. The pictorial registration of the earth isolated in the vastness of space suddenly made it seem small and relations on it necessarily close. (Dorrian 2013, 300)

Airplanes provided the material possibility for *aerial vision*. Accelerating a general shift in 'planetary consciousness', aviation and the development of airspace increasingly allowed the Western subject to regard the world as considerably smaller than it appeared in the nineteenth century. This was a way of seeing, which convinced aerial viewers that their mobility was now possibly boundless. Geographer Denis Cosgrove characterises it as an 'Apollonian gaze' that 'pulls diverse life on earth into a vision of unity…a divine mastering view from a single perspective'. (Cosgrove 2001,11) He continues 'the theme of ascent connects the earth to cosmographic spheres, so that rising above the earth in flight is an enduring element of global thought and imagination'. (Cosgrove 2001,11)

This shift in perception, part of what Harvey has codified as 'time-space compression', in turn affected conceptions of accessibility, communications, and the 'rest of the world'. (Millward 1998,99) Both the *aerial view* and *aerial access* have promoted a globalisation that includes remote areas alongside the major nodes in the global economy and provided new, three-dimensional features of contemporary social life. (Cwerner 2009,4) According to Harvey, capital accumulation has always been about speed-up and revolutions in transport and communications, which have the effect of reducing spatial barriers. The experience of time and space has periodically been radically transformed, with a particularly strong example occurring in the 1970s seen in the impact of telecommunications, containerisation and jet cargo transport. (Harvey 2001,123)

Harvey argues that 'as regimes of accumulation change they alter the objective qualities of space and time, with the consequences that representations of space also change, notably under modernity'. (Harvey 1989,284) In particular, as air transport speeds up the movement of goods and people, the world appears to shrink. According to Harvey, the uses and meanings of space and time have shifted with the transition from Fordism to flexible accumulation. This in part was accomplished through the rapid deployment of new organisational forms and new technologies in production. (Harvey 1996,494) The annihilation of space by time has led to organisational shifts, which include sub-contracting, outsourcing and the 'just in time' delivery system that reduces stock inventories.

Just-in-time inventory controls are increasingly important for companies around the world, with an increasing number of firms holding only very limited 'buffer' inventories in case they run short of critical sub-components or spare parts. Just-in-time requires the rapid and reliable delivery of components that only aviation can provide. Air freight and the freighter's ability to gather and distribute goods over huge distances in a matter of hours have changed the ways in which businesses define inventory, making it possible for stores to turn storage space into display space and forcing governments to reconsider the notion of inventory tax. 'What planes fly is what people imagine they want. Right now.' (Lopez 1998,85)

Airspace is an important economic asset. Not only do commercial aircraft pay to use it but also a buoyant aviation industry arguably strengthens the UK economy and stops investment being lost to overseas competitors. Thus, the Government is caught between an economic imperative to increase airspace and airport capacity and an environmental commitment to reduce greenhouse gas emissions by 2030. Some have suggested that building additional runways would reduce emissions by enabling aircraft to land immediately, rather than stack as they often do at present. Opponents however, claim this would simply generate additional traffic and would lead to a net increase in flights and emissions. (Budd 2007,9)

Social scientist Lucy Budd has done some important work investigating how airspace works and why it is configured and used in particular ways. Budd describes 'airspace' as 'abstract spaces of flow' that are socially produced, maintained and contested. While air traffic controllers and pilots work to create airspaces that are safe for flight, they are also increasingly aware of their social and environmental responsibilities to reduce noise and emissions as far as possible. (Budd 2009,130) Budd argues that far from being simple neutral 'tunnels' for mobility in the sky, airspaces consist first and foremost of social spaces that while dependent on technical and/or safety regimes, are also contingent on political actions and decisions. The more congested the sky gets, the more contested the geographies of airspace will become. (Cwerner et al. 2009,14)

2a. Management of airspace.

> If you're articulate, decisive and possess excellent concentration, numeracy and problem solving skills, a career as an air traffic controller (ATC) could be for you. The vast majority of air traffic controllers train via the trainee air traffic control scheme at NATS, the UK's major ATC provider. Entry without a degree is common, as aptitude is generally considered to be more important than qualifications. The minimum requirement is five GCSEs (A-C) including English and Maths. You need to be 18 or older to apply.
>
> Rachel Burge for CareerBuilder.co.uk
>
> (Job search - Five careers that don't require a degree)

The mantra learned by all air traffic controllers when training, is that they are there to provide a safe and expeditious flow of air traffic. An air traffic controller at NATS [4] (the main air navigation service provider in the United Kingdom) in Swanwick, Hampshire explained to me that while there was an expectation upon controllers to supply sufficient capacity that meets the business demands of the air traffic control system, their prime aim is safety. UK airspace contains some of the most densely trafficked airspace in the world, maintained and contested through the on-going practices of management, negotiation and opposition. (Budd 2009,115) The provision, regulation and use of UK airspace have become increasingly politicised, with government and industry regulators wanting a safe, competitive and efficient airspace system.

All aircraft that fly through designated 'controlled airspace' are under the supervision of air traffic controllers, following standardised procedures within a regulated system. To lessen the risk of misunderstanding, all air traffic control messages are conducted in English and each sector of airspace is administered

[4] NATS Holdings (formerly National Air Traffic Services) is the main air navigation service provider in the United Kingdom. It provides en-route air traffic control services to flights within the UK Flight Information Regions and the Swanwick Oceanic Control Area and provides air traffic control services to fifteen UK airports and Gibraltar airport. Set up in 2001, NATS is a private company, but the UK government owns 49%, the airline group owns 42% and 5% is owned by staff and 4% is owned by Heathrow Airport Holdings Ltd. (Boulton 2011)

using a dedicated airband frequency to minimise interference. (Budd 2009,125) At a national level, UK airspace is governed and administered by the Civil Aviation Authority (CAA) and NATS, the part privatised national air traffic services provider, in accordance with domestic and international law. (Budd 2009,118) In 2001 under a controversial Public-Private Partnership deal, NATS became jointly owned by the government, a consortium of airlines and its staff. It manages air traffic destined for and leaving from major UK airports and also provides navigation services for air traffic passing through UK airspace. (Hutter and Lloyd-Bostock 2013,7)

To help manage the diverse operational requirements of different airspace users, UK airspace is divided into two geographical regions. 'London' is administered from the en-route air traffic control centre at Swanwick, Hampshire while 'Scottish' sectors are controlled from Prestwick. Both regions are divided vertically, with a Flight Information Region (which is active from the ground to 19,500 feet) and an Upper Flight information Region (for airspace above 19,500 feet) in each. Different sections of airspace within these regions are further classified as being 'controlled' and 'uncontrolled', depending on the nature and volume of traffic flowing through them. (Budd 2009,119)

In order to generate sufficient capacity within the system, each sector at present is given a capacity value based on how many aeroplanes it is believed a controller can handle safely in an hour. For example, during busy times an air traffic controller based in Swanwick can be responsible for up to 25 aircraft an hour. (Benedictus 2008) When demand gets greater than the available capacity, the NATS network managers and operation supervisors must take action in order to reduce delays at airports, electing at any given moment to further divide or 'split' the airspace into smaller sectors.

The London region is one of the most complex regions of airspace in the world, with seven airports (one of which is the military base RAF Northolt) positioned within a 30-mile radius from one another, all generating traffic into a limited volume of airspace. Each airport has its own specific boundary where it controls aeroplanes within it. Beyond these boundaries, planes are delivered to and from the specific airport via the airways system. This creates a layering effect: towers on the ground controlling approach and departure around the airport, the Terminal Manoeuvring Area [5] (TMA) delivering traffic into and out of the airways system and the en-route airspace dealing with the transition/cruise between TMA'S and airports.

While airlines demand the flexibility to fly where and when their business requires, the military and general aviation users also require access to airspace for training and recreational purposes. (Budd 2009,118) In the interests of national defence and security, special use airspace controlled by the military (RAF) for tactical training occupy many thousands of cubic miles of airspace, which civil aircraft are forbidden to enter. The UK's European neighbours also separate areas for military and civilian air traffic, with many bilateral and multilateral air service agreements stipulating where aircraft can fly, which airports/airspace can be used, how often services are used and the airfares that can be charged. Existing airspace structure requires commercial aircraft to fly along strictly defined airways and circumnavigate large areas of sky that are reserved for military use. (Budd 2009,118)

According to an air traffic controller working at NATS in Swanwick, even though military controllers work alongside civilian controllers, albeit in uniform, the military controllers guard their airspace zealously and rarely allow civilian controllers to utilise their airspace, even during times when there is heavy commercial traffic. (Boulton 2011) The intractable stance on airspace by the military means that civil aircraft are often funnelled into a piece of airspace 30 miles wide in order to avoid military airspace. With areas of the sky permanently off-limits for reasons of safety or national security, the maintenance and safe production of airspace is subject to compounding complexity.

The spatial practice of Air Traffic Control is mediated by radar. As an important tool, radar is used at nearly all control centres to monitor the progress of individual flights and help controllers visualise traffic flows. Radar surveillance

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[5] A terminal manoeuvring area (TMA) is a controlled airspace region surrounding busy airports (usually large city with many airfields); normally permanent IFR (Instrument Flight Rules) with other traffic by dispensation. (Gunston 2009)

can only be provided in areas where the radar infrastructure is established, so it is not possible to monitor flights using radar over oceans. In these environments satellite surveillance and radio transmissions are used to maintain separation based upon height and time over specified positions. Radar produces two dimensional images of aircraft flying through three-dimensional space that are layered on top of a static grid of lines and symbols demarcating different airspace sectors, showing the positions of airports, navigation beacons and waypoints.[6]

Many controllers report that they comprehend the complex assemblage of different objects flying through multiple encoded space, by developing detailed three-dimensional mental pictures. One controller commented that ‘the construction of mental images is not something we do consciously, it just happens – I look at a radar display and instinctively see it in 3D’. (Budd 2009,125) A three-dimensional picture of airspace is constructed incorporating metaphors such as ‘tunnels’, ‘stacks’, ‘corridors’ and ‘grids’ to indicate where aeroplanes are positioned. The shaping of abstract models in a volume of air, contributes to the conceptual apparatus that engages the different material, elemental and technical registers of airspace.

While scanning the radar display, a controller will write instructions and flight levels onto paper strips called Flight Progress Strips which are printed with data such as call-sign, operator, aircraft type, intended routing, requested altitude, anticipated airspeed, scheduled time of arrival or departure. This information is uploaded from a flight and accompanies every flight throughout its journey. The controller continually annotates the strip as they keep track of the clearances and instructions they issue. As these strips are dependent on emerging contingencies, no two strips are ever the same and individual controllers literally ‘author’ the sky to reflect their personal view of the airspace under their command. (Budd 2009,126)

Since 2011, automated electronic flight strips have slowly replaced the paper-based strip system. While the appearance of the electronic slip closely follows

[6] A waypoint is a predetermined and accurately known geographical position forming start or end of route segment. (Gunston,2009)

the conventional paper strip, the new design aims to reduce the controller's manual workload. Next-generation flight data management, such as the introduction of automated electronic flight strips, have allowed for the processing of flight data to be more fully integrated with other operational computer-based segments of the air traffic control system.

Figure 2.1 Annotated electronic flight strips.
Source: <http//www.frequentis.com> [Retrieved 30 June 2014].

Currently on the cusp of massive change, the UK and European air traffic control system is being redesigned to create operationally feasible sector boundaries and routes to support a strong growth in air travel. These changes are driven, in the main, by incentives to reduce delays applied by the European regulator, the Civil Aviation Authority (CAA), by increasing airspace capacity while designing new fuel saving trajectories to meet Co2 emission targets. The air transport system is now strained and is operating beyond its originally designed capacity. With the demand in aircraft operations expected to grow significantly through to 2025, there is significant concern regarding our present system, as it will not be able to accommodate the projected traffic growth rates.

Antiquated systems are arguably one of the many concerns. The systems required to provide flight information in real time and the current processes, do not lend the flexibility needed to meet the growing demands of the dynamic airspace environment. (Lyons 2012,4514) When demand gets greater than the available capacity, NATS air traffic management must take action in order to stop delays at airports, so they will elect at any given moment to further divide the airspace using a tool known as sectorisation. Within this regulated framework, controllers have flexibility to manage their sector of airspace in different ways according to emerging contingencies. In order to generate sufficient capacity within the UK air traffic control system, each sector at present is given a capacity value based on how many aeroplanes it is believed a controller can handle safely in an hour. (Boulton 2011)

Experience in Europe suggests that en-route airspace capacity e.g. that of an ATC sector, is determined by air traffic controller workload i.e. the mental and physical work done by the controller to control traffic. (Majumdar and Ochieng 2004,3) This is in addition to spatial-geometric and temporal criteria based upon the performance characteristics of the aircraft in the sector. (EUROCONTROL 1991, cited in Mujumdar and Ochieng, 2004,3) The capacity of an ATC sector can therefore be defined as the maximum number of aircraft that are controlled in a particular ATC sector in a specified period, while still permitting an acceptable level of controller workload. Although there are differences between controllers in solving conflicts, the rules they are applying are always standardised. This flexibility and room for manoeuvre allows an air traffic controller to demonstrate individual ‘flair’ – a word used amongst air traffic controllers that is best characterised as ‘making the system work better for them’. (Boulton 2011) For instance when a specific request from a pilot requires extra handling and maneuvering, the controller will usually rise to the challenge in order to meet that request, using individual ‘flair’ to demonstrate the proficiency and adeptness of their controlling skills. (Boulton 2011)

Due to current predictions of an increase in air traffic over coming years, ‘flair’, is gradually being ‘designed out’, by a new computer-based tool called iFACTS (Interim Future Area Control Tools).[7] (Boulton 2011) This tool became fully

[7] iFacts is a new controller tool billed as ‘the biggest change in air traffic control since radar’. Developed by NATS (National Air Traffic Services) with systems engineering and software specialist Praxis, the system uses algorithms that project the flight plan trajectory of every

operational at Swanwick in 2011 and has changed the controlling of traffic from being a mainly manual operation to one that is more reliant on technology. IFACTS provides decision-making support and helps controllers manage their routine workload to increase the amount of traffic they can comfortably handle. (Boulton 2011) The future of air traffic control technology is increasingly reliant on computer software that creates flight profiles where conflicts are identified and resolved through design. Information that had been found on paper flight progress strips on the radar displays, are now being replaced with detailed trajectory and monitoring information that predicts future conflicts between aircraft. The phasing out of printed data recorded on flight progress strips has reduced the opportunity for a controller to exercise 'flair'. In order to handle more traffic in the future safely, a controller's flexibility to manoeuvre traffic (flair) will be constrained by new technology, such as iFACTS.

The introduction of iFACTS will be supported by new airspace infrastructure that will require little intervention by a controller. Instead aircraft will be equipped to fly a vertical profile with absolute certainty, so long as they are equipped with precision navigation capability. In effect, a tunnel will be created in the sky that controllers know as the designated profile of a piece of airspace belonging to a specific aircraft. Although there will be less intervention, an aircraft would have to assure the controller that it can conform to that profile and if not, the controller would then have to know the consequence of not following it.

The next generation of Air Traffic Management (ATM) systems must be prepared to manage complexity and uncertainty. A fundamental step in being able to manage uncertainty is by understanding the system and how it interacts with other systems. Thinking in terms of nonlinearity, decentralised control, networks and randomness are practical solutions. Secondly, it is critical to understand that the most complex element within the ATM system is that of the human being. System users and operators must be trained to anticipate challenges, emergent events and be prepared to resolve them from a modern socio-technical systems perspective. Next generation ATM systems ideally

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aircraft ahead by up to 18min, and this updates each time an aircraft is re-cleared. (Learmount 2012) The system is now operational and controllers at Swanwick are already working with it in the ACC's development department so NATS and Praxis can get feedback on ease of operation and ideas for optimising the man-machine interface.

should be mature and the foundation should entail the study of modern complex systems, requiring an understanding of the interactions and interrelationships between the technical, human, social and organisational aspects of the entire system. (Lyons 2012,4516)

Air Traffic Management is a crucial activity today. Sectors or specified airspace volumes are allocated an available capacity. When demand exceeds capacity, network management ensures that aircraft can pass safely from one sector to another under a managed environment, minimising the likelihood of controllers becoming overloaded (this is obviously a subjective issue) and therefore potentially leading to an unsafe situation. This task is managed centrally within the Eurocontrol region by the Central Flow Management Unit [8] (CFMU) based in Brussels.

Each State has a 'Flow Management Unit' that informs Brussels of any regional issues and requests 'Air Traffic Flow and Capacity Management' regulations to be applied to limit the aircraft through an identified hotspot. Although the management of aircraft flow exists to maintain safety, regulating the flow of traffic can create delays for passengers. The delay of passengers generally forces the design of airspace to change; ensuring continual optimisation of the available airspace so more aircraft can pass through the airspace safely, thus reducing delays. This has been highly effective within the UK, but becomes increasingly difficult to achieve because of the limit to optimisation, process and cost. The idea is that technology will support the necessary growth in the future, reducing the need for controllers to intervene and therefore reducing their workload per flight, thus increasing throughput at the same relative workload.

Globalised capitalism and the move toward borderless economies has not only shaped the aerial subject and their relation with space, but coincides with the new 'Single European Sky' initiative, originated from within the European Commission in 1999, when there was general dissatisfaction with the levels of

[8] All IFR (Instrument flight Rules) flight plans are tracked by a CFMU (central flow management unit). Each airport and air traffic control sector has a published maximum capacity. When capacity is exceeded, measures are taken to reduce the traffic. This is termed regulation. The aim is to use capacity effectively, keeping the average delay as low as possible, while ensuring capacity is not exceeded. (EUROCONTROL 1991)

delay experienced by airlines and passengers. The framework regulation of the initiative, establishes the European Commission as the regulator for the civil sector. The Single European Sky initiative creates a single European Upper Information Region (airspace) that is organised into functional airspace blocks, with the aim of ensuring that systems, equipment and procedures operate seamlessly. (Civil Aviation Authority 2011)

The geographical imaginations involved in Single European Sky are not limited to a rendering of a metaphorical ‘single sky’ overcoming all borders and obstacles, but incorporates a much more flexible conception of airspace, which is not static, but reflexively responsive to the desired vectors of aircraft. (Adey 2010,72) Aircraft will not fly according to partitioned airspaces along lines of sovereign territory, but will collaboratively set its flight trajectory, achieving preferred routing with ‘no preferred routes’. (Adey 2010,73) Shifts to these new spatial aerial architectures, away from a container-like definition of territory, mirrors the politics on the ground that has eliminated borders creating the single European market. Pressed on the grounds of efficiency and cost saving, proposals for a Single European Sky have been slowly moving toward placing greater emphasis on the environmental benefits a ‘single sky’ would provide.

To facilitate the formation of the ‘single sky’ above central Europe, a new Central European Air Traffic Service (CEATS) facility will become operational near Vienna later this decade to coordinate air traffic above Austria, the Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Bosnia and parts of Italy, but it is questionable whether the UK Government would similarly sanction the transfer of control of its airspace to a foreign nation. (Budd 2007,10) Politically, national jurisdiction over sovereign airspace remains important in the UK (witness the controversy surrounding the alleged use of UK airspace by the United States Central Intelligence Agency (CIA ‘rendition’ flights) and politicians are very unlikely to do anything to relinquish any of that control. However, the issue is complicated by the fact that airspace is both a national and an international space, governed simultaneously by various domestic, European, and international laws. (Budd 2007,9)

In February 2004, EUROCONTROL [9] received formal backing from European Union Governments to develop a 'Single European Sky' (SES) to increase capacity and harmonise the continent's fragmented airspace structure (whose 49 ATC centre's', 31 national authorities, 18 hardware suppliers, 22 operating systems and 30 programme languages were causing severe delay diseconomies and costing the European economy nearly €2bn a year in lost productivity). In anticipation of the formal launch of the SES initiative, 'Reduced Vertical Separation Minima'[10] (RVSM) procedures were introduced in European airspace in 2001. By halving the vertical separation distance between aircraft to 1000 feet, six new flight levels were introduced and airspace capacity increased by 15%. While critics voiced concern at the increased risk of mid-air collision, the new statistical rate of one collision every 150 years was considered 'acceptable'.

Other technological advances, including the use of more sophisticated noise abatement procedures, continuous descent approaches [11] (CDAs), 4D Air Traffic Control [12] and precision navigation (PR-NAV) [13] techniques have helped,

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[9] Eurocontrol is the European Organisation for the Safety of Air Navigation. Founded in 1960, it is an international organization working for seamless, pan-European air traffic management. Eurocontrol is a civil organisation and currently has 40 member states; its headquarters are in Brussels. Eurocontrol coordinates and plans air traffic control for all of Europe. This involves working with national authorities, (air navigation service providers, civil and military airspace users, airports, and other organisations. Member States include Albania, Armenia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine and United Kingdom of Great Britain and Northern Ireland. (EUROCONTROL 1991)

[10] Reduced vertical separation minima or minimum (RVSM) is the reduction of the standard vertical separation required between aircraft flying between FL290 (29,000 ft) and FL410 (41,000 ft) inclusive, from 2,000 feet to 1,000 feet (or between 8,850 and 12,500 m from 600 m to 300 m). This therefore increases the number of aircraft that can safely fly in a particular volume of airspace. (EUROCONTROL 1991)

[11] Continuous descent approach (CDA) or optimized profile descent (OPD) is a method by which aircraft approach airports prior to landing. It is designed to reduce fuel consumption and noise compared to certain conventional descents. Instead of approaching an airport in a stair-step fashion, throttling down and requesting permission to descend to each new (lower) altitude, CDA allows for a smooth, constant-angle descent to landing. (EUROCONTROL 1991)

[12] The 4D trajectory concept is based on the integration of time into the 3D aircraft trajectory. It aims to ensure flight on a practically unrestricted, optimum trajectory for as long as possible in exchange for the aircraft being obliged to meet very accurately an arrival time over a designated point. (EUROCONTROL 1991)

but it is unlikely the political will exists to take the Single European Skies proposal to its logical conclusion, the creation of a single airspace structure and ATC regime for the whole of the continent. Indeed, while the EU's 'Flexible Use of Airspace' [14] (FUA) programme aims to abolish distinct areas of military and commercial airspace in upper airspace, and improve airspace efficiency by enabling aircraft to fly the shortest straight-line route from A to B, technological and geopolitical obstacles currently prevent its adoption at lower altitudes. (Budd 2007,11)

Other possible solutions have included introducing a differential pricing structure for airspace users whereby those that have paid the most are given preferential Air Traffic Control treatment and awarded access to the 'best' (i.e. most direct) routes. However, this would create a 'two tier' structure enabling large carriers to buy the best routes thereby forcing smaller competitors to use longer, less efficient routes. Whether such a scheme is operationally viable, or even desirable, is open to debate. Others are placing their hopes on technological advances including new versions of TCAS [15] (Traffic Alert and Collision Avoidance System), which will be able to give resolution advisories in the lateral as well as the vertical plane, new 'free flight' navigation protocols based on advanced GPS (Global Positioning Systems) software, and new generations of aircraft and aircraft fuels.

Both Boeing and Airbus are promoting the environmental performance and 'green' credentials of their latest airframes, and several airlines are offering customers the opportunity to 'offset' the carbon emissions their flight generates. One of the most significant improvements to environmental performance could

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[13] Aircraft P-RNAV equipment automatically determines aircraft desired flight path by a series of way points held in a database. (EUROCONTROL 1991)

[14] The EUROCONTROL Concept of the Flexible Use of Airspace (FUA) is that:
- Airspace is no longer designated as purely "civil" or "military" airspace, but considered as one continuum and allocated according to user requirements.
- Any necessary airspace segregation is temporary, based on real-time usage within a specific time period.
- Contiguous volumes of airspace are not constrained by national boundaries.

[15] A traffic collision avoidance system or traffic alert and collision avoidance system (TCAS), is an aircraft collision avoidance system designed to reduce the incidence of mid-air collisions between aircraft. It monitors the airspace around an aircraft for other aircraft equipped with a corresponding active transponder, independent of air traffic control and warns pilots of the presence of other transponder-equipped aircraft which may present a threat of mid-air collision. (EUROCONTROL 1991)

be achieved by revolutionising the existing airspace structure. This would enable aircraft to fly the shortest route between A and B and adopt the most fuel-efficient climb and descent profiles. (Budd 2007,11)

While airspace is produced by the practices of controllers and pilots, people on the ground challenge it and oppose its use. Current expansion plans and rising levels of public concern about aviation's contribution to climate change have caused the issue to rise up the political agenda. Some larger organisations, such as HACANClearskies (a voluntary residents association campaigning to reduce noise based at Heathrow) and SSE (Stop Stansted Expansion), have been instrumental in producing alternative understandings of airspace, which challenge the dominant economic and operational discourses employed by airports, airlines and pro-aviation lobbies. In this sense airspace is not just a tunnel in the sky, but also an important social space in its own right. (Budd 2009,132)

While the majority of campaigns oppose the development of new infrastructure, such as additional runways or new terminals, others are challenging changes to airspace that have resulted in commercial flights flying over their homes and communities for the first time. (Budd 2009,130) In 2005, the Dedham Vale Society won a High Court ruling against Stansted Airport and forced them to withdraw new flightpaths that the group claimed, were ruining the rural tranquility of 'Constable' country. (Millward and Clover 2006 in Budd 2009,130)

In October 2003, East Midlands Airport (EMA) submitted an airspace change proposal to the CAA that sought to extend the area of controlled airspace around the airport and reorganise the way air traffic movements were handled. These included plans to amend existing approach and departure procedures, and re-siting existing holding stack areas to increase capacity and improve safety. While the plans were predicted to lessen the acoustic impact of aircraft operations, a number of residents found themselves under the re-routed flightpaths. They mobilised against the plans, believing there would be landscape despoliation, property devaluation and unacceptable levels of noise pollution in a predominantly rural part of the country. (Budd 2009,130)

Following a public meeting in January 2004, a group of local residents formed ELVAA (East Leicestershire Villages against Airspace) to raise awareness of the airspace change, stimulate public opposition and act as a focal point of resistance. Though EMA remains at present undesignated, ELVAA supporters used their lived experience of the airspace change to produce alternative notions of airspace that are largely incompatible with those of the airport. (Budd 2009,132)

The spatial geography of the UK also causes its own problems. As towns and cities have grown and airports developed, it has become apparent that many of them are in the 'wrong' place. Coventry airport is arguably too close to Birmingham, the short-lived EU-Jet commercial services from Manston in Kent caused problems for controllers owing to its proximity to other airports in the south east and its proximity to the boundary of foreign airspace, while the prevailing winds and resulting runway alignments at Heathrow, Birmingham, and Manchester often require aircraft to fly over densely-populated urban areas. (Budd 2007,9)

While increasing numbers of people want to fly, no one, it seems, wants to be disturbed by aircraft. The use of airspace itself has become a contentious issue, with an individual's 'right' to peace and quiet juxtaposed against other peoples' 'right' to fly. While the majority of objections are directed at commercial flights, military aircraft and general aviation are not immune. While people living in Wales, complain about the noise from low-level military training flights, others allege the drone of light aircraft ruins the tranquility of the English countryside. Yet while most media coverage focuses on how airspace is being contested by people on the ground who oppose its use, it is important to recognise it is also being contested 'in the air', with different groups of users trying to secure themselves a bigger share of the sky and exclude others from accessing it. (Budd 2007,2)

Commercial air travel is becoming an increasingly emotive subject and the debate surrounding who should benefit from and who should suffer the impact of noise and airport development has had a long history. (Budd 2009,130) In 1966, when plans were drawn up for the new international airport Narita on the plain at Sanrizuka, 40 miles east of Tokyo in Japan, it was assumed local farmers would allow the Airport Authority to purchase their land. However this land in the late nineteenth century had been owned by the Emperor and comprised of large estates and stud farms, becoming known for the 10,000 cherry trees that would annually blossom there. By the twentieth century the area had become a community of local farms engaged in small-scale full time farming. As site surveys were carried out for the new airport it became increasingly obvious that some of the farmers would not be moved off their farms without a fight. Supporters of the farmers purchased tiny symbolic patches of land and moved into the fields around Narita so as to make it awkward for the authorities. (Pascoe 2001,105)

To make their voices heard, the affected people formed the ‘League of Sanrizuka and Shibayama Farmers Against Narita Airport’, drawing up the front line for the battle that was to follow. In October 1967, the government mobilised riot police to forcibly restrain local farmers angered by a survey of the outer site. In 1971, the government and the farmers clashed violently on two occasions as authorities forcibly confiscated land inside the site designated for Phase I construction. In September that year, during the second round of expropriations, an elderly woman, Koizumi Yone, was evicted from her home. Her house, the land around it and a rice field were confiscated. To resist, the farmers (their ranks swelled with supporters from the student movement) built underground strongholds on their land, chained themselves to trees and defended themselves with their bare hands. Images of this fighting flashed around the world, and Sanrizuka earned the unflattering sobriquet of ‘Japan’s Vietnam’. In 1978 it was reported that protesters fought police for three days to block the opening of the airport. Six days earlier police tore down a 65 foot steel tower built by protesters to obstruct the flight path at the end of the runway.

During stage-two expropriations, three riot police were killed in the fighting and one of the farmer’s friends took his own life in despair. In July 1991, the Narita Airport Corporation began building a second runway inside Toho Hamlet. However, protests forced the Corporation to cease work. In December 1996, the Transport Ministry announced it would complete the project by the year

2000, a date it subsequently revised to March 2001. In May 1999, ignoring the wishes of Toho residents, it suddenly announced it would finish the second runway by June 2002. This was the same attitude the authorities displayed in the 1970s when they dropped their original bombshell. Once again, they failed to obtain the consent of local residents. Their current attitude in 2014 seems to be: if you don't sell up, we'll build a runway right up to your front door. Having been bullied for over thirty-three years the remaining residents of Toho Hamlet are unlikely to give in to the airport authority's intimidation.

Ki-atsu: the sound of the sky being torn, (2011) is a sound-film by artist Angus Carlyle and anthropologist Rupert Cox based on fieldwork in the Toho Hamlet, situated at the end of the Runway B at Narita International Airport. (Carlyle and Cox 2011) The film comprises of a number of recordings made on the site of the two remaining farming families – of the estimated 360 who arrived after the Second World War – continuing to make their livelihood from an organic small-holding with fields of fruit and vegetables, pens of pigs and a barn with egg-laying hens. Over the years the farmers have turned cedar forest and scrub into productive arable land, the fertility of the soil derived from the weathering of volcanic ash sent up by the eruptions of Mt. Fuji.

The Shimamura family live and work at the end of Runway B, while almost all of their departed neighbours land has been transformed into steel and concrete. These two forms of life butting up uncomfortably against one another are observed in Carlyle and Cox's sound-film, recording the particularities and peculiarities of nature and commerce. The film is a reminder that the expansion and renovation of airports are never finished, constantly being reshaped to meet capacity demands, which involve the obliteration of all kinds of life previously existing. Surrounded on all sides by taxiways and acres of airport, the family and their farm is an exception that is slowly being absorbed into the airport's infrastructure. However Carlyle and Cox's sound recordings of vegetables being harvested and animals being reared on the site of the Shimamura farm, reveal the sonic details of resistance to the rule-governed nature of airspace that allows no exceptions.

One of the ways in which the Shimamuras continue to oppose the expansion of the airport and the loss of their livelihood, is by contesting the imposition of a sonically defined 'airspace' (Pascoe 2001) onto their space of habitation. 'I don't hear anymore' – these were Mr Shimamura's words to Carlyle and Cox, in response to a question meant to elicit details about the positive sounds and spaces of audition on his farm. As he spoke he bent forward and indicated the area of his neck below his ears where the muscles had become hard and stiff after years of involuntary tensions. The signs of this somatic contraction suggests that while Mr Shimamura may not hear aircraft in the active sense of listening, his body is continuously touched by their noise. With his body constantly matched against the physical and psychological dimensions of aircraft noise, Mr Shimamura now seems to choose not to hear.

Mr Shimamura's passive resistance characterised by his refusal to hear, forces his body to occupy the constant noise from the aircraft above him, absorbing the rhythm of aircraft noise, which has now become normal. As the Shimamura family is only one of two remaining families left, they are too few in number to create a statistical argument, making it difficult to seek legal redress and compensation from airport authorities. Because the rules that govern airspace allow no exception, Mr Shimamura's determination to occupy his own land has meant that he and his family have been absorbed into the environs of Narita airport, surrounded by a steel wall observed by security guards in a watch-house. The family must leave and enter their farm by a road tunnel that links them to the outside world.

When Narita Airport finally opened in 1978 after violent protest, the Diet of Japan passed a special statute, the 'Emergency Measures Act Relating to the Preservation of Security', specifically banning the construction and use of buildings for violent and coercive purposes relating to the new airport. In effect Narita airport itself has become a form of a state of exception, with legislation resulting from the emergency measures still being enforced today. As if in a constant state of emergency, departing passengers arriving at the airport are still subject to baggage searches and travel document checks before entering the main terminal. Protest signs against the airport on some of the perimeter fences seen by aircraft passengers are a reminder that airports are a place where global and local issues and the interests they represent interact and seek solutions. (Kesselring 2009,41)

Speaking of the ‘geopolitics of air travel’, Henri Lefebvre recognised the fundamental role that the ‘International’ airport played in the globalisation of society and the economy, pointing up the structuralising influence of global spatial mobility. (Kesselring 2009) For Henri Lefebvre, the development of capitalism and its praxis raises difficulties in the relations between space and time:

> Let everyone look at the space around them. What do they see? Do they see time? They live time, after all; they are in time. Yet all anyone sees is movements. In nature, time is apprehended within space — in the very heart of space: the hour of the day, the season, the elevation of the sun above the horizon, the position of the moon and stars in the heavens, the cold and the heat, the age of each natural being, and so on. … Time was thus inscribed in space, and natural space was merely the lyrical and tragic script of natural time.
>
> (Lefebvre 1991,95)

With the advent of modernity, time has vanished from social space. According to Lefebvre, ‘oppressive and repressive powers use their ideological domination of abstract space in ways that relegates time to an abstraction of its own — except for labour time — to assure it serves capitalist production’. (Lefebvre 1991,393) The sounds of aircraft in flight or on the ground are expressive of the movement of people and things between nodes, in an international network of travel.

In contrast, the sonic tactility of the farmers, as their hands pull at, cut off and sort vegetables, speaks of different material energies and different relationships. The working patterns of the farmers are the points established by Carlyle and Cox from which to test scales of rhythm: the heating and cooling of the seasons, the shifting topographies of flight, the cycles of sowing and harvest, the bending and stretching of the body at work. Their sonic tracings are expressive of relations between farmers, food and customers that are mutually constitutive and productive of a sense of place and belonging. (Carlyle and Cox 2011)

For most of us, it is from supermarket shelves that our food, a large proportion of which is air freighted, can be found. The supermarket is the human interface to a vast network of supply-chain, demand chain and customer relationship management software's, steel containers, offshore factories all forming a complex assembly of everyday purchase commands with vast economies of production and distribution. However the reality of such a network's performance is also an uncontrollable accumulation of very real and opaque unintended consequences. In the growing need to further control, manage, engineer and reshape today's airspace to meet our needs, there is a dependency not only on extraordinarily complex technological systems, but the need to plan for and anticipate the destabilising effects caused by natural phenomena that are only partially understood.

Controlling complex aviation networks requires the ability to cope with the ongoing tension between plan and reality, between predictability and contingency. (Peters 2009,174) In this relational character of exchange, the complexity and fragility of a tightly coupled, complex and quite fragile network of airline movements, create intricate webs of interrelated events that are increasingly vulnerable to small disturbances. As much as forensic analysis of past failures and an improvement in our ability to predict performance and wear has improved the ability of infrastructure systems to withstand the effects of hazards, failures can be expected to continue to occur as error, neglect or breakdown. Indeed many systems are premised on a certain degree of breakdown as a normal condition of their existence. (Petroski 1985, cited in Graham and Thrift 2007,5)

The following chapter discusses the eruption of the Icelandic volcano Eyjafjallajökull (2010), which led to the unprecedented closure of UK and much of European airspace for six days. Air traffic control and air transport regulators were forced to admit that they had been confronted with an eventuality that was a risk to safety and one they were not prepared for. While the air traffic control system has as its fundamental value - safety, it does so in order to facilitate trade, transport etc. where profound economic interests are at stake.

The closure of airspace revealed a substantive opposition between the system imposed on airspace and the interests air travel facilitates within the economy of air transport. As an exogenous natural event with worldwide repercussions, unrealistic expectations were brought to bear on the regulatory decision-making processes governing air transport. With far reaching consequences, including huge financial losses for airlines, the eruption of Eyjafjallajökull exposed an underlying contradiction between the demands of safety on the one hand and the demands of economic efficiency and civil society on the other.

Chapter Three

The Volcanic Ash Cloud

> There are only two emotions in a plane: boredom and terror.
>
> — Orson Welles, interview to celebrate his 70th birthday.
> The Times of London, 6 May 1985.

If you fly into London's Heathrow, the UK's busiest airport, you will first join a landing sequence within one of the four holding stacks in the airspace above the outskirts of London. The Heathrow stacks are always occupied and most aircraft hold for at least 10 minutes in order to maximise runway capacity. A continual reservoir of airplanes fly in descending circles, from the top of the stack to the bottom, where they will be taken out of the holding pattern by an approach controller and guided to the runway in standardised three mile gaps. Looking up at the sky from the ground, these densely trafficked air corridors are invisible, apart from the interweaving layers of contrails – water vapour trails left behind by a passing jet. Marking out the dimensions of airspace, these mobile crisscrossing trails are a reassuring sign that things are working well in the air traffic system.

When NATS took the unprecedented decision to close UK airspace due to the cloud of ash emitted from the erupting volcano Eyjafjallajökull in Iceland in 2010, they were complying with an underlying principle that conditions the air traffic system's existence – safety. The intrusion of a sublime event like the ash cloud demonstrated the limits of risk management in the air traffic control system. Once the ash cloud found its way into some of the busiest air traffic corridors in the world, the presence of highly abrasive volcanic ash was considered too dangerous to allow aircraft to occupy the same space as the airborne tephra. The risk management capability of aviation technology, in terms of engine tolerance to volcanic ash, was uncertain, prompting a decision by regulators to opt for 'zero tolerance', in the interests of safety.

Closing airspace was essentially a matter of restricting the provision of air traffic control services. The International Civil Aviation Organisation (ICAO) [1] guidance meant that normal air traffic control services could not be provided in airspaces affected by volcanic ash. (Hutter and Lloyd-Bostock 2013,8) Identifying the system's limitations as a rational construct in relation to this exceptional event, NATS made the prudent and rational decision to close airspace. NATS took the most conservative approach based on a statistical analysis of risk within the broader air traffic control system. However, while the air traffic control system is based on risk limitation and regimes of safety that are absolutely central to the functioning of the air transport system, the air travel system is also a commercial system where interests were being compromised by the insistence of achieving the safest possible outcome in relation to the ash cloud event. While rationality prevailed, the business demands upon the system to provide sufficient capacity, led to a tension where the managing of more aeroplanes and risk, became a tradeoff.

Although volcanic ash is recognised as a known threat to aircraft, there seemed to be an information barrier between the scientific community and the aviation authority, the airlines, government and public - who were affected but underprepared. (Donovan and Oppenheimer 2011,5) The problem seemed to stem from there being no defined safe limit set within the air traffic system for volcanic ash, thus the application of a 'zero tolerance' procedure was brought into question. In this chapter, I will discuss some of the underlying factors that contributed to why the severity of the Eyjafjallajökull ash cloud became such a

[1] Also known as the Chicago Convention (Hutter, Lloyd-Bostock 2013) this established ICAO as a specialized agency of the United Nations charged with coordinating and regulating international air travel. It codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth. The ICAO Council adopts standards and recommended practices concerning air navigation, its infrastructure, flight inspection prevention of unlawful interference, and facilitation of border-crossing procedures for international civil aviation. In addition, the ICAO defines the protocols for air accident investigation followed by transport safety authorities in countries signatory to the Convention on International Civil Aviation (Chicago Convention). ICAO's International Airways Volcano Watch Operations Group advises ICAO what standards and recommended practices need to be included in Annex 3 concerning volcanic ash dispersion and international air travel. The International Civil Aviation Organization (ICAO) is a specialized agency of the United Nations.

complex calamity. These factors include a combination of increased air traffic in scarce airspace, climatic conditions (an unusually stable weather system and northwesterly winds from Iceland) and the tight coupling of airline systems meeting highly competitive commercial demands.

The ash cloud event revealed a contradiction whereby the air traffic control system has one goal – safety, which is absolutely essential to the functioning of the air transport system, and at the same time is also a commercial system. I refer to Harvey's emphasis on the way in which globalisation has revolutionised the qualities of space and time. Many of us are fully implicated in the capitalist reorganisation of space and time with global travel becoming a necessary part of our working lives, whether we like it or not. As well as the air transport of people, high-value-added goods and foodstuffs are being transported by air, giving rise to economic structures and interdependencies that mesh with the schedules of airline networks. (Kesselring 2009,42)

Presuming the Eyjafjallajökull eruption is a sign of things to come, as opposed to a one-off event, I question what the eruption means for imaginaries around and dependencies on flying and ask how we might seek to recalibrate our infrastructures. The event has generated further research concerning responsibility, in an effort to clarify legal and ethical responsibility of air traffic control and the airlines regarding the clearing of aircraft into airspace where there were high levels of volcanic ash present. If one accepts that contemporary life is a dynamic and teeming space of exchanges that involve earth's processes—a constant negotiation of movement and materiality among humans, geological forces and materials, then the volcanic ash cloud event offers new provocations.

3a. How the volcanic ash cloud event unfolded

In March-May 2010, an eruption of the volcano Eyjafjallajökull in Iceland sent a plume of volcanic ash and debris over 30,000 feet into the sky. Describing the ash cloud as a 'significant safety threat to aircraft', UK air traffic control took the unprecedented step of closing national airspace to all commercial traffic, a move followed quickly by other European governments bringing international, transatlantic and European air travel to a standstill. Air travel systems and networks unravelled leading to cascading disruption as 750 tonnes of volcanic material was released into the atmosphere every second. (Budd et al. 2011) Carried by the prevailing winds to Scandinavia, northern Great Britain and eventually continental Europe, the ash found its way into some of the busiest airspace in the world.

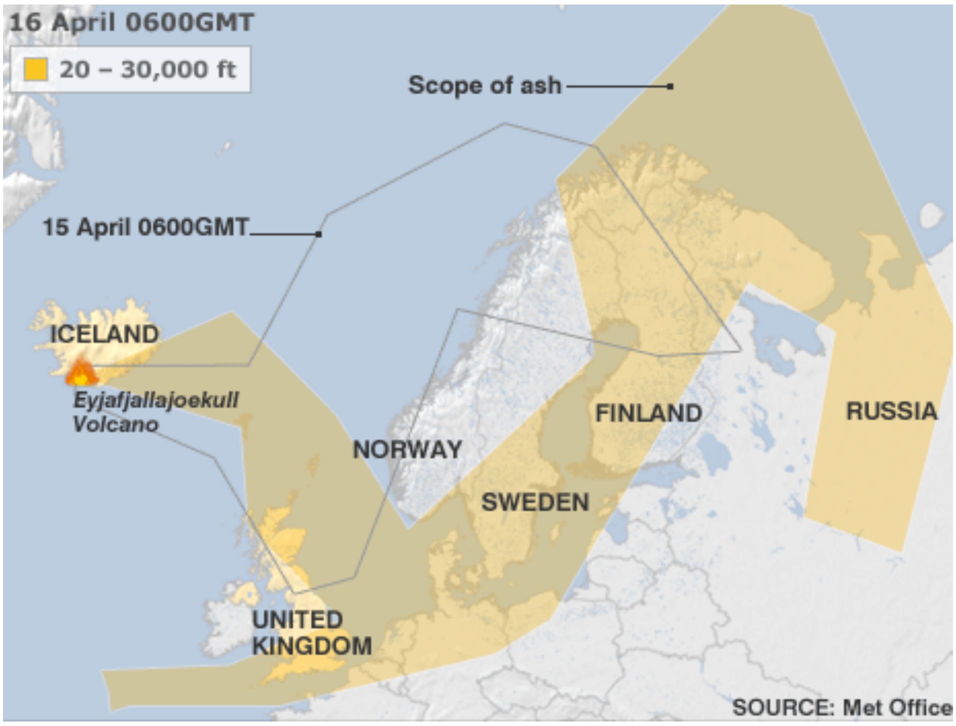

Figure 3.1 Extent of Iceland volcano ash cloud.
Source: Met Office. Available at: <http://news.bbc.co.uk/1/hi/8623534.stm> [Retrieved 2 July, 2014].

Volcanic ash poses a direct threat to aircraft engines through potential damage caused by tiny particles of extremely abrasive materials such as silica making up 58% of the matter contained in the cloud. In lay terms when ash particles enter the hot interior of a jet engine they melt into a glassy substance, clogging the small openings that direct the airflow into the engine. This in turn can cause an aircraft to lose power in flight with potentially catastrophic consequences, thus providing ample reason for air traffic control management to be extremely cautious when a volcanic eruption takes place. The immediate response by UK and European Civil Aviation regulators to shut down controlled airspace over the UK, North Atlantic and much of Northern Europe commenced on the 14th April 2010. The closure continued through to the 23rd April 2010, continuing intermittently during following weeks in different parts of Europe, as the path of the ash cloud was tracked.

A phone call in the dead of night was the first inkling the people living at the foot of the dormant Eyjafjallajökull volcano had that it was about to erupt. Advised to evacuate in 20 minutes, the warning was clear, if they stayed they would risk being washed away by torrents of melt-water unleashed by the release of energy that had begun inside the volcano, no more than four miles above them. A few hours later a huge evaporation cloud, like a mushroom, rose to 20,000 feet high, followed by dark ash blown by the wind that turned day into night as it fell and blotted out the sun. Twenty-four hours after the eruption, the plume was continuing to grow, blowing across the Norwegian Sea to Scandinavia and southeast across the Shetland Isles, as far as the north coast of Scotland. Air traffic controllers in Aberdeen had seen the plume coming and by noon the next day they predicted that local airspace would close for a few hours. By 3.00 am the next day the whole of Scotland was a no-fly zone and before dawn the Scottish government's civil emergency resilience unit was activated. By 2.30 pm the vast cloud had reached England causing the shutdown of all Britain's airports.

Exploring the immensity and turbulence of Nature and human responses to it, geographer Nigel Clark has called attention to the volatility and uncertainty of the physical systems that the human species and other life forms depend on. Clark asks what we might make of the experience of vulnerable bodies caught up in events beyond their control or comprehension, events whose ultimate origin is not even of this earth. With the question of our inhabitation of a changeable and uncertain planet in mind, Clark explores the idea of exorbitance, calling for a further opening to the elemental forces that underpin human life. This means that far from unbinding the social from the natural, we are compelled to reconsider the question of a social ordering or communal formation that responds to the imperatives of the earth. (Clark 2010)

Given that the problem of volcanic ash for air travel is well known, there was something about the ash cloud that surprised. As an airborne body of dust, it appeared outside of the sphere of human intervention, neither caused by human action or susceptible to being reshaped by human action. (Adey and Anderson 2011) Resonating more with the disruptive force of an exorbitant nature than visions of a dominated nature (Yusoff 2010), the ash cloud exceeded attempts to grasp and handle it. Made up of infinitely small particles, the cloud was material and immaterial, formed and formless. It lacked the properties of shape consistency and clear and distinct boundaries that would have made it a tangible object. (Anderson and Wylie 2009).

In examining the significance of clouds in the popular imagination, cultural historian, Steven Connor argues that 'it is difficult to think about the meaning of the cloud, or the cloudy, in the collective imagination without recognising the freight of fear, malevolence and ill-omen with which clouds are often charged'. (Connor 2009) This is why volcanic eruptions and their menacing clouds of ash may be regarded as sources of the sublime; that is part of their appeal to volcanologists and poets alike, in the act of imagining — boundlessness. (Connor 2009)

No cloud has ever evoked a more sinister threat than the 'mushroom cloud' of the atom bomb. The image of the mushroom most aptly suggests the cloud's characteristically hypertrophic proliferation, a word that has become associated with the spread of nuclear weapons in particular. The image conjoins a rapid and terrifyingly uncontrollable process of growth with the bomb's sinisterly lingering aftermath, associated both with radioactive fallout as the cloud begins to curl back to earth, and with the sombre shadow of apocalypse under which humanity has lived since 1945. The distinctive shape of the mushroom is common to many powerful explosions, and in fact the first reference to a 'mushroom cloud' recorded by the Oxford English Dictionary is from 1909 and refers to the eruption of the volcano Mt Pelée, Martinique. (Connor 2009)

For those living near the volcano in Iceland, the eruption was spectacular and visibly present, evoking a category of the sublime as it emerges, or reemerges, in European aesthetic discourse, especially following its codification by Edmund Burke and Immanuel Kant – as a response to the power or size of nature. Burke shifted the emphasis in discussions of the sublime towards experiences provoked by aspects of nature, which due to their vastness or obscurity, were likely to fill us with a degree of horror. These feelings were linked to the body being overwhelmed by nature, overpowering the senses, resulting in ‘a sort of delightful horror, a sort of tranquility tinged with terror.’ (Burke 2008,123) Kant wrote in the *Critique of Judgement:*

> The feelings of the sublime is, therefore, at once a feeling of displeasure, arising from the inadequacy of imagination in the aesthetic estimation of magnitude to attain its estimation of reason, and a simultaneous awakened pleasure, arising from this very judgement of the inadequacy of sense of being in accord with ideas of reason, so far as the effort to attain these is for us a law.
>
> (Kant 1790,106)

Thus because the sublime addresses what cannot be commanded or controlled, it is grounded in an awareness of lack. As a consequence of this awareness of an inaccessible form of excess, argues Kant, we come to a recognition of our limitations, and so transform a sense of negative insufficiency into a positive gain. (Kant, 1790,106)

For those of us not living in close proximity to the erupting volcano, the cloud remained invisible, introducing a sublime evoked by absence, a failure of representation at the centre of an unprecedented measure. Excessive in its absence, the ash cloud heightened a sense of our own physicality, shifting us out of the utilitarian way we live our lives into a different register of experience, which included encountering something new. The experience of modern life itself has been viewed by such thinkers as Jean-Francois Lyotard and Fredric Jameson in terms of the sublime, as extreme space-time compressions produced by globalised communication technologies that give rise to a perception of the everyday as fundamentally destabilising and excessive. (Morley 2010,12)

Inspired by the effects of the volcanic ash cloud, Britain’s Poet Laureate Carol Ann Duffy wrote *Silver Lining*. (Duffy 2010) Describing the sky as ‘clean as a wiped slate’, Duffy asks whether we might find a moment to enjoy our exclusion from the international airways, to hear the birdsong often drowned out by aircraft. (Adey 2014,173) From the domestic garden, Duffy draws attention to the natural world and our relationship to it. She then goes further, reminding us of the legacy of poets who have also drawn our attention to the natural world - all this whilst acknowledging the ambivalence of the enforced grounding.

The sublime functions in art in much the same way, with an immediacy of experience that makes the perceiving subject question its own understanding of reality. Because we cannot find ‘the thing that is happening, or the moment’ within the work of art, we start to find a greater awareness of our self-experiencing it, the noises around us etc. One such art work *4’33”* (1952), composed by artist John Cage, is a performance piece where a performer sits at his or her instrument for the requisite amount of time without sounding a single note, while the audience hears the sounds occurring in their surroundings. Cage’s piece *4’33”,* was first performed by David Tudor in 1952, who sat at the piano, opened the keyboard lid, and sat silently for 30 seconds. He then closed the lid. He reopened it, and then sat silently again for a full two minutes and 23 seconds. He then closed and reopened the lid one more time, this time for 1 minute 40 seconds. He then closed the lid and walked off stage.

Part of what makes the performance so compelling is the utter simplicity of the concept. The composer creates nothing at all. The audience witnesses this very basic act, the act of sitting still and being quiet. (Pritchett 2014) The piece has been described as being difficult for audiences. Confronted with the silence in a setting we cannot control and where we do not expect this kind of event, might provoke a number of responses ranging from a desire for it to be over, a desire for more interesting sounds to listen to, or we might feel frightened, insulted, bored, baffled, doubtful, agitated, sleepy, attentive, philosophical or because we get it, a bit smug. (Pritchett 2014)

Apparently the piece was based upon an experience Cage had within an Anechoic chamber (a room designed to completely absorb reflections of either sound or electromagnetic waves) at Harvard in 1951, which brought about a significant transformation in Cage’s understanding of silence. Cage heard not the absolute silence he had been expecting, but rather two distinct sounds emanating from his own body. As a result Cage came to understand the impossibility of silence, redefining it as, not the complete absence of sound, but the presence of unintentional noises. Just as Cage forces listeners to re-adjust and think through their expectations of what contemporary music is and sounds, we can reflect on Eyjafjallajökull in a similarly thoughtful way.

Air travel operations within the air traffic control system are time-based and subject to continual change within airspace itself, which always remains constant. When Eyjafjallajökull erupted and the air traffic control system shut down, these time-based procedures governing movement were suspended. With airspace no longer being able to be 'worked' all that marked the presence of the threatening ash cloud was the absence of familiar streaks left in the sky behind aircraft – contrails. Lacking the familiar sound or visual trace of the temporal rhythms of air travel, the clear blue sky seemed to be 'saying nothing'.

The volcanic eruption forced us to acknowledge that airspace is never entirely a socially or techno-socially constructed space, as it is always premised on an 'earthly' outside, which can never wholly be internalised. The suspension of air travel during the closure of airspace can be compared to the way Cage suspended the 'normal' performing of musical/auditory space in *4'33'.* While Cage permitted the 'outside' noise to intrude, we are left to wonder whether it is this environmental intrusion that perhaps supports the very condition of possibility of every work of art or musical performance. As an evocation of silence, stillness and structure, *4'33'* becomes palpably present in its very absence, forcing a retreat into the imagination.

During an interview I had with an air traffic controller working at NATS in Swanwick (one of the UK's two main air traffic control centres), I was told that the ash cloud event turned the usually busy air traffic control operations building eerily quiet. The controller said 'it was surreal…. on a full daytime shift controllers were just sitting around playing monopoly'. (Boulton 2011) Suddenly standardised air traffic control procedures and airline timetables were subjected to last minute changes because of a cloud that no one could see. While telling me this, the controller pondered for a moment over what he thought was unusual about the six days following the airspace closure – the consistently clear blue skies. In a slightly contrite way, he seemed to have given considerable thought to the absence of aircraft and their contrails, further speculating upon whether these vaporous trails blocked the sun. Puzzling over the production of high-level cloud and the environmental impact of aircraft, the controller diverted our conversation away from a prosaic exchange about the difficult task of managing the crisis. In fact he seemed rather submissive at the sight of a beautiful clear sky he couldn't work. Recalling Burke's notion of the sublime and the enormity of nature, we were all now securely grounded, safe from the horror above and yet the clear blue skies signalled a humiliating sign of defeat.

The volcanic ash cloud event generated further work concerning responsibility, after controllers refused to be responsible for clearing an aircraft through an ash cloud they couldn't see. (Boulton 2011) Perhaps ironically, there was something about the air travel system that had been overlooked, while being overseen. The words 'oversee' and 'overlook' have diverged in opposite directions. To oversee something is, as in the Latinate form, to supervise it: to watch it closely as it happens (for that which one oversees, like that which one observes, is usually a process rather than an object). One wishes to avoid missing anything. Overlooking means just the opposite. To overlook means to miss something, to let something slip or pass unobserved in what one sees. Thus, one oversees in order not to overlook anything.

The opposition of meanings comes into focus in the word 'oversight' and it's ordinary conversational meaning, which is 'a mistake made through inattention'. In the case of overseeing, the word 'over' seems to imply temporal intensification as well as a spatial over laying; one hovers over the object of attention, in order to be able to look again and again if need be. In the case of overlooking, one seems to have one's sights fixed telescopically too far ahead, so that one misses what is immediately to hand or under one's nose (but who can see anything that is under one's nose?). Thus, in overlooking, one under looks. (Connor 2008) However, perhaps 'under looking' might be usefully employed here to zoom in on what is under our feet - a ground that is constantly moving.

Prior to the ash cloud reaching UK airspace on April 15th 2010, the volcano had been erupting for almost four weeks, which should have been enough time to put in place contingency plans that would have addressed maintaining safe flying in crowded airspace. (Sammonds, McGuire and Edwards 2010,8) Speculation over the ash and its dangerous ‘potential’ effects upon aircraft, shifted attention and significant criticism towards Civil Aviation protocols and preparedness to anticipate and react to such natural calamities. With what seemed like a collective catastrophe of total breakdown, everything surfaced - positive and negative. By April 18th 2010, many passengers and airlines had become increasingly frustrated at what they perceived to be a lack of urgency by regulators to 'get Europe moving' and questioned whether the restrictions were proportionate to the risk the ash posed. (Budd 2011)

As confusion reigned, regulators were accused of handling the exceptional situation with a knee-jerk reaction that appeared out of all proportion and poorly coordinated. Accused of bumbling in their endeavors to restore the air traffic system to some normality, criticism focused on how state organisations, such as the Civil Aviation Authority, came to their conclusions, how they addressed theory and empirical data; and how they anticipated threats like the volcano to their operations. (Adey, Anderson and Lobo Guerrero 2011, 340) However, airlines had received warnings about the effect of volcanic ash well before the Icelandic eruption of 2010. (Sammonds, McGuire and Edwards 2010,1)

According to a study carried out by University College London, the core of the problem lay in the fact that prior to the eruption, the aviation industry had still not agreed a safe threshold of ash in the atmosphere, below which aircraft would be permitted to fly. (Sammonds, McGuire and Edwards 2010,7) The fundamental problem was an absence of data detailing ash tolerance, combined with a lack of consensus among airframe and engine manufacturers, airlines, international safety regulators and aerospace engineers as to what constituted a 'safe' concentration of atmospheric ash. (Sammonds, McGuire and Edwards 2010,7)

Until April 2010, more than 30 years of civil aircraft encounters with ash clouds had failed to concentrate the minds of stakeholders sufficiently, to establish an agreed safe limit. (Sammonds, McGuire and Edwards 2010,7) The issue was highlighted in 2008 at the 4th meeting of the International airways Volcano Watch operations group, where the situation seems to have been explained away, partly as a consequence of difficulties in attracting formal aviation industry representation at science-focused workshops on volcanic ash. (Sammonds, McGuire and Edwards 2010,7)

In light of a series of ‘almost accidents’, the recommended aviation industry risk strategy has been for pilots to avoid volcanic ash plumes or to exit them as soon as possible, using a descending turn and following a reverse bearing. Such strategies were designed however, to prevent the coming together of aircraft and columns of dense ash close to erupting volcanoes in places like Alaska and Indonesia, where volcanic activity is more common. They were not established to handle the lower risk associated with more dilute ash clouds relatively remote from source. Furthermore, they were designed for air-routes with room to manoeuvre, which make avoidance and alternative flight paths possible. They were not suited to a situation that involved a large, extended, ash cloud – initially of unknown density – spread across the crowded airspace of the UK and Western Europe.

Eyjafjallajökull’s cloud of fine volcanic ash became airborne in an unusually stable jet stream. Anticyclones over the north Atlantic rapidly blew the ash cloud south and east towards mainland Europe and into some of the world's busiest airspace. Even though the ash cloud was subject to a set of protocols that work towards anticipating and therefore governing air mobility, the ash cloud seemed to be outside the sphere of human intervention and the standardised construction of airspace. As the crisis ran its course the winds carrying the ash continued changing course, making it difficult to know which sectors of sky might be closed, when, or the length of time they would remain shut. While uncertainty existed about the effects of the specific form of ash from the Eyjafjallajökull eruption, the possibility of damage was made present through examples of past encounters with ash. (Adey and Anderson 2011,13)

A number of early warning systems have been established to anticipate the formation of an ash cloud, track its movement and adjust flight plans accordingly. Detection of volcanic ash is beyond the capability of an aircraft's on-board radar, so volcanic ash is detected, tracked and modeled by organisations such as the London Volcanic Ash Advisory Centre (VAAC).[2] The Eyjafjallajökull ash cloud was translated into calculable risk through its representation on maps, which were circulated from the Volcanic Ash advisory Centre (VAAC) based at the UK Met office. Images from satellites and other data were assembled and analysed using a model for atmospheric dispersion that was originally designed to predict the spread of nuclear gases, developed in-house at the UK Met office at the time of the Chernobyl nuclear accident.[3] Predicting the dispersion of the ash cloud for the next 24 hours, the maps were produced daily from satellite imagery and atmospheric modeling. These maps were further translated by NATS, as the UK's Air Navigation Service Provider, converting the data onto aviation charts.

It is by turning to these interconnected systems of airspace infrastructure that we begin to understand how the actual eruption became an 'event'. During a teleconference of the Extraordinary Board Meeting of the Civil Aviation Authority (CAA), it was noted that the cloud was altering in shape as they spoke and had changed even since the papers before the Board had been written. (Adey, Anderson and Lobo Guerrero 2011,340)

The guidance given to the Civil Aviation Authority by the Volcanic Ash Advisory Centre was the 'Avoid Avoid Avoid' rule, requiring aircraft to steer clear of any kind of ash cloud. The idea is that given enough space in the sky, pilots can steer around an ash cloud or, depending on the height of the cloud, fly over and

[2] The Volcanic Ash Advisory Center (VAAC) is a group of experts responsible for coordinating and disseminating information on atmospheric volcanic ash clouds that may endanger aviation. As at 2010, there are nine Volcanic Ash Advisory Centers located around the world, each one focusing on a particular geographical region. Their analyses are made public in the form of Volcanic ash advisories (VAA) and often incorporate the results of computer simulation models . The network was set up by the International civil Aviation Organisation(ICAO), in the 1990s following incidents where commercial aircraft had flown through volcanic ash resulting in the loss of engine power. It was recognised following these and other incidents that volcanic ash was a danger to commercial aviation and that the only way to ensure that there would be no loss of an aircraft was to alert pilots in a timely manner to divert their flight around the cloud. (Civil Aviation Authority 2011)

[3] The Chernobyl disaster (1986) was a nuclear accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine. It was the result of a flawed reactor design that was operated with inadequately trained personnel. Killing 30 people the explosion and fire released large quantities of radioactive contamination into the atmosphere, which spread over much of Western USSR and Europe. (World Nuclear Association 2014)

under. However in the congested skies over Europe where many aircraft have to share the same airspace, Richard Deakins, chief executive of NATS, made the decision to close airspace entirely to commercial traffic, believing such avoiding options were not practical. Declaring that ‘the threat from the ash cloud was real’, Deakins argued that ‘during the time of the ban, there were a number of reported incidents relating to military aircraft, which were not grounded’. (Deakins 2012) Just before the ban was imposed on April 15th, Finnish Air Force F-18s were found to have ash damage in their engines. With no other guidelines available therefore, the decision by NATS and similar organisations on the continent to issue a near blanket no-fly ban once a discernable volcanic cloud was detected, must be viewed as justifiable. (Sammonds, McGuire and Edwards 2010,12)

When Mount Vesuvius erupted in March 1944, it wiped out a fleet of 88 US B-25 bombers that were parked on the ground while stationed at Pompeii airfield. (Brooker 2010, cited in Birtchnell and Buscher 2011,4) While no lives were lost, the damage to aircraft caused one of the heaviest losses to any US bombardment group in World War Two. Since then a number of encounters between jet aircraft and ash clouds, notably over Japan and Alaska, in the late 1970s had resulted in minor damage. The potential seriousness of the issue was highlighted when in 1982, British Airways flight 009 from London – Auckland (Boeing 747-236B) flew within an ash cloud arising from an eruption of Mount Galinggung in Indonesia. All four engines failed due to the influx of ash, which melted on entering the engines, blocking the turbines. Disaster was narrowly averted when the plane descended on gliding. As the inactivated engines began to cool, the ash re solidified and broke away, enabling air to pass through the engines once more, allowing them to re-start. (Stewart 2002)

In 1989, a similar incident occurred when a KLM flight 867 from Amsterdam – Tokyo (Boeing 747-406) experienced complete engine failure and the back-up electrical system, after flying through an ash cloud resulting from the eruption of Mount Redoubt in Alaska. Only after descending 14,000 feet were the pilots able to re-start the engines and land the aircraft safely in the state capital Anchorage.

Without reliable calculations of risk acceptable to those responsible for regulating airspace, it was inevitable that NATS and the UK's specialist aviation regulator – the Civil Aviation Authority (CAA) would apply already existing rules regarding volcanic ash – zero tolerance based on ICAO instructions. The decision to close down UK airspace reflected the challenges faced by NATS, focusing the aviation industry on the fragility of their operations when exposed to such weather phenomena. Keenly focused on a duty of care, legal implications were also a key focus.

Meanwhile the CAA began working with interested parties towards a less precautionary response. A series of teleconferences were established, drawing together almost 100 organisations including NATS, the Department for Transport, the UK weather service (Met office), airports and airlines/aircraft, to assess whether slightly denser contamination than the current ICAO level would be safe. (Hutter and Lloyd-Bostock 2013) The first conference was held on the 16th April, 2010, where eventually it was agreed by European Transport Ministers that a new safety limit of 2 milligrams per cubic metre of air and a new three-band model for classifying ash would take effect from 0600 on the 20th April. (Hutter and Lloyd-Bostock 2013) With a new zoning system in place, airspace was reopened that evening, after five days of closure.

Deposits of ash across the UK and much of Europe as a consequence of volcanic eruptions in Iceland are well documented. [4] As I have already mentioned, the problem of volcanic ash for aviation is far from unprecedented and has long concerned air transport regulators and industry representatives. Volcanic ash and fast-moving jet aircraft are not compatible and the damaging consequences of the two coming together are manifold. Volcanic ash presents a problem for modern jet powered (in particular) aircraft for two main reasons. Firstly, such ash is silica-rich and therefore abrasive, especially when striking an aircraft at a relative speed in excess of 800 kilometres/hour. Secondly, the composition of most volcanic ash is such that its melting temperature lies within

[4] A number of ash horizons preserved in the peat-lands of Scotland and northern England, testify to Icelandic eruptions around 4300, 2176, 1150, and 500 years ago that deposited ash across parts of the UK, while Iceland-sourced ash layers are also found in Ireland, Germany and elsewhere in Europe (Barber et al. 2008).

the operating temperature range (1000°C) of modern, large, jet engines. (Miller and Casadevall 2000, cited in Sammonds, McGuire and Edwards 2010,11) The effects of ash on an aircraft depends on specific circumstances, which include the concentration of volcanic ash in the cloud, the length of time the aircraft spends within the cloud, and the actions taken by the pilots while in the cloud.

With more than 80 documented instances of aircraft flying through ash, the risks to a commercial airliner are well summarised. (Miller and Casadevall 1999, cited in Sammonds et al. 2010,7). First, air quality in the cockpit and cabin may be compromised by the intake of ash. Secondly, instrumentation may be damaged. This includes potential blockage of the Pitot tubes that measure speed in flight. The aircraft could stall if this information cannot be relayed to pilots (as occurred in the fatal crash of Air France flight 447 in June 2009, when ice obstructed the Pitot tubes). Forward surfaces, including the windshield, can be abraded by ash. Abrasion can also erode the compressor blades in the jet engines and thus reduce performance. As jet engines operate at temperatures that are higher than the melting point of silica, ash can fuse onto surfaces within the engine, especially turbine vanes and parts of the combustion chamber. This can cause engines to 'flame-out' and stall through loss of compression, although, as the aircraft descends, higher atmospheric pressures may allow an engine to be restarted. (Alexander 2013,10)

For six days during the volcano's explosive phase, starting in April 2010, the eruption punched through the ice cap causing melt waters to mix with the rising magma. Substantial quantities of lava spilled out from the crater and tumbled down the mountainside in a dazzling display, but not much ash was produced. On April 13th it stopped, but the next day a much larger more explosive eruption started within the volcanoes main caldera, which is filled with ice. As the magma had pierced the ice cap, a greater column of ash rose to a height of three to six kilometres.

Geologists explained that the large quantity of ash was caused partly by the interaction of the magma with the melt-water, but also by the chemical composition of the magma. [5] According to paleontologist Richard Fortey, 'the rocks beneath us are like an unconscious mind beneath the face of the earth, determining its shift in mood and physiognomy'. (Fortey 2005,32) Today, thanks to the refinements in Global Positioning Satellites, the smallest heaves in the surface of the ground can now be measured. In theory, it should be possible to recognise the potential for a volcanic eruption far sooner than ever feasible in the past. Sudden acceleration in the 'inflation' of the ground or changes in gas emitted from fumeroles, might indicate an impending crisis.

Delving into the realm of rocks, tectonics and bare forces of the planet, Fortey reminds us that we live in a world that shifts. Geology acts as a collective unconscious for the world, a deep control beneath the oceans and continents. (Fortey 2005,9) Fortey not only explains the way tectonic plates exert their influence, ultimately controlling the personality of the planet, but describes the sheer immensity of time involved in Earth history. Instead of collapsing time using the twenty-four hour clocks or running tracks, or other commonly used analogies that attempt to bring geological time down to a domestic scale, Fortey suggests 'we imagine a tectonic plate spinning about six times around the whole world with a speed not much exceeding the rate at which our fingernails grow'. (Fortey 2005,77)

Volcanic ash clouds in themselves are not dangerous; they become a hazard within the horizon of the globalised and ever-expanding aviation industry. Sociologist Ulrich Beck writes:

> The 'fate of side effects', against which our mobile life is formed, shattered for one historical moment, mirroring a globalised air traffic system at the mercy of 'internalised nature'. The volcanic ash cloud is the cow on the motorway; it is the 'enemy' of the 'flight society' and its airlines alone.
>
> (Beck 2011,14)

[5] Water initially chills the magma at the interface to a hot glass, which then shatters; the water penetrates the mass of shattered hot glass and is transformed into high-pressure superheated steam by a runaway process of heat transfer and further magma fragmentation, until a violent explosion results. (Sammonds,McGuire and Edwards 2010)

Questions were raised as to why nations in Northern Europe were so surprised and poorly prepared for an event that was anticipated by science and aviation communities. Once an eruption is underway, satellite imagery has been developed to track ash clouds, identifying and quantifying ash in the atmosphere. Such tracking technology is an indication that the aviation hazard posed by Icelandic volcanism has been recognised by scientists, operational meteorological institutes and the aviation authorities for many years – and yet it seemed this appreciation of the hazard had not led to integrated UK or EU policy.

The UK National Risk Register, first published by the Cabinet Office in 2008, did not mention the volcanic threat despite advice given at an early stage in its drafting of the specific threat of Icelandic eruptions (nor does it discuss seismic hazard in the UK). It is now being revised in light of the eruption. Even within the scientific community, projects aimed at investigating the threat of plumes from Iceland had been proposed but not funded. Thus, the events beginning on the 14th April 2010 required a rapid and extreme response to what was in fact a small eruption, and in the reactive formation of advisory committees and conferences across the EU. In this context, European governance structures failed to heed the advice of the United Nations International Strategy for disaster Reduction, emphasising the importance of preparation over response as a means of reducing disasters. (Donovan and Oppenheimer 2011,5)

The extent of risk, amplified by epistemic uncertainties concerning jet engine performance, led to governance advocating the application of the *precautionary principle*. (Donovan and Oppenheimer 2011,8) The *precautionary principle* asks us to take regulatory action on the basis of possible 'unmanageable' risks, even after tests have been conducted that find no evidence of harm. We are asked to make decisions to curb actions, not on the basis of what we know, but on the basis of what we do not know. The European Commission's communication puts in a nutshell the context for applying the *precautionary principle*: 'Whether or not to invoke the *Precautionary Principle* is a decision exercised where scientific information is insufficient, inconclusive or uncertain and where there are indications that the possible effects on the environment, or human, animal or plant health may be potentially dangerous and inconsistent with the chosen level of protection'. (European Commission 2000,10)

Philosopher of risk management, Francois Ewald, identifies the origins of the *precautionary principle*, in Aristotle and describes it as 'a concept based in the question of morality and decision-making in situations of uncertainty that may be incompatible with real-life practices of contemporary Western societies'. (Ewald 2000) Rooted in matters generally concerning the environment and health management, its applications were developed in the context of thinking about governmental responsibilities and extended to crisis management.

Precautionary logic indicates a paradigm shift regarding the use of science in risk regulation, describing a kind of reasoning that urges us to look for doubt instead of certainty and to always consider that an unseen threat may always lie in wait. The *precautionary principle* is invariably a conservative form of risk aversion. As Ewald (2002,282) writes: '(t)he precautionary principle (sic) does not target all risk situations but only those marked by two principle features: a context of scientific uncertainty on the one hand and the possibility of serious and irreversible damage on the other'. (Adey and Anderson 2011,13)

While NATS felt they were justified in their decision to close airspace on the premise that they were saving lives, the hazard of an erupting volcano did not fit easily into governance structures at national and international levels. One of the difficulties lay in the conflicting evidence regarding probabilistic risk to aircraft and the lack of procedures in place to deal with volcanic ash. These conflicts revealed contradictions that were otherwise concealed by the normal functioning of the air travel system and the way it rationalised itself. It could be argued that NATS and the air traffic control system was overwhelmed by the volcanic ash cloud and therefore responded in a rationally conservative fashion that limited risk, which is the basic logic of the entire system. The shut down of the airspace system not only indicated congruence between the sublime and the impossibility of rational analysis but also revealed the systems limitations as a scientific rational construct in relation to an exceptional event.

In the end the decision to allow airspace to reopen did not seem to come from NATS as those that manage airspace, it came from politicians in what seemed to be a stunning reversal of policy. Precautionary reasoning was swiftly abandoned for a decision-making procedure in which we accept that there is a level of risk that is worth taking in order to reap the benefits of air transport and this seems effectively, to be a form of cost benefit analysis.

The ash cloud crisis was a situation in which the systemic level decisions faced by air traffic control and aviation regulators, were also involving representatives of those served by the system. As long as the system is functioning, politicians and airlines are happy to leave the running of the system to the experts. However NATS decision to close airspace, exposed the extent to which the regulatory system is not identical to the various organisations that depend upon it. After all, the public face of NATS could be seen as being dominated by commercial goals and the need to sell its wares. Describing it's vision strategy on it's website [6] NATS summarises its vision as being 'the acknowledged global leader in innovative air traffic solutions and airport performance' and 'playing a pivotal role in Europe by working together with all aviation partners to deliver a Single European Sky that will help to meet the safety, capacity and performance challenges of European aviation in the 21st century'. (Hutter and Lloyd-Bostock 2013,10) Clearly over-regulation runs the risk of killing what it's supposed to be sustaining.

Raising the question of responsibility and who should effect preparations for such an event, the network disruption revealed much about the interplay between the organisation of liberal global mobility and the presence of the state. One such question asked, who should effect preparations for such an event and how do scientists communicate the potential impact to stakeholders? Along with NATS, the UK's aviation regulator - the Civil Aviation Authority, came in for a lot of criticism on how they addressed empirical data. While the public seemed to expect volcanologists to be able to advise on whether or not to book air travel, air traffic controllers had suddenly become 'policemen of the sky'. (Boulton 2011)

[6] www.nats.aero/

Even if one thinks of a volcanic eruption as a brute fact, the meaning of it is dependent on social systems, from the language we articulate in our concerns and our interpretation of the media and communication systems that spread news of the event. If the media saturates the airways with large volumes of information, it may serve as a risk amplifier. The symbolic connotations and volume, as well as the extent to which the information has been disputed and dramatised, can influence social amplification. Such dramatisation also increases fears by exaggerating the potential consequences and abetting widespread panic. Sensational headlines create salient messages that are easily conjured in public minds, but not easily stifled. The media also tends to become a battleground for contentious viewpoints. (Alemanno 2011,84)

When experts face off, it further heightens uncertainty and deceases credibility in the spokespersons. Not surprisingly, this results in an amplification of risk, perpetuating public distrust. In this type of environment where confusion is rampant, trust plays a considerable role in public perceptions of the severity of risk. In addition to advisory bodies, airlines also introduce their own safety communications to the public. British Airways ran test flights and announced that they received the all clear. However, the North Atlantic Treaty Organisation (NATO) reported finding ash in a jet engine, contradicting British Airway's reassuring claims. As previously discussed, in an environment of competing claims, public distrust perpetuates. Such contradictory levels of flight safety assurance therefore contributed to levels of public distrust.

The media framing of the ash cloud event included attempts by the UK's red top newspapers to sensationalise the threat to human life. When flights were restarted on the 21st April 2010, copies of the *Daily Star* had to be removed from airport newsagent shelves over fears that it's splash headlined - 'Terror as plane hits ash cloud', featuring a computer generated image of a Boeing 747 aircraft with engines ablaze, could cause panic among travellers. (Plunkett 2010) The image used in the splash was taken from a TV reconstruction of the 1982 British Airways Boeing 747 incident. The documentary, previously broadcast on the *National Geographic* channel, was to be shown on *Channel Five* that night. The *Star* story, which featured four images from the documentary, described how a 'stricken British Airways jumbo jet is engulfed by “flames” after flying into a deadly cloud of volcanic ash’. (Plunkett 2010) The dramatic pictures were supposed to show the horrifying reason why flights were grounded for five days but there was no explanation on the front that this was a TV mock-up of an incident from 1982. A source at Gatwick airport said the story was irresponsible ‘Anyone who saw that front page would have naturally assumed these were images from a flight that had gone through a volcanic cloud after the restrictions were lifted last night. It was clearly designed to sell papers by inducing panic, which is the last thing any of us need right now.’ (Plunkett 2010)

While Eyjafjallajökull was not the first volcanic eruption to endanger aircraft and disrupt air traffic, both its short-term socio-economic effects and longer-term regulatory implications were profound. On an average weekday, 25,000-28,500 commercial flights, plus many thousands more military and private aircraft, use European airspace. The recurrent closure of airspace seriously limited air traffic in 23 countries around the EU and its periphery, causing the cancellation of 108,000 flights. In these exceptional circumstances some people found themselves deprived of their consumer rights as established by the European Union directive on air passenger rights (Regulation 261/2004). There were numerous media accounts of people not receiving information from airlines, not getting care in the form of meals and accommodation and not being offered fare reimbursement or re-routed to their final destination.

The crisis exposed a tension between two narratives that pulled in different directions. On the one hand air traffic control and meteorological services issued a response based on theoretical models and empirical data alongside zero tolerance specifications provided by aircraft manufacturers. Pulling in the opposite direction, the social and economic implications of the ash cloud event presented a deeper problem - the vital importance of air transport in supporting the economy. Ten million individuals were affected and had to cancel their trips or find alternative travel arrangements at serious economic cost for the passengers, carriers, and insurers involved.

Unbeknownst to most passengers unaware of the complex legal arrangements found in the small print of their travel documents, their travel security was broadly held in two places: travel insurance policies, and the legal protections afforded to each airline passenger by their carrier. (Adey and Anderson 2011,17) Most travel insurance providers chose to separate volcanic eruptions from volcanic ash events for purposes of determining coverage, with eruptions covered as natural disasters and ash clouds covered as weather events. Acting on an 'event' in relation to the insurable interest of the passenger's welfare, the technology of insurance must contain definitions over what sort of mobile event-risk they would protect. Some chose the term 'bad weather' to define the eruptions, which meant in some cases that cover was offered, whilst others were refused cover on the basis that the event was a 'natural disaster'. Broken down in this way, the security of passenger mobilities financialised by insurance products, appeared to be much more insecure and contingent on the specifities of their policy wording. (Adey, Anderson and Lobo Guerrero 2011, 341)

The disruption opened up a complex relation between mobility and its financialisation by insurance products, governing movement and experience almost as if from below. Passengers were left questioning - who would take care of them? With the contingency of the cloud's changing path, the hidden and complex categorisations of insurance, interpreted differently by different agencies and people, brought doubt and ambiguity into travellers plans and decision making. (Adey and Anderson 2011,17) When Denise Mc Donagh, had a seven-day wait for a Faro to Dublin flight because of the volcanic ash disruption, the Irish airline Ryanair refused to compensate her for the 1,130 euros (£968.00) she spent on a hotel, food and transport. However Ryanair's refusal to compensate over the ash cloud delay broke European Union rules. Ryanair had argued the eruption of Iceland's Eyjafjallajökull volcano was so extraordinary that normal rules should not apply. Michael O'Leary, chief executive officer of Ryanair was quoted as saying 'You can't make airlines responsible for all these acts of God.' (BBC 2013)

At the beginning of this year, in a landmark case, Ryanair was told to compensate McDonagh. In it's judgment published on 31st January 2013, the Luxembourg-based court found that the closure of part of European airspace as a result of the volcanic ash eruption, constituted extraordinary circumstances hence Ryanair had an obligation to provide care. (BBC 2013) The judges' ruling - now binding across the Economic Union - said ‘such events constitute “extraordinary circumstances”, which do not release air carriers from their obligation to provide care’. (BBC 2013) The court said that it did not recognise a separate category of ‘particularly extraordinary’ events, beyond ‘extraordinary circumstances’ and that all airlines must provide care to passengers when flights are cancelled. The court stated that the provision of care to passengers is particularly important in the case of 'extraordinary circumstances', which persist over a long time and it is precisely in situations where the waiting period occasioned by the cancellation of a flight is particularly lengthy that it is necessary to ensure provision of care throughout that period. (Bachelor 2011)

The cancellation of 108,000 flights cost the airline industry in excess of $1.7 billion in lost revenue. Perishable goods, normally air-freighted into Europe, were left to rot in warehouses overseas. As the disruption ran into its fourth day, UK newspapers ominously reported that supermarket stocks of fresh fruit and vegetables were running low. (Roberts 2010,32). The twentieth century manufacturing model means that transport systems are an essential component of the industrial process, operating on a ‘just in time’ delivery resulting in factories holding just a few hours of stock and a wide distribution of component producers around the world. The heavy reliance on air transport meant that airspace closure and flight bans not only affected airlines but were also felt across the manufacturing spectrum, as mounting pressure to know how long the disruption would continue became essential for maintaining business continuity and planning. (Sammonds, McGuire and Edwards 2010,17) According to the EU transport commissioner Siim Kallas, the disruption caused by the Icelandic volcanic ash cloud could have cost firms across Europe up to €2.5bn (£2.15bn). (Gabbatt 2010)

Only a few days after the eruption, the national tabloid newspaper, *The Sun* (2010), featured the story of bride-to-be Kelly who had to call off her dream wedding in Antigua, as well as presenting images of holidaymakers and businesspeople ‘racing' off to buy bicycles in order to qualify for the last remaining tickets reserved for cyclists on cross-Channel ferries. The national tabloid also reported the somewhat comical image of 'City workers thumbing lifts from truckers'. (Budd et al. 2011) Within days of the closure of European airspace and amidst reports that the UK emergency planning committee was to be convened, the then UK Prime Minister, Gordon Brown, instructed senior Cabinet ministers, who were then engaged on the general election campaign, to implement plans for ending the 'temporary exile' of some 200,000 British citizens stranded abroad. Raising the spectre of the evacuation of Dunkirk during World War Two, it was subsequently announced that Royal Navy cruise ships and commercial shipping would be deployed to repatriate British citizens. (Brown 2010, cited in Budd et al. 2011)

Philosopher Slavoj Zizek argues that the most important lesson to be learned from the Icelandic eruption was the extent to which our survival depends on a series of stable natural parameters, which we take for granted. (Zizek 2010) The socio-technical system of global air mobility is not only a complex assembly of human and non-human agencies, it is also dependent on the natural environment and constantly taken into account by systems of monitoring, calculating and structuring of performances in accordance with its exchanges with the ‘natural system’. The most well known example related to international air travel is the sophisticated meteorological surveillance systems providing flights with real-time data and information about emergent weather systems. (Jensen 2011) During the crisis the respective roles of the Met office and Air Traffic Control in monitoring and managing the ash cloud came under close scrutiny, raising questions regarding formatting and standardisation that enabled the flow of information. (Boulton 2011)

According to a senior controller coordinating the crisis at NATS, the relationship between Air Traffic Control and the Met office was excellent although fraught in terms of coordinating a plan that would simplify procedures – ‘it came down to a depiction of airspace’. (Boulton 2011) Facilitating the crisis involved overcoming obstacles that had never before been encountered. Working together with the Met office, air traffic controllers had to plot maps that could depict moving volume of ash and overlay these with aviation charts that could determine sectorisation.[7] (Boulton 2011) Once the data collected by NATS and

[7] Sectorisation is a process that creates the virtual division of airspace. Thus, the provision of air traffic services is broken down in the different sectors into tasks with manageable workload. Increased capacity demand is generally met by provision of more sectors. Usually the demand

the Met office had been formatted to fit each of their respective systems, it had to be quickly disseminated, due to enormous pressure from airlines. (Boulton 2011) The crisis starkly exposed the shortcomings of existing arrangements revealing a complex set of interdependencies, which revolved around the necessity to maintain fully functioning air transport, while managing high levels of systemic risk.

One of the unexpected effects of dealing with risk during the ash cloud event, was the extent to which risk became an unintended medium of communication within an air travel industry where participants within the air travel system tend to revolve around themselves. As the volcanic ash cloud was a publicly perceived risk, it compelled greater communication between airlines, the meteorological office, government and air traffic control, cutting through the self-absorption of the various systems supporting air travel. NATS were acting on ash cloud predictions that while uncertain, was the only information upon which to base decisions. This information was also needed by airline operators in order to make their business decisions, culminating into an unusual situation that allowed a global airline audience to 'listen in' on air traffic control procedures and protocols. (Boulton 2011) According to the controller I interviewed, the way in which different organisations worked together, led to better processes and systems for dealing with the type of chaos that 'reigned down' on them. The disruption led to improved airspace definitions and new methods for depicting unknowns, such as hazards. (Boulton 2011) Another outcome of the event culminated in UK air traffic control management taking the view that pilots, airlines and airspace users were responsible for knowing their aircraft and should be qualified to make a decision on whether to fly through ash after receiving notification of its presence. (Boulton 2011)

One could argue it was not the volcano as an ontologically objective thing that disrupted aerial life, rather it was the status and identity afforded to it by scientific apparatus of meteorology, aeronautics, vulcanology and so on.

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is calculated as short-term operational predicts, based on planned flights. Opening/closing of sectors should closely monitor the demand to achieve efficient use of all available resources. For example, dynamic arrangements should be made to ensure the availability of the required air traffic controllers. Failure to provide required sector configuration on time may lead to potential risks arising from sectors' overload, inter-sector miscommunication, etc. (Boulton 2011)

Experiments produced models suggesting the ‘failure’ of jet engines encountering volcanic ash. This knowledge combined with discourses by NATS on safety produced an identity construction of danger. As European airspace began to reopen slowly, even though Eyjafjallajökull was still throwing ash into the upper atmosphere, risk and security practices ascribed to the eruption kept changing due to conflicting opinions amongst the scientific community concerning jet engines and ash. It seemed to come down to a disjuncture between the need for air travel in the world economy versus risk to human life and contestation over the ‘tolerance’ of jet engines. Scientific evidence suggesting it was safe to fly just as pressure from airlines became most intense, certainly revealed the importance of capital in our lives and the extent to which scientific knowledge is forced to comply with commercial and personal interests.

The number of states imposing total bans was sufficient to prevent over 80 per cent of flights across Europe from the 17th-20th April, 2010. (Alemanno 2011,101) The ash cloud crisis elicited polemics on the hardships passengers were forced to endure, resulting in a media frenzy that bled into the policy arena of regulatory bodies and their dialogue with representatives from transportation agencies, governments and private carriers. What began as a question over how to best respond to the needs of millions of stranded passengers, quickly evolved into a broader discussion over policy and the lack of flexibility and responsiveness operating at the heart of regulatory bodies. Questions were raised over how and by whom the decisions were made and how closures could have been better targeted with a more rapid return to normal services. In outlining social and economic implications of the ash cloud event, a deeper problem of the vital importance of air transport in supporting the industrial base became apparent.

While airspace is sovereign territory controlled by individual nations, countries within Europe have agreed to administer the upper airspace jointly, i.e. through a centre for air navigation safety dealing exclusively with aircraft seeking to fly across the continent in high altitude. According to social theorist Ulrich Beck, the harmless beauty of Iceland’s volcanic cloud encapsulates the state of Europe. (Beck 2011) The difficulty in setting limit values for the dangerousness of ash is countered by a polarity of interests as well as a lack of coordination among the regulating agencies. In the words of the vice president of the Dutch pilots union, ‘We are asking the authorities to look at the situation because 100% safety does not exist. It is easy to close airspace because then it is perfectly safe, but at some time you have to resume flights’. (Smith et al. 2010,16)

Germany found a legal trick that allowed planes to fly, despite ash. A report in Der Spiegel claimed that in response to pressure applied by German airlines, flights took place under controlled visual flight rules (CVFR).[8] These rules, usually intended for amateur pilots in their Cessna’s, were suddenly cleared for use by airliners weighing hundreds of tons. The flight ban that applied during times when there was volcanic ash in the air, did not apply to CVFR flights. (Deckstein and Traufetter 2010) Controlled visual flight rules mean that pilots no longer receive instructions from air traffic controllers. Instead, all they receive are warnings, such as when their aircraft is coming dangerously close to another aircraft. An important aspect of CVFR flights is that because of the high degree of uncertainty, pilots must avoid all clouds or fly below them. For three days, from the 19th to the 2ist of April 2010, the German transportation ministry ‘tolerated’ this practice. Some 30 airlines requested permission to conduct CVFR flights. Air Berlin completed 559 and Lufthansa 395 of these out-of-the-ordinary flights. (Deckstein and Traufetter 2010)

Ulrich Beck has described the decision to allow flight’s operating under these rules as operating under ‘Lufthansa’s stage direction’. (Beck 2011,15) The point Beck makes is that the pressure applied by an airline, transformed Germany practically overnight into a ‘new kind of flight society at one’s own peril’. (Beck 2011,15) According to Beck, it was a scenario where jets were flying through air layers containing residues of volcanic ash without any clarity of whether the cloud is dangerous or not. (Beck 2011,15) As it now turns out, pilots and air traffic controllers voiced serious doubts about the practice at the time. Safety standards were compromised by the fact that aircraft were allowed

[8] CVFR (Controlled Visual Flight Rules) (Gunston 2009) are used in locations where aviation authorities have determined that VFR flight should be allowed, but that ATC separation and minimal guidance are necessary. In this respect, CVFR is similar to Instrument Flight Rules (IFR) in that ATC will give pilots headings and altitudes at which to fly, and will provide separation and conflict resolution.

to fly at altitudes of less than 3,000 metres for long periods of time, because the risk of collision with birds and other aircraft became greater at lower levels.

The debates continue to this day. In hindsight, Lufthansa safety pilot Jürgen Steinberg wrote that he regretted having approved the CVFR flights: 'This cannot happen again. Today my recommendation in the same situation would be: Don't do it'. So far, no one has dared to criticise the company's decision this openly. Steinberg admits that pilots felt that the situation was 'both unsatisfactory and threatening'. (Deckstein and Traufetter 2010) Pressured by the company, Lufthansa pilots reported that an internal order made the airlines position clear - the responsibility during CVFR flights in terms of evasion, lies with the pilot under 'see and avoid' rules. An experienced older Lufthansa captain called it unacceptable that CVFR flights were ordered in a non-emergency situation. He claimed that many younger pilots were worried about flying under those conditions and contacted him for advice. However, he was unable to help them saying, 'I had my last experiences with visual flight maneuvers more than 30 years ago'. According to Der Spiegel, Lufthansa's fleet management gave the following advice to anyone who was considering refusing to fly under visual flight rules: anyone who has concerns should call in sick. (Deckstein and Traufetter 2010)

While attempts were made to predict the ash cloud's behaviour by dispersion models and the warnings issued by the London VAAC's volcanic eruption detection system, there was something about the cloud that seemed to be outside of the sphere of human intervention. The 30,000 foot plume of ash and smoke rising from the beneath the Earth's crust was cause for awe, a humbling experience that seemed to mock human dreams of omnipotence. Constrained by geological forces, the ash cloud event was a reminder of the many ways that human demands press against the raw physicality of the earth and the extent to which emotions are tied to our relationship to nature and global mobility. As an irritant, volcanic ash will continue to demonstrate the power to transform the air travel system that we all rely on. The eruption of 2010 and the resulting ash made us more aware of the inherent risks of air travel, calling into question the illusion of human technological achievement and infallibility.

While mass media and other visualising techniques create the specter of risk, it remains irrelevant whether we are living in a 'safer' world because if disaster is anticipated then that produces a compulsion to act. (Beck 2006) This in turn conceals an irony, the irony of the promise of security made by scientists, companies and governments, which in turn contribute to an increase in risks. (Beck 2006) The countenance of risk by airlines and air safety regulators is offset by endless national safety council studies designed to reassure those of us that fly, with assertions such as 'you'd have to fly every day for 22,000 years to be involved in a fatal air crash'. (Podmore 2011) The statistics show us that one is more likely to lose one's life on a train or a bicycle than flying on a commercial airliner.

However every occurrence of a major air disaster violates the basis of the unshakeable safety that appears to be promised. A single crash of a commercial airliner forges a public perception that the risk associated with air travel is getting higher. This stems from the large loss of life (and associated wide spread news reporting) and the passenger's lack of control over their environment. Both of these reasons result in increased fear and hence a higher degree of perceived risk. We might just cast our minds back to what the chief executive of NATS, Richard Deakins had to say during a *BBC* radio interview when he said 'the threat from the ash cloud was real'. (Deakins 2012) It could be argued that proximity to the 'real' is endured by us all and at the heart of global anxiety. Ulrich Beck makes a key distinction between risk and catastrophe:

> Risk does not mean catastrophe, risk means the anticipation of catastrophe. Risks exist in a permanent state of virtuality, becoming topical only to the extent that they are anticipated. Risks are not 'real', they are 'becoming real'.
>
> (Adam, Beck and Loon 2000,166)

In order to cope with and manage risk (Beck 1992) we need to understand not only the technologies, but also the organisations and institutions that implement, sustain and co-evolve with these technologies. (Leveson et al. 2009) Commercial demands on airlines have substantially increased, creating greater traffic density and the reduced separation between planes and operations taking place in all weathers. According to sociologist Charles Perrow, these heightened requirements on the air travel system has engendered a tighter coupling of the systems and an enhanced workload on the crew and on air traffic control at very specific moments, moments that push the system to its limits. (Perrow 1999,128-131)

Perrow describes numerous failures in what he terms as 'tightly coupled, complex systems'. (Perrow 1999) In the search for speed, through-put, efficiency and the ability to operate in hostile environments, he posits that we have neglected the kind of system designs that provide reliability and security. Perrow identifies a particularly troubling characteristic of these tightly coupled, complex systems as predictably failing but in unpredictable ways. Because of the complex nature of the relationships that exist between system components, similar chains of events do not always produce the same phenomena. (Perrow 1999,146) However system level or 'normal' accidents of major consequence continually occur. (Little 2010,28) Although improvements to technology and a better understanding of system interdependencies are necessary to ensure the reliable provision of infrastructural provision, organisations and their internal cultures play a key role in the provision of these services. (Little 2010,28)

It is possible that Perrow has misclassified the Air Traffic Control system as tightly coupled because one could argue that Air Traffic Control (ATC) is as safe as it is because the system itself, has been deliberately designed to be loosely coupled in order to increase safety. (Leveson et al. 2009) The ATC system is carefully divided into non-interacting sectors and flight phases (en-route, arrival, and takeoff and landing) with the interfaces between the sectors and phases (for example, handoff of an aircraft between two air traffic control sectors) limited and controlled. Maintaining ample separation between aircraft also ensures loose coupling, so that mistakes by controllers can be remedied before they impact safety.

What is striking about organisations such as Air Traffic Control, is that in circumstances of extreme stress they perform well in complex, high-risk environments, maintaining an unrelenting focus on safety as a core value and an organisational culture that nurtures and supports it. Therefore, the closure of airspace as an enforcement of an overall system safety constraint was necessary in an uncertain operational environment. While NATS is an organisation that judges itself on the grounds of efficiency, that is, saving airlines fuel, increasing capacity and avoiding passenger inconvenience, the decision to close airspace was made on the grounds of safety.

One year after the Eyjafjallajökull eruption, a European commission press release memo, stated that there had been major improvements in international volcanic ash guidelines, very significant progress to fast track the Single European Sky and intensive work to produce transparent information for airlines on thresholds for ash. However the work being done to improve crisis preparedness and improving systemic resilience, such as establishing a single ash threshold, is proving to be extremely challenging. It has become increasingly clear that in reality, every volcanic ash crisis may be different and the nature of the ash will be different. So establishing a 'one size fits all' threshold is not viable in the short term. While some in the industry believe volcanic ash should now demand high attention others question this, comparing it to thunderstorms arguing that they are more frequent and their impact equally or more serious than volcanic ash.

The eruption of Eyjafjallajokull demonstrated the weaknesses in Europe's diverse air traffic control network. It also became clear that fierce competition between airlines and the 'invisible hand' of market forces would not tolerate further closures of UK and European airspace. While European air traffic controllers correctly prioritised passenger safety above all other factors, the scenario left many airline industry commentators and journalists frustrated with the European Union's apparent inability to swiftly and effectively act on changing meteorological and airline information. They were particularly vocal in their criticism of the CAA for closing airspace and taking a long time to reopen.

The CAA became the focus of public blame for acting with excessive caution at huge and unnecessary cost, and was accused of being at the centre of a policy fiasco (Budd et al. 2011,31). In media reporting of the crisis the fact that the regulators were constrained by internationally agreed rules was lost. The complex regulatory position and relationships between the CAA, NATS, Met Office and VAACs were confused, as were the legal powers and responsibilities of different bodies. (Hutter and Lloyd-Bostock 2013,17)

The pressure applied to NATS to reopen airspace tells us a great deal about Modernity and modern rationality. Highlighting concerns regarding risk and safety, the ash cloud event flagged up the important issue of regulation and why unrealistic expectations often appear to be placed on regulatory bodies in contemporary society. The central justification of regulation is that it controls undesirable risk and it is embedded in socio-cultural and political risk environments, which are in the business of managing feelings of vulnerability and demands for security. (Hutter and Lloyd-Bostock 2013,22) While regulators manage these demands they also need to allow business to continue, which means they are invariably blamed, when things go wrong. In the case of the ash cloud event and the decision to close of airspace in the interest of safety, they were blamed for being too precautionary. However if there had been loss of life due to a plane crash, things would have been very different.

In contrast to the volcanic ash cloud that triggered the absence of aircraft and their vapour trails, is the image of a destroyed airliner, Air New Zealand 901. As a trail of debris, extending hundreds of metres up the northern slopes of the volcano Mt Erebus in Antarctica, the photograph is a reminder of how things can go horribly wrong. The photograph taken from the air, depicts a long black smudge that appears more like a trail of soot thrown up by the volcano. The only object recognisable is the tail section of the DC-10 airliner, bearing the distinctive 'Koru' symbol of New Zealand's national airline. One of fourteen scheduled sightseeing flights over Antarctica from 1977 until 1979, Air New Zealand 901 was a flight that represented more than a modern mode of transport. Mining the sublime, the flights offered an exciting visceral experience, providing unique views of vast swathes of the Antarctic wilderness, from the comfort of an air-conditioned cabin.

Occurring in 1979, the catastrophic crash of Air New Zealand 901 is a historical example of how operational risk can allow unintentional safety deficits to enter the system. These deficits made significant the dangers of the weather phenomenon, ‘whiteout’. Also known as a malevolent trick of the polar light, ‘whiteout’ combined with ‘human error’, putting a lid on overreaching rationality and reigning in reasons hubris.

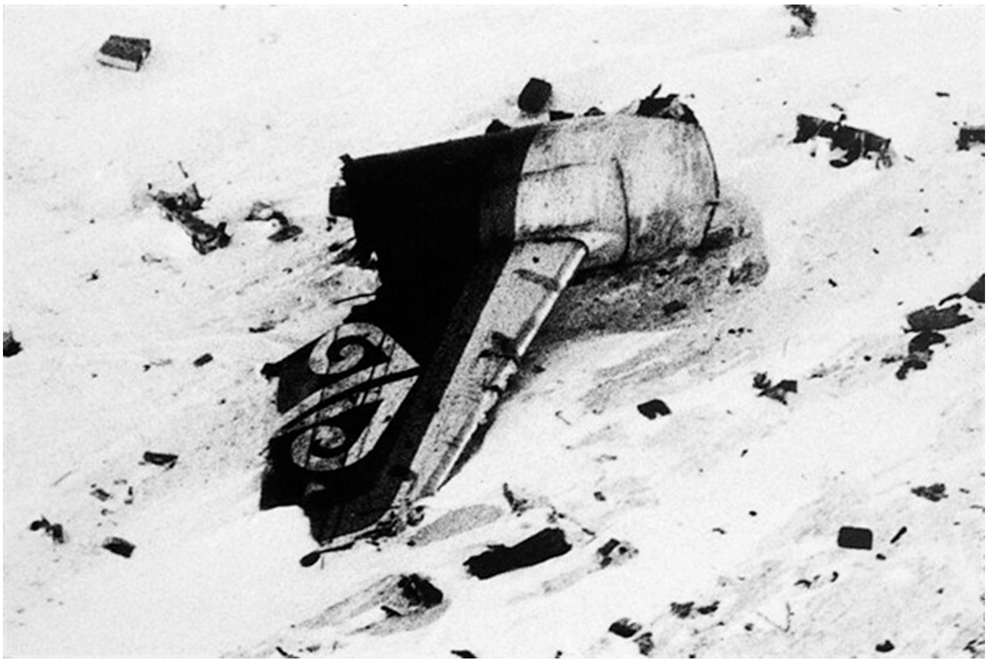

Figure 3.2 Tail section of TE901 bearing Air New Zealand’s logo – the Koru...
Source: Otago Daily Times. Available at:
http://www.odt.co.nz/entertainment/books/176022/mountain-pain.> [Retrieved 7 July, 2014].

As a provocation for rationality to reinvent itself, air disasters are seen as opportunities to reflect on the air travel system, processing failures in order to continue improving aviation safety. However, while the air transport industry is on the whole successful at learning from air accidents, the safety regimes governing air travel reflect a particular kind of rationality that also expresses a commitment to the growth of the airline industry. The intimate connection between air safety and the commercialisation of air travel means that an intrinsic conflict between stakeholders will always exist within the system.

Chapter Four

The Erebus Disaster

> Shouldn't death be a swan dive, graceful white – winged and smooth leaving the surface undisturbed?

Don DeLillo (White Noise,18)

> Every technology produces, provokes, programs a specific accident….the invention of the boat was the invention of shipwrecks. The invention of the steam engine and the locomotive was the invention of derailments. The invention of the highway was the invention of three hundred cars colliding in five minutes. The invention of the airplane was the invention of the plane crash. I believe that from now on, if we wish to continue with technology (and I don't think there will be a Neolithic regression), we must think about both the substance and the accident.

(Virilio and Lotringer 1997,37-38)

With the competitive advantage of speed, the aircraft is another instrument of globalisation, harnessing and accelerating things and people. According to theorist Paul Virilio, the comprehensive technologization of the globe, signals both integration and disintegration, both control and accident. For Virilio, the accident is an exceptional condition already contained within and rigorously predicated by the invention that made it possible. Virilio argues that the crash occurs because the machine has been designed to speed-up in order to keep pace with the movements of the world system, while at the same time leaving no room for error. (Virilio 2006, cited in Featherstone 2001) Therefore accidents are not unforeseeable faults in otherwise perfect operations, but are integral aspects of the technological devices and scientific systems produced by modernity's drive for progress. (Davies 2013,42)

The last chapter examined the fragility of air travel and a systemic shut down caused by the external threat of an erupting volcano. Forcing us to reflect on our dependency on air travel, the ash cloud event brought firmly into the public domain, issues of risk acceptability and our socio-economic 'reliance' on air travel. I shall now focus on the air accident and what it can tell us about the limits of technological and regulatory systems we construct to support our normalised reliance on air travel and further investigate the displacement of risk attached to air travel. This chapter examines a specific air accident – the crash of New Zealand 901, a DC-10 airliner killing all 257 people on board in 1979.

The total destruction of Air New Zealand 901 (TE901) occurred upon colliding with an active volcano (Mount Erebus), while on a sightseeing flight in one of the most remote and hostile regions of the world – Antarctica. Focusing on risk and socio-technical systems (people, organisations and technology) the Air New Zealand crash – known as the Erebus disaster, can tell us something about the intimate connection between air safety and commercialisation in ways rarely possible when such systems are functioning normally. The Erebus disaster is an early example of how complex systems designed to eradicate failure, can produce behaviours that can cause an accident. In this case, attempts by air accident investigators to blame the pilots was challenged by a 1981 New Zealand Royal Commission of Inquiry, which revealed pilot error was the consequence of a systemic failure.

An in-depth analysis of the Air New Zealand accident reveals how the slow, incremental movement of a system's operations towards the edge of it's safety envelope ended in catastrophic disaster. A leading academic specialising in Complexity and Systems thinking, Sidney Dekker has termed this type of system failure as a 'drift into failure'. (Dekker 2006,24) Drift into failure is hard to recognise because it is about normal people doing normal work in (seemingly) normal organisations - not about obvious breakdowns or failures or errors. (Dekker 2006,24) According to Dekker, no organisation is exempt from drifting into failure. The reason is that routes to failure trace through the structures, processes and tasks that are necessary to make an organisation successful. (Dekker 2011,12) What makes the crash of TE 901 so complex is that the protective structures (even those within the organisation itself) set up and maintained to ensure safety, was also subject to the interactions and interdependencies within the operation it was supposed to control and protect.

The failure to vet the proposal for the Air New Zealand Antarctic sightseeing flights in various forms to a comprehensive and vigorous system of appraisal and control, eventually led to safeguards being either omitted or peeled away. Meanwhile incubating from within Air New Zealand's organisational system, a correction of an earlier error of the flight route flown by previous flights shifted the flight path coordinates, electronically programming the aircraft on a collision course with Mount Erebus. Multiple causes conspired to generate an accident with contributing factors totally invisible to the participants at the time. Assumptions the crew held about the technical system they believed made them safer proved fatal; the computer technology installed to eliminate error provided the path to an error. Such was the over confidence in the computer-based electronic navigation system built into the aircraft designed to protect against pilot error, which allowed a navigational time bomb in the cockpit to lie in wait.

The material and psychological effects of the polar weather phenomenon 'whiteout' [1], was also a significant factor in the cause of the Air New Zealand crash, returning us to the key role external elements played in the previous chapter. While the ash cloud crisis revealed the extent to which the Earth's geological processes can destabilise and shut down the air travel system, the Erebus disaster invites us to further consider forces from nature, in this case 'whiteout' weather, when combined with a set of internal failures. I shall argue that failures interior to the system brought external factors (whiteout) into play, resulting in the aircraft colliding with Mt Erebus.

[1] Whiteout is an optical phenomenon in which uniform light conditions effectively make it impossible to distinguish shadows, landmarks or the horizon. This can occur when the snow cover is unbroken and the sky is overcast. Whiteout is a serious hazard as it causes a loss of perspective and direction. (Australian Antarctic Division 2002). Flying in whiteout conditions, the pilots on TE901 would never have seen the mountain approaching. Because the air in polar regions is extremely dry, the light reflected from the very dry snow crystals is altered in quality and diffused in such a way that the contours of the hills and even the presence of black objects such as rock faces are wiped out. Whiteout has a marked effect on a pilot's perception because visually there is a lack of intermediate texture.

While carrying out company expectations in conducting low-level sightseeing flights, Air New Zealand Antarctic crews had not been given training in the dangers of whiteout. As a known polar atmospheric phenomenon, anticipation of whiteout weather should have extended the criteria of operational visibility, particularly in relation to the airline's advice given to Antarctic crews, of a 'visual meteorological conditions' (VMC) [2] 'let down' procedure over McMurdo Sound.[3] The crews were permitted by the airline to descend to a minimum altitude of 6000 feet, provided they were in VMC conditions. A lack of understanding of whiteout in the Antarctic contributed to the mindset of TE 901's flight crew.

Having attended an Air New Zealand briefing on the 9th November 1979 for the proposed sightseeing flight, the crew was presented with material showing the flight path of previous flights, which would take them down McMurdo Sound. When TE 901 reached the waypoint coordinate believed by Captain Jim Collins to be the entrance of McMurdo Sound, conditions seemed perfect so he elected to make his descent over the clear sea ice in visual conditions, in accordance with airline procedure. (Vette and MacDonald 1983,310) In fact the aircraft was flying in visually deceptive whiteout weather conditions on a flight track that had substituted the summit of Mt Erebus with the adjacent McMurdo Sound. The whiteout became contingent when Captain Colllins made the decision to carry out a visual descent below the minimum safe altitude for the area. Further investigation into the cause of the accident revealed that this descent procedure had been carried out on previous flights and sanctioned by the airline to afford passengers a better view.

The accident investigation was the subject of heated controversy that continues to this day, due to the differing findings of two accident investigations. I shall firstly discuss the original findings by the chief air accidents inspector, Ron Chippendale, who blamed the 'probable cause' on error by the pilot, Captain

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[2] VMC (Visual Meteorological Conditions): flying conditions which provide a specified range of forward visibility making it possible and permissible for pilots to fly using a visual means in avoiding obstacles such as cloud, terrain and other aircraft. (Gunston 2009)

[3] A stretch of water in Antarctica that extends about 55km long and wide, connecting the Ross Sea to the north with the Ross Ice Shelf cavity to the south via Haskell Strait.

Jim Collins, saying the DC-10 aircraft would have flown well clear of Mt Erebus if the crew had kept it above approved levels.

4a. Chippendale Report

The crash of New Zealand 901 was first investigated by the office of Air Accidents of the Civil Aviation Division (CAD) of the Ministry of Transport. The CAD attributed the cause of the accident to the aircrew descending below the minimum safe altitude of 16,000 ft and continuing the flight below this altitude in poor visibility towards Mt Erebus when they were unsure of their position. (Vette and Macdonald 1999). In charge was the Chief inspector of Air Accidents, Ron Chippindale. After a site investigation in Antarctica, Chippindale and his investigators returned to New Zealand to continue their enquiries. This included checking the personnel records of the crew, and studying weather conditions at the time of the crash and other contributing factors. Chippindale's enquiries also took him to the United States and the United Kingdom where he visited the manufacturers of parts of the aircraft and the scientists who had analysed the digital flight data recorder (DFDR) and cockpit voice recorder (CVR).

On the 4th March 1980, an interim accident report was sent to parties whom Chippindale considered might bear 'some degree of responsibility for the accident'. (Chippendale 2013) These parties were the legal representatives of the estates of the pilot and co-pilot of TE901, Air New Zealand and the Civil Aviation Division (CAD) of the Ministry of Transport. They were given 90 days to comment on the report before it was finalised. At the time Chippindale refused to reveal who had been sent the interim report, advising that to do so would indicate the report's findings. But it soon became clear who had not received it - including the aircraft's manufacturers, McDonnell Douglas - and reports followed that a fault with the aircraft had been eliminated as a cause. The Opposition New Zealand Labour Party, a consortium representing the estates of deceased passengers, and the New Zealand Airline Pilots Association (NZALPA) were among those demanding to see the report. The NZALPA eventually obtained a copy of the report from the pilot and co-pilot's legal representatives and learnt that the interim report blamed the accident on ‘pilot error’.

In the days prior to the air accident investigation report's release, Chippindale advised the media that he had experienced some difficulty finding 'the ultimate cause'. (Chippendale 2013) He explained that what he had said in the report was what he thought was the 'probable' cause - the last thing that made the accident inevitable, but that there were other factors leading up to the accident. (Chippendale 2013) These other factors, outlined in the conclusions section of Chippindale's report, included omissions and inaccuracies in the route qualification briefing - in particular that the briefing may have given a misleading impression of the route - and the fact that the route was changed after the briefing.

The shift of the destination waypoint [4] 27 miles west was deemed an error by the air accident investigator, however subsequent commentators took the inspector's reference to the 'error' to mean an alteration 14 months later of the destination waypoint 27 miles east. The change of the flight path, which according to the accident investigation caused the crash, was referred to by Air New Zealand, not as an 'error', but a the correction of a previous error which had been made 14 months earlier. This verbal sleight of hand enabled the airline to maintain in public that there was no 'error' in the computer flight path at the time of the crash.

Amid the controversy over who had received Chippindale's interim report, calls were being made for a public inquiry, which led to the New Zealand Government commissioning a Royal Commission of Inquiry to investigate the place, time, causes and circumstances of the accident, together with any other matters that might involve the public or civil aviation safety. Justice Peter Mahon, who would conduct public hearings, in order to thoroughly investigate the crash and possibly 'rubber stamp' the CAD report, headed the Inquiry.

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[4] Waypoints are a Predetermined and accurately known geographical position forming start or end of route segment.. (Gunston 2009) Waypoints are used to help define invisible routing paths for navigation. For example, artificial airways—"highways in the sky" created specifically for purposes of air navigation—often have no clear connection to features of the real world, and consist only of a series of abstract waypoints in the sky through which pilots navigate; these airways are designed to facilitate air traffic control and routing of traffic between heavily traveled locations, and do not reference natural terrain features. Abstract waypoints of this kind have been made practical by modern navigation technologies, such as land-based radio beacons and the satellite-based GPS.

However Mahon's findings disagreed with the CAD report and not only cleared the flight crew from blame but transferred the blame to Air New Zealand. (Mahon 2013) Mahon concluded that the single dominant and effective cause of the disaster was the mistake made by those airline officials who programmed the aircraft to fly directly at Mt. Erebus and omitted to tell the aircrew. That mistake, according to Mahon was directly attributable, not so much to the persons who made it, but to the incompetent administrative airline procedures, which made the mistake possible. In Mahon's opinion, neither Captain Collins nor First Officer Cassin nor the flight engineers made an error contributing to the disaster, and were not responsible for its occurrence. (Mahon 1984,25)

Even though the Chippendale report did direct some criticism at Air New Zealand and the Department of Civil Aviation (CAD), the probable cause according to Chippindale was 'pilot error' - a decision made by the captain to continue a flight at low level toward an area of poor surface and horizon definition when the crew were not certain of their position and the subsequent inability to detect the rising terrain which intercepted the aircraft's flight path. The report explained that at the time of the crash, the aircraft was flying at about 450 metres above sea level in whiteout atmospheric conditions.

Chippindale concluded that the flight would have proceeded safely had the pilot not descended below the minimum safe altitudes specified by CAD and Air New Zealand. (Chippendale 2013) Although the poor visibility was attributed to whiteout conditions, the report strongly inferred that the pilots knew that they were flying in poor visibility. Chippendale reprimanded the CAD for not monitoring Antarctic flights more rigorously, including inadequate pilot briefings and procedures, specifically a late flight-path alteration that was not mentioned to the crew. (Chippendale 2013) However the main blame was reserved for the pilots, especially the captain, who was criticised for descending to a low altitude when he was unsure of his position and unable to see the terrain.

4b. Mahon Report

While assessing the possible origins of culpability for the disaster, Justice Mahon found the co-ordinates of the DC-10's navigation computer had been changed incorrectly without ensuring the crew knew of the alterations, resulting in the aircraft being programmed to fly into the mountain. Mahon also found that the airline had briefed its pilots to fly low, weather permitting. (Mahon 2013) While the conflicting verdicts both have elements of validity, the issue seems to be one of emphasis. Implicit in both conflicting opinions regarding the accident's cause was that failure emerged opportunistically, non-randomly, from the very webs of relationships that bred success and were supposed to protect the airline from disaster.

Releasing his report in 1981, Mahon concluded that the specific cause of the DC-10 airliner's crash was a typing error 14 months prior that led to a low-level flight plan being superimposed over the 3,794-metre peak of Erebus, combining with 'whiteout'. (Mahon 1981) According to the American Meteorological Society, in a whiteout, 'neither shadows, neither horizon nor clouds are discernible; sense of depth or orientation is lost; only very dark, nearby objects can be seen'. (American Meteorological Society 2014) It was not only the error within the aircraft's navigational system that confiscated the horizon, but the invisibility of visibility caused by whiteout weather.

Mahon's report stirred up controversy, particularly in his condemnation of the Government owned national flag carrier, Air New Zealand, in his assertion that the airline had intentionally misled the inquiry through an 'orchestrated litany of lies'. (Mahon 1984,249) When presented to the New Zealand Government, the report was rejected in it's entirety and the conclusion of Chief Inspector of Air Accidents, Ron Chippendale that pilot error was the direct cause of the tragedy was accepted. The airline had sought a judicial review of the judgment and a Court of Appeal judgment in December 1981 decided Mahon had exceeded his terms of reference in suggesting criminal conspiracy. In October 1983 the Privy Council upheld this decision. (Air New Zealand v Mahon 1983,685) This action, at the time, threw the whole of the country into turmoil and disbelief. The public and the press were incredulous that the report could be rejected, for what seemed at the time for political and economic reasons.

I shall now examine the chain of events leading to the crash of TE 901, including the initial preparation for the Antarctic scenic flights, which were undertaken by Air New Zealand and the New Zealand's Governments Civil Aviation regulator. I shall argue that the airline's hubristic attitude subtly influenced decisions and trade-offs made by Air New Zealand's crews and management hierarchies at the time. I place great emphasis on Mahon's insightful analysis of the human condition, particularly in his assessment of the 'stance' taken by the airline. Mahon was vilified for his report, which refuted the initial assumption of 'human error' as a determinable cause of the accident, exposing the Chief accident investigator's opinion as to 'probable cause' as being untenable.

Justice Mahon claimed that Chippendale's report intended to leave little room for any further scrutiny that could potentially expose pre-existing and long-standing latent failures, arising in the airlines managerial and organisational practices. By investigating these 'standing conditions' and naming them as a latent failure that contributed to the disaster, Mahon helped to shift the focus of accident investigation from apportioning blame to 'identify[ing] those systemic failures which either foster and enable human error, or which fail to contain and negate its consequence.' (Air New Zealand v Mahon 1983,685)

While the aim of this sort of accident investigation is to preclude a similar recurrence, the Erebus disaster is unprecedented in addressing the deeper, most influential factors that lie behind a large number of air accidents – those factors relating to the management of an organisation and the regulatory system it operates within. The way humans construct and interact with complex systems and the potential for catastrophe inherent within that interaction is now more clearly understood, because of the Royal Commission into the accident involving Air New Zealand.

Although not popularly received, the Mahon report was revolutionary in 1981, however it was not until 1994, 13 years after the Mahon report was shelved, that ICAO (International Civil Aviation Organisation) decided his report was valid. Indeed many ICAO states have only recently dared to cite deficiencies within the regulatory system as being significant contributors to accidents and incidents. (Cranfield University Department of Transport 2005) Today in a time when safety regulation expresses a commitment to additional aviation capacity, another question is raised that asks whether the airline industry's growth imperative, is both creating and being subject to more environmental risk, which safety regulations and technology are not addressing.

Justice Mahon's fair and uncompromising analysis explicitly identifies what was central to the disaster, judging the primary cause of the crash to be the act of the airline changing the computer track of the aircraft from McMurdo Base to Mt Erebus without telling the aircrew. He also uncovered an organisational structure with poor communication and administration procedures that contributed to the main cause. Mahon's report found that Air New Zealand attempted to blame their pilots in order to simplify the cause of the crash and it's political ramifications. Citing a number of factors that contributed to the crash, the Mahon report was significant, revealing the airline's overestimation in their safety procedures and a technological systemic hubris that produced risky behaviour. Ironically, exogenous factors such as the purely contingent existence of whiteout weather and the economic imperative of flying low-level for sightseeing purposes, would not have come into play if the flight crew had been told of the late changes made to the last leg of the flight path. According to a senior Air New Zealand pilot, Captain Gordon Vette, 'mistakes meshed with each other like wheels within wheels, until a final wedge jammed the machinery'. (Vette and MacDonald 1983,106)

On the morning TE 901 was due to depart Auckland Airport for the sightseeing flight over Ross Island in Antarctica, I was in the control tower working a morning shift as an air traffic control assistant. I had a clear view of the passengers boarding the aircraft that was positioned below at the domestic terminal. The flight was scheduled to leave Auckland at 8.03 am (NZDT) but was delayed several minutes when an anxious passenger demanded to be let off. The passenger eventually agreed to re-board the plane after being assured by Air New Zealand staff that the Antarctic flights were safe. At 12.49 pm, approximately four hours after the aircraft had departed Auckland, the ground proximity warning system (GPWS) on board the aircraft began sounding a warning that the plane was dangerously close to terrain. Although the Captain, Jim Collins, immediately requested go-around power, there was no time to divert the aircraft and six seconds later the plane collided with the side of Mt

Erebus and disintegrated, instantly killing all 257 passengers and crew on board.

At 11.00 pm that evening Air New Zealand's Chief Executive Officer Morrie Davis, held a press conference stating that little hope could have existed for the missing airliner after 8.00 pm as it would have run out of fuel. There had been no message from the aircraft announcing that it was in difficulty. (Mahon 1984,15) As Justice Mahon puts it in *Verdict on Erebus* (1984), 'the big passenger jet with 257 people on board had vanished'. (Mahon 1984,16) On 29th November 1979 at 12.55 am, a US Navy aircraft from McMurdo Station sighted the wreckage of the missing airliner on the northern slopes of Mt Erebus. The first images obtained of the crash site conveyed the horror of unimaginable destruction, which was later described by Justice Mahon: 'here was the white snow-covered rising ground of the mountain with the wreckage looking like nothing more than a long black smear extending hundreds of yards up the ice slope'. (Mahon 1984,16)

The disaster was at first inexplicable. The crash investigators found that the McDonnell Douglas DC-10 series 30 aircraft was operating perfectly. The tape of the cockpit conversations between the pilots revealed nothing untoward until the very final seconds. The hundreds of photos taken by the passengers showed the plane was flying in clear air in good weather seconds prior to impact. How could a modern aircraft flown by skilled crew using the most sophisticated navigation equipment available, fly into a towering volcano in broad daylight without anyone aboard seeing what was coming?

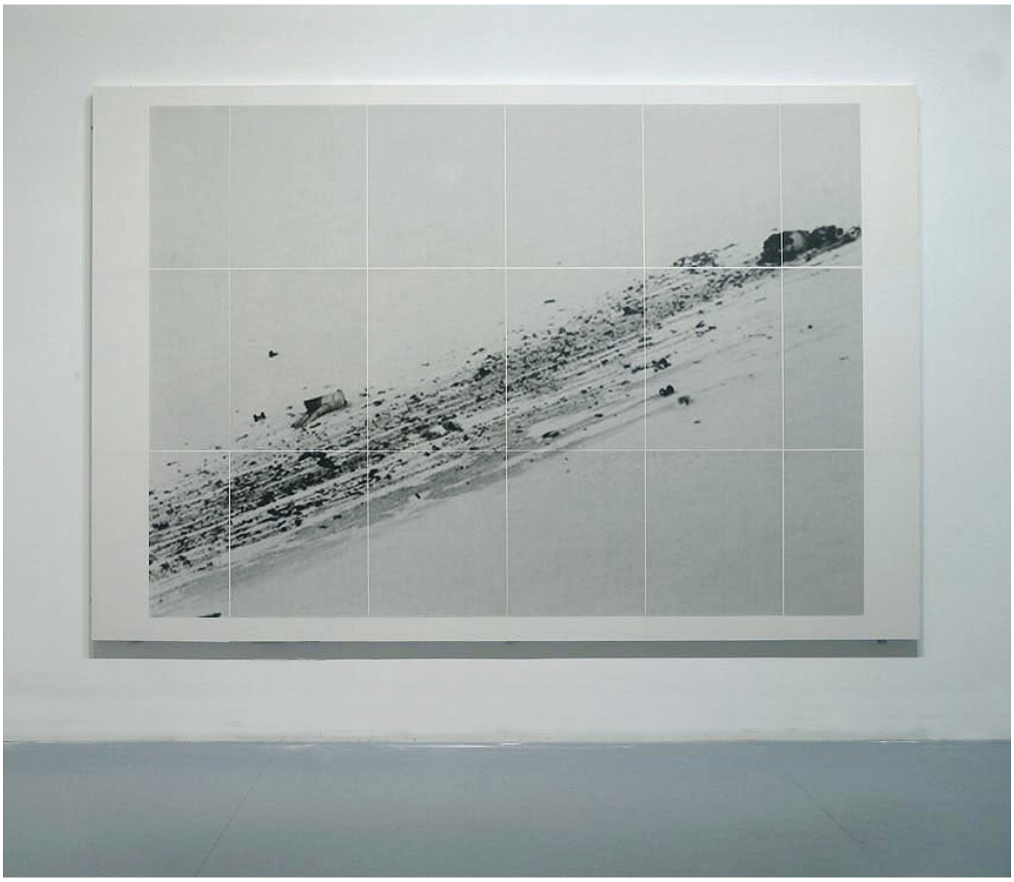

Figure 4.1 Vicki Kerr. (2011) TE 901 crash site - Mt Erebus.
Newsprint on Alupanel, 353 cm x 243 cm. Source: Vicki Kerr

Yet for all its isolation it was one of the best documented aviation catastrophes. The aircraft's electronic sensors were working and decipherable. Almost every passenger on the sightseeing trip carried cameras (mainly 35mm still and super 8 and 16mm movie) and shot film up to the last second. These were painstakingly salvaged and developed, while Antarctic weather scientists monitored local weather patterns, receiving sophisticated film from satellites. Apart from information gathered from the flight data and cockpit voice recorders from the wreckage at the crash site, cameras were retrieved to extract photographs taken by the passengers. These images were included as primary evidence in the absence of human witnesses to the incident. Probably no other major disaster in history has been so well photographed at the precise time of the tragedy. The most macabre photograph was taken as the photographer passed from life to death and his or her finger pressed the camera button. (Suter 1991,151) Ironically, while the role of photography was significant in identifying the atmospheric conditions at the time and the aircraft’s altitude, it was complicit in the crew's decision to fly below the designated minimum safe altitude.

On the 9th November 1979, Captain Jim Collins and First Officer Greg Cassin attended a route qualification briefing with Air New Zealand's Route Clearance Unit. During this briefing the pilots were advised of a visual meteorological conditions (VMC) let down procedure over McMurdo Station. Within a specified sector overhead the McMurdo Tactical Air Navigation system (TACAN), they were permitted to descend to a minimum altitude of 6000 feet (1830 metres) provided they were operating in VMC conditions. If VMC could not be maintained then 16,000 feet was the minimum safe altitude.

One of Air New Zealand's most experienced pilots Captain Gordon Vette, who refused to accept Chippendale verdict of 'pilot error', believed Captain Collins and his crew were acting totally in accordance with airline regulations. Having flown for 34 years with the airline, Vette had been Captain of one of the Antarctic flights. In his book *Impact Erebus* (1983), Vette states 'we enjoyed excellent viewing in what I took to be completely safe conditions, which were exploited to the complete satisfaction of all aboard'. (Vette and MacDonald 1983,171) Vette claimed that all of the flights would have descended below the altitude of the surrounding terrain, confident because they had full visual conditions and plenty of space in which to manoeuvre. According to Vette, this was the impression clearly conveyed at the airline's Antarctic briefings - along with the normal understanding that once the crew had reached their cloud break procedure height of 6000 feet, they could - if they maintained visual flight conditions – fly exactly as they were cleared to do so by American McMurdo (ATC) Air Traffic Control. (Vette and MacDonald 1983,310)

Captain Vette's detailed investigation on the pilots' behalf, assisted Mahon in determining that Captain Collins was justified in believing that the airline sanctioned, if not encouraged, flying beneath 16,000 feet before reaching the McMurdo radio beacon. This 'low flying' was written about extensively in tourist publications and in in-house journals. From Collins viewpoint, he was sent by the airline to conduct a visual (VMC) let down procedure [5] over McMurdo for a sightseeing trip over Antarctica, the tacit purpose of which was to provide passengers with value for money. In accordance with Air New Zealand pre-flight briefings, descents below 16,000 feet were conducted visually, that is, clear of clouds and with good visibility, or by radar from McMurdo air traffic control. The former was used, although to be absolutely correct the aircraft should have requested and been cleared for a 'visual approach'. Instead, the clearance was for a 'descent maintaining VMC', which means visual meteorological conditions, that is, clear of clouds and with good visibility. Since the requirements for maintaining VMC are similar to those for a visual approach this anomaly was not a factor in the accident.

Believing he was descending at the entrance of McMurdo Sound and having received approval to descend from McMurdo air traffic control in relation to their own traffic, Collins initially descended to 6000 feet. As McMurdo ATC expected TE 901 to follow the same route as previous flights down McMurdo Sound and in accordance with the route waypoints previously advised by Air New Zealand to them, McMurdo ATC offered Flight 901 radar let-down to 1,500 feet (460 metres). According to the Cockpit Voice Recorder (CVR), the last contact the crew had with McMurdo ATC was an approval to descend to 2,000 feet VMC, while being kept advised of altitude, and proceed visually to McMurdo.

However, TE 901 was unable to be located by the radar equipment and the crew experienced difficulty establishing VHF communications (probably because unbeknown to everyone, the aircraft was behind the volcano). Upon finding an adequate clear air gap in the cloud cover, the aircraft descended with terrain beneath in view. CVR transcripts from the last minutes of the flight before impact with Mt Erebus, indicated that the flight crew believed they were flying over McMurdo Sound, well to the west of Mount Erebus and with the Ross Island shelf visible on the horizon. Despite most of the crew being

[5] Visual Meteorological Conditions (VMC) are conditions in which pilots have sufficient visibility to fly the aircraft under visual flight rules (VFR). VFR are regulations for flying aircraft in conditions generally clear enough to allow the pilot to see where the aircraft is going. A let down procedure allows the pilot to bring an aircraft past all hills and obstructions to a particular position at low height. .(Gunston 2009) In this instance the let down procedure followed by the crew was under Visual Flight Rules as opposed to Instrument Flight Rules.

engaged in identifying visual landmarks at the time, they never perceived the mountain directly in front of them.

Approximately six minutes after completing a descent in Visual Meteorological Conditions, TE 901 collided with the mountain at an altitude of approximately 1,500 feet (460 metres). The aircraft was flying in clear air, beneath a cloud ceiling that diffused the daylight in a way that made the upward sloping white surface of the mountain directly ahead indistinguishable from the horizontal white expanse. Mahon stated damningly that he did not believe that either the airline or Civil Aviation ever understood the true danger of whiteout or thought it to be anything other than some loss of visibility in snow showers. (Mahon 1984)

Even though it was revealed during the Royal Commission that the Director of Civil Aviation, E. T Kippenberger knew of the perception difficulties during a whiteout, there had been no instruction in the perfidies of polar whiteout given to the crews, the great majority of whom had never flown to the ice before. (Mahon 1984) In fact Civil Aviation had a wealth of knowledge about whiteout weather. Negligently, they chose not to pass it on. Kippenberger wrote in 1969 of whiteout conditions caused by difficulty of depth perception, evident particularly in overcast 'no shadow' conditions with a ceiling of 3000 feet or below. (Holmes 2011,227)

From cockpit voice recordings and passenger photographs, Justice Mahon with the aid of Captain Vette, was able to conclude that Mt. Erebus was not shrouded in cloud and that the pilots did not see the mountain in front of them, even though atmospheric visibility was 40 kilometres. They could see a horizon (albeit probably a false one) and were in clear sight of ground and water beneath them, but could not see Mt Erebus ahead. Not only did they not see the mountain, they could not see that they couldn't see it. Unfamiliar with 'sector whiteout conditions', the crew were tricked into thinking they could perceive full visual depth within their field of view. Two photographs developed from passenger film showing cabin bathed in sunlight moments before impact, indicated fine weather and good visibility. (Vette and MacDonald 1983,64-65) Because the crew were not informed of the change in the navigation coordinates in the system, they lost what pilots call 'situational awareness',[6] before the aircraft had even become airborne.

Originally the course had them flying into McMurdo Sound, which in whiteout conditions looked very similar to Lewis Bay at the foot of Erebus, where they over-flew just before impact. (Vette and MacDonald 1983,133) The crew had developed a mind set which interpreted geographical features and the scenes around them in relation to McMurdo Sound, not Lewis Bay and Erebus. This mindset in conjunction with the whiteout phenomenon that rendered Mt Erebus invisible allowed them to mistake their true position and fail to see the mountain in clear air ahead of them.

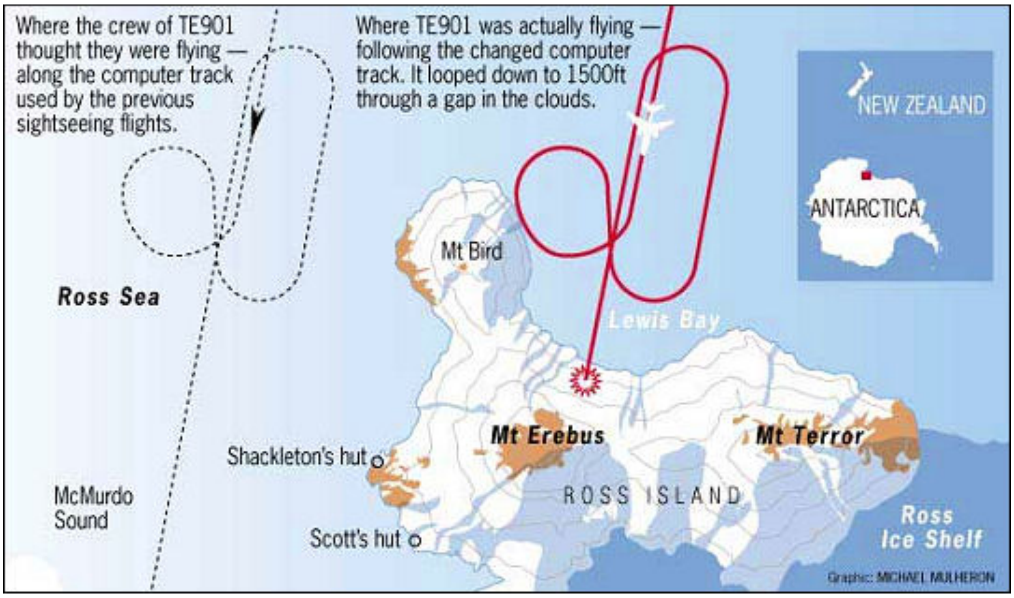

Figure 4.2 The actual flight path compared with the assumed flight path in McMurdo Sound. Source: Michael Mulheron. Available at: <http://www.thelogbook.com/earl/2012/04/21/erebus-iii/> [Retrieved 1 July 2014].

[6] Situational awareness is the unquantifiable ability of a pilot to keep abreast of what is happening (Gunston 2009) It can also be understood as the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their status after some variable has changed, such as time, or some other variable, such as a predetermined event. As a field of study, situational awareness is concerned with perception of the environment critical to decision-makers in complex, dynamic areas from aviation and air traffic control.

It was because visibility was judged to be so good that the pilots decided it safe enough to fly below the minimum safe altitude and fly following visual flight rules (VFR).

Visual flight rules are a set of regulations under which a pilot operates an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going. While the photographs taken from the sides of the aircraft verified weather conditions were clear enough, the clear air (whiteout weather) ahead of the aircraft presented the flight crew of TE 901 with a uniform visual field in which markers, such as the horizon and shadow, would not appear. The aircraft was immersed in a meteorological milk bowl containing smooth, unbroken snow-covered ground, a uniform overcast sky and light reflections that made ground and sky visually inseparable.

Implicit in planning the eleven-hour, 5,400 mile Antarctic flights was the DC-10's Area Inertial Navigation System (AINS),[7] a predecessor to the modern flight management systems we see on board aircraft today. Able to provide high-integrity position information without reference to ground-based navigation aids for long periods, it enabled the DC-10 to make the flight to Antarctica and back safely and accurately – and it captivated journalists. One journalist enthused: 'Area Nav!... 12 million bits of information went in the bottom, and from the top issued a fool-proof intelligence… Pick the point, feed the coordinates in, and it would take the plane there! It wasn't enslaved to magnetic north or sun or stars – only to numerals. Nothing could be safer!' (Chapple 1977,14,15) The inertial navigation system (INS) operated by inserting into the aircraft's computer a series of waypoints located by co-ordinates of latitude and longitude. The system could be locked into the steering controls of the aircraft so that it could be flown automatically from one waypoint to another. (Vette and MacDonald 1983,97)

[7] An inertial navigation system (INS) Assembly of superaccurate gyros to stabilize a gimballed platform on which is mounted a group of super-accurate accelerometers – typically one for each of the three rectilinear axes – to measure all accelerations imparted, which with one automatic time integration gives a continuous readout of velocity, and with a second time integration gives a readout of present position related to that at the start.. (Gunston 2009)

For an ordinary scheduled flight, for example Auckland to Honolulu, the airlines flight plan was contained on a cassette, which pilots fed into their on-board navigation computer. The tapes were updated every 28 days. Whenever a change to a route was made between the issue of cassettes, the consortium of airlines that produced the cassettes issued a notice to airmen (NOTAM) giving details. The Antarctic flights not being a standard route, did not have cassettes, instead their flight plans were keyboarded into the DC-10's computer.

The New Zealand scientific community, at least, seemed satisfied with the preparations that had been made. Robert Thomson, superintendent of the New Zealand Antarctic Division (and subsequent commentator on several Antarctic flights) stated that 'if such over flights were conducted well within the capacity of the aircraft and all normal flying regulations and procedures strictly observed, such flights would be no more hazardous than the flights that occur daily across the north polar route… such as the direct flights from Anchorage to Copenhagen'. (New Zealand Pilots Association 2009,8)

A few months before the Erebus accident, concerns were voiced about commercial Antarctic over-flights. A meeting of twelve countries with a stake in Antarctica pointed out that whilst they reaffirmed the traditional principle in the Antarctic of rendering all assistance feasible in the event of an emergency request for help, commercial over-flights were operating in a particularly hazardous environment where emergencies could arise that were beyond the capacity of permanent Antarctic expeditions to respond adequately. (New Zealand Pilots Association 2009,8)

It was also noted that the over-flights exceeded the capacity of their Antarctic operations to respond adequately to an unplanned emergency landing. On 26 June 1968, the United States released a 'Policy Statement with Regard to Support of Foreign Government, Commercial and Private Aviation in Antarctica'. This document set down the limitations within which aviation activities over Antarctica would need to operate. Essentially it stated:

> Because of the limited nature of resources available, the U.S would only support government-operated aircraft operating as part of the U.S

> scientific endeavors in Antarctica; and commercial or private aircraft operations that would clearly further the interests of the United States Antarctic program.
>
> (New Zealand Pilots Association 2009,8)

The decision as to whether a proposed flight would meet proper safety standards was invested in the Commander US Naval Support Force, Antarctica. This suggests that the flights proposed by Air New Zealand and QANTAS would have come under scrutiny. Interestingly, in the post-Erebus inquiry, the Chief Traffic Controller and MAC Centre Supervisor at McMurdo Sound, Warrant Officer C.R Priest, stated in his affidavit:

> We were not aware at the time, of the sector within which the Air New Zealand DC-10 flights were said to be required to fly. This required sector as now identified to me by representatives of the Royal Commission would in my opinion have been absurd. Any radar controls contemplated by those planning such flights for purposes of assisting in descent manoeuvres would have been virtually impossible… There could be no adequate ground based control should it have been required. I re-emphasise that to the best of my knowledge, Operation Deep Freeze [8] was unaware of any officially approved Civil Aviation Division (CAD) or Air New Zealand flight plan or descent approach. However, had such a flight plan or descent approach been provided for Deep Freeze consideration and had it been agreed to provide radar let-down assistance, I would have regarded such a plan as extremely ill-advised for the reasons stated.
>
> (Vette and MacDonald 1983,310)

Another passage of interest in the U.S policy statement is a discussion around the unreliability of altitude-sensing devices in the Antarctic. In hindsight, the document's words are a dark portent:

> While considerable reliance must be placed on radio and radar altimeters, pilots must be constantly aware of the altitude errors inherent

[8] Operation Deep Freeze is the codename for a series of United States missions to Antarctica, beginning with "Operation Deep Freeze I" in 1955–56, followed by "Operation Deep Freeze II", "Operation Deep Freeze III", and so on. Given the continuing and constant US presence in Antarctica since that date, "Operation Deep Freeze" has come to be used as a general term for US operations in that continent, and in particular for the regular missions to resupply US Antarctic bases, coordinated by the United States Military.

> in emission-type altimeters when used over snow or ice surfaces. Radio and radar altimeters must be constantly monitored while operating in conditions of poor surface and horizon definition because gradual rises of upward sloping terrain masses frequently cannot be detected visually.
>
> (New Zealand Pilots Association 2009,8)

The document also makes reference to illusions and mirages caused by whiteout conditions. Almost nine years before the first Antarctic over-flight by Qantas, the American authorities in Antarctica had expressed concern at the increasing levels of aircraft activity there. However, rather than ban or restrict such operations, their response was to draw up a set of guidelines – and set in place procedures – for the safe operation of a variety of aircraft.

Sociologist Charles Perrow was one of the first researchers to discard the traditional approach to failure analysis that focused on the technical cause of an accident or event and the underlying human error that gave it life. (Little 2012,28) Perrow's claim is based on his assertion that the technical and human elements of large technical systems are inseparable and sufficiently complex to allow unexpected interactions of failures to occur, and so tightly coupled as to result in a cascade of increasing magnitude. Perrow ascribes many of the causes of normal accidents to organisational issues, such as the nature of the power hierarchy and the culture of the organisation itself. (Little 2012,28) When the pursuit of efficiency or profit becomes the motivating value of an organisation whose prime responsibility should be safety or reliability, the results are likely to be unacceptable on both counts. While trade-offs between competing objectives are an organisational reality, they and their consequences must be transparent and understood. Otherwise devastating but predictable failures will continue to occur within infrastructural systems and in the investigation that follows the conclusion will be that the failure was preventable. (Little 2012,28)

With rewards constant and tangible, departures from routine may become routine across an entire operation or organisation. Dekker terms this behaviour as 'borrowing from safety'. Without realising, people start to borrow from safety and achieve other system goals because of it - production, economics, customer service, political satisfaction. Behaviour shifts because other parts of the system send messages about the importance of these goals, often in subtle ways. (Dekker 2006,116) In the past the view predominantly held, was that human error caused accidents and in order to find out what went wrong you must find people's inaccurate assessments, wrong decision and bad judgments. (Dekker 2006,36) This view has been revised, instead identifying human error as a symptom of trouble deeper inside the system where cause can be found in people's assessments and actions making sense at the time, given the circumstance that surrounds them. (Dekker 2006,62) Dekker argues that this new view on human error sees the complex, dynamic systems in which people work as not basically safe at all. In fact, these systems are inherent trade-offs between safety and other pressures, such as economic pressures; pressures that have to do with schedules, slots, competition, customer service, public image. (Dekker 2006,62) Occasionally work fails, exceeds, lags or otherwise deviates from ordinary parameters just enough, it morphs from acceptable ordinary actuality into unacceptable catastrophic potentiality.

Captain Gordon Vette's analysis of the Erebus disaster influenced the work of cognitive psychologist James Reason, investigating the involvement of human factors in accidents and incidents. Reason's work on risk analysis resulted in an accident causation model known as the 'Swiss Cheese' model. The model represents all 'holes' as causes of equal importance with front holes at the 'blunt' end (latent failures) being just as significant as the holes closest to the accident or at the 'sharp' end (active failures). Under this model there is no primary cause. The latent failures are as important as the active failures. Reason's model (Reason 1997) of how accidents could be seen as the result of interrelations between real time 'unsafe acts' by front line operators and latent conditions, turned out to be highly pedagogical, and a large number of safety analysts around the world quickly started to use it in different industries. The ICAO Human Factors and Flight Safety Working Group adopted it in the early 1990s as a conceptual framework.

However Dekker argues that without the benefit of hindsight, error is hard to define and seeing the holes is difficult and therefore the 'Swiss Cheese' model is not necessarily helpful in accident prevention (remember the Flight TE 901 pilots could not see that they could not see Mt Erebus). Therefore to try and understand why an accident occurs, it is necessary to reconstruct the unfolding mindset of the organisation and individuals concerned without the benefit of hindsight. According to Dekker our language of failures is a language of mechanics. We describe accident trajectories, we seek causes and effects, interactions. We look for initiating failures, or triggering events, and trace the successive domino-like collapse of the system that follows it. (Dekker 2006,120)

Dekker believes accident causation models, such as the 'Swiss Cheese' model, may be lagging behind the socio-technical developments that have taken place in aviation, leaving us less than well equipped to understand failure, let alone anticipate or prevent it. (Dekker 2011,92) The Erebus disaster reminds us that there is no efficient, quick road to understanding human error, as error classification methods make us believe. Once Mahon's Inquiry acknowledged that safety and failure were emerging properties of systems that try to succeed, the cause became one that was systemic, in that attributions and responsibility for error became difficult to know where to apportion individual blame. Instead of constructing a cause, Mahon documented a pattern of failure begging the larger question - what was the mechanism by which failure succeeded?

According to the CAA (Civil Aviation Authority) responsible for regulating aviation in the UK, the remarkably low accident rates in commercial air transport, reflect the success of vigilant organisations, legal apparatus, and social learning about accidents. Due to the exponential growth in aviation, which is set to rise by 3% per year, the CAA's strategic objective for enhancing aviation safety is: To enhance aviation safety performance by pursuing targeted and continuous improvements in systems, culture, processes and capability.

What seems to be suggested in the CAA strategy is that aviation will gradually 'design out' the potential for air accidents to occur. This can be achieved, according to Gretchen Haskins, Group Director of Safety Regulation (CAA), by testing the system as a total system, looking at how the system needs to perform operationally and ensuring the combination of human and machine can achieve performance criteria, particularly in unusual circumstances. Moving towards a predictive approach to safety risk management, aviation regulators target specific problems, particularly those related to human performance and the interface between humans and system complexity associated with the rise of automation. (Haskins 2013)

4c. Human and Technology Interface

The response to human error elimination has been to take the technology driven route. If humans cannot be induced to stop making mistakes, then eliminate the human - as the source of error - from the task as far as possible. This analysis drove the design philosophy of Airbus Industries in Europe and generated the famous aviation industry joke that an Airbus is designed to be 'flown by a pilot and a dog - the pilot is there to feed the dog and the dog is there to bite the pilot if s/he touches anything'. However the automated flight deck has so far failed to significantly reduce accident rates. Research has found that automation can lead to different kinds of accident, in much the same way that word processors with spell checks did not eliminate newspaper misprints, but merely led to different kinds of misprint.

As recently as 2009, a high profile commercial air crash resonates with the Air New Zealand disaster. Air France Flight 447, an Airbus 330-203 airliner from Rio de Janeiro to Paris went missing in the early hours of June 1st 2009, the aircraft and its 216 passengers and 12 crew remained missing for several days. It was reported, 'no other airliner had vanished so completely in modern times'. (Ross and Tweedie 2012) On finally locating the wreckage of the aircraft, media reports indicated the cause of the crash was not solely due to pilot error.

When Fight 447 flew through a thunderstorm the pitot tubes [9], a pressure measuring instrument used to determine the speed of an aircraft froze, disconnecting the auto pilot, which in turn caused the co pilot, who was alone in the cockpit at the time, to make a catastrophic error, ascending the aircraft into a dangerous stall instead of leveling off or descending to pick up speed. The aircraft nose-dived into remote equatorial waters between Brazil and Africa,

[9] A pitot tube is an open-ended tube facing forwards into fluid flow, thus generating internal pressure equal to stagnation pressure (in case of supersonic flow, that downstream of normal shock). (Gunston 2009)

eventually being located in uncharted seabed to depths of 4,700 metres. When the 'black box' [10] was eventually found, the transcript revealed that the last words spoken in the cockpit by the co pilot who made the first catastrophic error was: 'but what's happening'? Initial investigation into the cause of the crash suggested that the Air France pilots did not seem prepared for the situation they found themselves in. French investigators identified many factors, but singled out human error finding that the pilots, although well trained, had fatally misdiagnosed the reasons that the plane had gone into a stall and that their subsequent errors, based on this initial mistake, led directly to the catastrophe.

The final verdict on the cause of the crash also blamed the failure of the 'flight director', a computer that issues orders to the pilots throughout the flight. (Popham 2013) It was complexity, as much as any factor, which doomed Flight 447. Prior to the crash, the plane had flown through a series of storms, causing a buildup of ice that disabled several of it's airspeed sensors — a moderate, but not catastrophic failure. The pitot tubes, which give pilots vital information about the plane's speed had frozen - a problem that had occurred with previous Airbus flights but the company had yet to address. As a safety precaution, the autopilot automatically disengaged, returning control to the human pilots, while flashing them a cryptic 'invalid data' alert that revealed little about the underlying problem. Confronting this ambiguity, the least experienced of the two pilots, Cedric Bonin, took the controls and proceeded to fly the aircraft manually. Bonin's seemingly inexplicable actions caused the plane to climb, but it was actually losing altitude. Bonin appears to have continued to hold back on the aircraft's control column (sidestick), while not understanding what was happening, a procedure that likely made the situation worse.

The reason he persisted in pushing the plane upwards, the report revealed, was that the all-important 'flight director' computer was broken and issuing the wrong instructions. The plane's altitude alarm, the loudest alarm in the cockpit, was quite erroneously warning him that the plane was losing altitude – information that clashed with the warning that the plane was about to stall. While Bonin's

[10] The black box, otherwise known as flight data recorder, is a popular term used by the media to describe an electronic device employed to record any instructions sent to any electronic systems on an aircraft. It is used for accident investigations, as well as analysing air safety issues, material degradation and engine performance. (Gunston 2009)

action banked the aircraft into a climb the plane's airspeed slowed, sending it into a stall. Confusingly, at the height of the danger, a blaring alarm in the cockpit indicating the stall went silent — suggesting exactly the opposite of what was actually happening. The plane's cockpit voice recorder captured the pilots' last, bewildered exchange:

(Pilot 1) Damn it, we're going to crash... This can't be happening!
(Pilot 2) But what's happening?

Less than two seconds later, they were dead.

Echoes of the Erebus disaster run through the Air France crash — circumstances where adding safety-enhancements to systems actually makes crisis situations more dangerous, not less so. Both crews never understood the danger they were in.

The crash of Air France 447 has led to a profound rethink about the extent to which modern airline pilots depend on their computers, leaving them literally helpless in a crisis like this. According to Roger Rapoport, an American aviation expert and author of *The Rio/Paris Crash: Air France 447*: 'Modern pilots are not trained for crises like this. They are not trained to fly at high altitude. An experienced military pilot might have known what to do in a situation like this, but not these pilots.' (Popham 2012) Commenting on the Air France crash and the increasing reliance of automation in the operation of modern aircraft, William Voss, president of the Flight Safety Foundation, Virginia said 'This is a problem not just limited to Air France or Airbus, it's a problem we're seeing around the world because pilots are being conditioned to treat automated processed data as truth, and not compare it with the raw information that lies underneath'. (Associated Press 2012)

Given the computer-mediated environment in which pilots work, perceptual demands are considerable. They needed to synthesise accurate spatial awareness from a considerable amount of coded raw data. These sorts of tasks require training, skill, discipline and judgement together with quick, prudent decision-making based on knowledge of the aircraft's systems and natural environment, crew capabilities and personal limitations. (Budd 2009,129) In both the Air New Zealand and the Air France cases, the development of systems designed to reduce the possibility of error or failure can create a greater possibility of accidents that are fatal. Computerised control systems intended to remove the possibility of localised slips, lapses and fumbles on the flight deck can, as we have seen in these cases, increase the probability of higher level mistakes with the capacity to cause the destruction of the entire aircraft and its occupants.

The reasons are rooted partly in the pernicious nature of over-complexity, and partly in the way that human beings psychologically respond to risk. Unfortunately, human beings psychological responses to risk often makes the situation worse, through twin phenomena called risk compensation and risk homeostasis. Counter-intuitively, as we add safety features to a system, people will often change their behavior to act in a riskier way, betting (often subconsciously) that the system will be able to save them. (Zolli 2013) We rightfully add safety systems to things like planes and oil rigs, and hedge the bets of major banks, in an effort to encourage them to run safely yet ever-more efficiently. Each of these safety features however, also increases the complexity of the whole. Add enough of them, and soon these otherwise beneficial features become potential sources of risk themselves, as the number of possible interactions — both anticipated and unanticipated — between various components becomes incomprehensibly large. (Zolli 2013)

This, in turn, amplifies uncertainty when things go wrong, making crises harder to correct: Is that flashing alert signaling a genuine emergency? Is it a false alarm? Or is it the result of some complex interaction nobody has ever seen before? Imagine facing a dozen such alerts simultaneously, and having to decide what's true and false about all of them at the same time. Imagine further that, if you choose incorrectly you will push the system into an unrecoverable catastrophe. Now, give yourself just a few seconds to make the right choice. How much should you be blamed if you make the wrong one? (Zolli 2013)

On 4th November, 2010, during a scheduled flight from Singapore to Sydney, Flight QF32, a Qantas four-engined Airbus A380 avoided near disaster, when a failed engine sent debris into the wing, severing independent wiring and hydraulic cables. The pilots flying the aircraft took 50 minutes to work through 54 computer-warning messages after the engine explosion caused systems damage. Even though the ‘superjumbo’ was designed to fly by computer, requiring minimal human interference, it was the expertise of the pilots that was needed when their 6 inch by 8 inch displays suddenly became filled with alert warnings after an engine exploded. Instead of the usual three-person crew in the cockpit, there happened to be five experienced pilots, including three captains aboard the plane. One captain was giving the flight's captain, Richard de Crespigny, an annual check of piloting skills. The captain doing the evaluation was himself being evaluated by a third captain. There were also first and second officers, who were part of the normal three-pilot team.

De Crespigny concentrated on flying the plane, while the others dealt with the computer alarms and made announcements to passengers, some of who were seeing flames streaming from the engine. According to De Crespigny, ‘large pieces fell off the aircraft knocking through the wall of a house in the suburbs of Batam’. (Fidler 2012) People on the ground on Batam Island in Indonesia were tweeting messages through social media. News of the catastrophic failure was on the world’s major news agencies via social media within 13 minutes, during which time Qantas’s share prices plummeted. (Fidler 2012)

This incident raised questions regarding the effectiveness and safety of fly-by-wire technology (a system that replaces the conventional manual flight controls of an aircraft with an electronic interface). When pilots are given too much information after an incident, there is a danger they may spend their time dealing with the error messages rather than flying the plane. More than six hundred wires broke disrupting the major key networks on the aircraft while none of the engines were functioning normally, because fuel transfer systems had failed. Primary and secondary backup systems all failed so the pilot elected to invert the logic by control checking the technology onboard the aircraft that still did work.

Acting as a mediator Richard Woodward, an A380 pilot with Qantas and Vice President of the Australian and International Pilots Association, explained what happened in the cockpit of the A380:

> The amount of failures is unprecedented. There is probably a one in100 million chance to have all that go wrong ...I don't think any crew in the world would have been trained to deal with the amount of different issues this crew faced.
>
> (Collins 2010)

Woodward later praised the plane, saying it was a testament to its strength that it was able to continue to fly relatively well despite all the problems. (Collins 2010)

The Australian Transport Safety Bureau report into the failure of a Trent 900 engine on board the Qantas Airways Airbus was supported by the manufacturer Rolls-Royce. The incident was caused by a leak from an oil pipe on one of the aircraft's four engines. The oil pipe was one of a small number, which had been incorrectly manufactured as a result of a measurement error during a precision drilling procedure. Rolls-Royce had missed several opportunities to identify the potential for cracking in the oil pipes at the manufacturer's Hucknall factory in Nottinghamshire. According to the report, these opportunities were missed because of ambiguities within the manufacturer's procedures and the non-adherence by a number of the manufacturing staff to those procedures. (Clancy 2013) The report went on to add that it was 'likely' there was a culture at the Hucknell factory within which 'not sticking' to quality procedures was a considered 'viable form of behaviour'. (Clancy 2013)

A culture existed within the engine manufacturer's Hucknall facility where it was considered acceptable to not declare what manufacturing personnel determined to be 'minor' non-conformances in manufactured components. (Clancy 2013) As a result, the components were fitted on a number of the Trent 900 engines and the problem only came to light after the Qantas engine blew up. It was the first major safety scare to affect the A380, and led to Qantas suspending its operation of the aircraft for around three weeks.

The near catastrophic crash of Qantas 32 is a reminder that every time we get on an airplane we do so in a profound act of trust. For although most of us know very little about the technology supporting flight, we uphold the belief that flying is one of the safest forms of travel. Embedded in that assumption, is that people are highly trained and do their job properly, while backed up by redundancies and fail-safes within the system. Qantas 32 almost crashed because of the loss of over half of the aircrafts backbone network, due to a fatigue crack in an oil feed stub pipe. Oil released during the flight caused an internal fire separating the pressure turbine disc form the drive shaft. The disc accelerated with sufficient force that the engine structure could not contain it, releasing high-energy debris that caused significant structural and systems damage. While Rolls-Royce admitted its safety and quality standards 'fell short', Qantas welcomed the findings stating, 'The response of the crew and Qantas employees on the ground was a testament to the outstanding safety and training culture that Qantas is known for'. (Australian Business Review 2013)

Back in 1977 there existed a profitable market for Antarctic sightseeing flights after Sydney based electronics millionaire, Dick Smith chartered a Boeing 707 for a flight from Sydney to the northern Antarctic coastline. The response was so great that he stepped up to a larger Boeing 747 aircraft and chartered more flights. Not to be outdone by the Australians and seeing a potential rival in Qantas, Air New Zealand came up with 'the Antarctic experience'. Enlisting the spirit of adventure, Air New Zealand scheduled fourteen flights from 1977-1979, designed and marketed as a unique sightseeing experience.

Each flight carried an experienced Antarctic guide, who would point out scenic features and landmarks using the aircraft public-address system. The non-stop 11 hour flight would leave Auckland at 8am, returning to Christchurch, New Zealand about nine hours later. The aircraft would make a 45 minute stop in Christchurch to refuel and change crews before arriving back in Auckland at about 9pm. The distance to the South Pole from Auckland is about 3,200 nautical miles and the return distance to Christchurch is about 2,800 miles, making it a round-trip of about 6,000 nautical miles. The enterprise encapsulated the paradoxical concept of mobility, being conducted at a time when burgeoning environmental awareness was coupled with the first oil crisis (1973).

Exhibiting parallels with current claims about the Boeing 787 Dreamliner, advertisements in Jetaway, Air New Zealand's international in-flight magazine, focused on its impressive fuel efficiency and environmental friendliness: 'Air New Zealand… introduce this special part of the world [the Pacific] to their passengers with a special kind of pride and they do everything possible to care for it. That's why Air New Zealand chose General Electric CF6 engines for their fleet of DC-10s.' They knew these engines would help keep the skies over the Pacific clean and quiet… would leave no trail of smoke… produce much less noise than narrow-body jet aircraft… and consume 25% less fuel. Air New Zealand's branding 'nobody does it better' seemed to appear on advertising billboards dotting the Auckland skyline, just as they invested millions of dollars buying the latest and most innovative aircraft to come off Macdonald Douglas's assembly line - the DC-10 series 30.

The commercial airliner introduced a mobility that was not just about the geographic dimension of movement, but signified a connection between mobility and modernity. The Air New Zealand Antarctic flights offered a distinctiveness that reinforced the modern notion of subjectivity, appealing to members of the educated middle class as a consumer choice. However the advanced technology of the commercial wide-bodied jet aircraft over Antarctica was troubling in its cultural overall effects. Air New Zealand not only offered a unique viewing experience, but was also a way for New Zealand to nationalise it's vision of Antarctica, extending it's stake in Antarctica by aerial possession in the name of eco-tourism. Scripted for the visual consumption of aerial photography, the Antarctic sightseeing experience reflected a growth in tourism and air travel, which had started in the 1960s. Now a lot more of the public could enjoy the sights of the hostile Antarctic ice from a sealed, temperature regulated cabin environment that eliminated the dangerous, the uncomfortable and the inconvenient.

Figure 4.3 Vicki Kerr (2011) Still from ‘the Antarctic experience’ video, edited archive film footage of the Air New Zealand Antarctic sightseeing flights. 6 mins. DVD.
Source: Vicki Kerr

The prospect of flying to the edge of the world resonates with narratives of the Heroic era (1890s - 1910) sea voyages to Antarctica. According to academic and writer Margaret Cohen, the edge zone of the maritime world underscores a critical feature of modernity: a fascination with risk that cannot be explained only in terms of profit and instrumental reason. While long-term hopes for profit drove exploration of uncharted waters, the short-term yield was often loss, if not death. However the edge zone’s powers of destruction did not discourage exploration. The edge makes apparent the extent to which novelty, that cardinal value of modernity entails risk, danger, and violence. Baudelaire eloquently captured this face of novelty in Le Voyage, where travellers yearn to journey to ‘heaven or hell, what does it matter, to the depths of the unknown ... to find the new!’ (Cohen 2004/5)

The perception of risk was developed in seafaring and long-distant trade, and it is within this context that people first identified travelling as an instrument for social change and individual progress. As a metonym for globalisation, artist Allan Sekula and filmmaker Noel Burch use the sea to pursue the idea that the compression of time and space can be observed from the deck of a containerised cargo vessel. Their essayistic documentary film *The Forgotten Space* (2012) portrays the contemporary maritime world, understood in relation to the complex symbolic legacy of the sea. No longer is the sea a romanticised site of disaster, as depicted in pre-industrial shipwreck scenes where exploiting the sea for financial or territorial conquest was to risk destruction. In a modern inversion, the sea is subdued while monolithic container ships rationalise the sea into a flat submissive surface.

Driven by increasingly automated systems, these giant cargo ships are important mechanisms for the transportation of goods we consume. In *The Forgotten Space*, we see people looking at computer screens and not engaging with the sea, in fact the sea is always calm. With the sea becoming a flat set of coordinates, Sekula and Burch turn our attention to the subtraction of the natural environment. With the ocean benign and completely tame, the sea becomes a representation of the vectors that link the world economy together or the interstices between the threads of the world economy. In order to understand the sea in our world economy Sekula and Burch look at the sea as an effect, inadvertently reproducing the capitalist fantasy of an annihilated sea without resistance to capitalism, which they are trying to critique. What we end up with is a sea that does not create any frictions, that does not have any contradictions and instead is conquered.

It would seem that by pacifying the sea and arguably the air we are subscribing to an ideology of limitless mobility. Reading computer screens instead of feeling the rhythm of the waves and the gusts of the wind, the sea seems to be forgotten by crews of the containerships. Just as the spaces of the port, the ship, the truck, the train, the sea and the internal space of the container, are forgotten by the consumer. Like those that sail ships across seas that have become idealised flat surfaces, in which space is abstracted from geophysical reality, pilots operating advanced commercial airliners spend much of their time monitoring electronically displayed information. They routinely fly high above the weather, on automatic pilot and descend less often for fuel. (Lopez

1998,101) In this kind of self-absorbed travel, built on dashboard knowledge of one's surroundings, a sense of both geographic scale and particularity is ruptured. (Lopez 1998,101)

We tend to view different technologies in primarily instrumental terms. In other words we tend to see technological devices as tools to be used to certain ends. In so doing tools are in themselves, assumed to be neutral or value-free. Yet this view ignores the fact that our everyday activities, our movements, and forms of communication are structured or shaped at a very profound level by the technologies that we use. As theorist David Kaplan has put it: 'Human life is thoroughly permeated by technology'. (Kaplan 2004 cited in James 2007,2) Arguably, a technical device or system is never simply or merely a tool, rather: 'Technological devices and systems shape our culture and environment, alter patterns of human activity, and influence who we are and how we live'. (Kaplan 2004, cited in James 2007,2) By any account it is difficult to sustain the instrumentalist view of technology as a neutral or value-free tool since, if tools are made for specific ends or objectives, they are necessarily inserted into a complex web of human life and interaction, or again as Kaplan puts it: 'Humanity and technology are situated in a circular relationship, each shaping and affecting the other'. (Kaplan 2004 cited in James 2007,2)

Paul Virilio's claim, 'every technology produces, provokes, programs a specific accident', (Armitage 2013,17) seldom converges upon discourse around new technologies or the systems that support them. However as the Erebus disaster reveals, while new technologies and the development of systems promise greater convenience and safety, they also have the potential to create new kinds of accidents and in air travel these can be catastrophic. On looking back at the Erebus disaster, Virilio's theoretical argument suggests a dark poetic irony. The trust placed upon a technological system's capacity to eradicate internal failure - pilot error, or compensate for exogenous contingencies – whiteout, proved fatal. A systemic failure led to the aircraft being in the wrong place at the wrong time, without giving the pilots the tools to deal with the critical situation they found themselves in. In this sense the Erebus disaster is the opposite of the ash cloud crisis described in the last chapter, where limitations in the airspace system were acknowledged in the face of the raw physical force of an erupting volcano.

Lessons continue to be learned from the Erebus disaster. Staying ahead of the game with respect to its competitors, Air New Zealand saw a way to expand it's market by popularising New Zealand's intimate connection with one it's closest neighbours. Air New Zealand's tourism focus in Antarctica created new forms of behaviour within the organisation, which tended to destroy established structures that acted as a barrier to the airlines commercial interests. Both Air New Zealand and Civil Aviation regulators underestimated the airline's exposure to risk, in a particularly difficult geographic and climatic environment where the pilots found themselves in a situation unable to cope and 257 people died.

Conclusion

I wrote this dissertation as a practising artist interested in the public's confidence in, and understanding of (in the broadest sense) the infrastructures supporting air travel. My work as an artist is central to the methodology governing my research, but at the same time I have drawn upon a wide range of theoretical and empirical studies in what may be broadly termed mobility studies. My research project, in both its practical and written elements, attempts to address our confidence in the infrastructural systems supporting air travel.

Through the combination of empirical and creative work I expose the critical infrastructural systems supporting air travel, by tackling the ways in which these complex systems break down, when faced with catastrophic exogenous and endogenous threat's. By focusing on disruptive and catastrophic events we are forced to consider the relative powerlessness of the human subject when confronting the sublime. It is this provocative aspect of the sublime and the fissure created by break down and disaster that contributes to expanding our imaginary construction of how the air traffic system actually works. In attending to failure, my argument has not been to try and undermine the air transport system; instead I am suggesting the need for a more nuanced and technologically sceptical view of air travel and the systems supporting it.

Given the diverse research drawn upon in my thesis – particularly within the social sciences and art – I have suggested a further opening up of airspace and mobility as a field of investigation, which includes the social, cultural and political relations which airspace and air travel intersect, make or break. In an attempt to further understand aeromobilities through my own artistic research process I have made a series of artworks that contribute to making airspace systems visible. Using the method of configuration identified by Lucy Suchman (2012), I have produced a particular way of looking at the air transport system that has been driven by works of art and social scientific inquiry. The relation between these two forms of inquiry, allow what might be termed a dual perspective from which to approach an analysis of aeromobilities. The first is a perspective that attempts to immerse itself with a range of subjective experiences of the air traffic system: the second adopts a more external perspective, which at least aspires to a level of objectivity about the system's functioning. Turning towards moments of breakdown or crisis, the relation between 'inside' the air traffic system and it's constitutive 'outside' reveals the system as an object that does not always work. A point I have developed through the case studies and artworks, seen most specifically in the case of the Erebus disaster, is that when the objective language of the system fails, fracturing into the subjective voices of the various people involved, a greater emphasis is placed on the subjective dimension of mobility.

The relation between the analysis of aerial life as social phenomena and the artworks I have presented has drawn my research towards states of exception or crisis, making visible the relationship between the public and the air transport system. The artworks also reveal the performativity of labour behind the scenes. These works are not supposed to be read, they are there to be responded to, providing enigmatic triggers. What is at stake is the loss of a solid sense of the system. Contributing to the acquisition of knowledge, the artworks attempt to expand the way in which we might think about the air transport system. As a means of speculation, they make connections that create alternative systems of order that call into question known systems.

As a major component of the global economy, regular and relatively risk-free air travel is centrally implicated in supporting our lives. However while the infrastructure supporting air travel is on the whole successful, the interaction between humans and complex systems will always create the potential for catastrophe or break down. When the volcano Eyjafjallajökull erupted in Iceland causing UK and European airspace to close in the interest of safety, the air traffic control system had reached its limits.

Paradoxically, our unquestionable faith in technology and in the omnipotence of the air travel system is based upon knowing that no system is foolproof and that the consequences of failure can be horrific. An act of blind faith sustains the trust that we are safe when we fly, trumping the rationality of the system. As the volcanic ash cloud event revealed, commercial interests were able to exploit the belief people have in the safety of air travel, calling on their abiding trust that it was safe to fly in the demand that airspace reopen due to insufficient proof of a threat to air safety. As airspace gradually reopened, the confidence vested in the probable outcome of a plane not crashing while flying through an ash cloud, expressed the commitment we have towards air travel rather than a cognitive understanding of the technological systems that support it.

According to an air traffic controller at NATS, the ash cloud event, while being a massive challenge, resulted in new processes and systems that involve improving airspace definitions and depiction. (Boulton 2011) In a move that seems to indicate the level of commercial pressure applied to aviation regulators by airlines during the crisis, the managers of UK airspace, NATS have drawn up new procedures, which now makes clear their responsibility. (Boulton 2011) Rather worryingly the responsibility for an aircraft while flying through volcanic ash will no longer be in the hands of air traffic control. Instead responsibility will lie with the pilots and the airline, on the understanding that they have been advised of the presence of ash and they know the technological capability of their aircraft to safely fly in such conditions. (Civil Aviation Authority 2011)

The prospects for growth in the air travel industry should give us pause. What has emerged as an area of concern is that the shut down of the air traffic control system not only revealed the extent to which air mobility shapes and defines the scope of our movement, but has made explicit the economic consequences of air travel disruption and its impact upon human needs. While the safety systems supporting air travel are in themselves not commercial, they under ride an increasingly globalised commercial world in which air travel is crucial to the economy of the whole planet.

While the efficacy of the ash cloud made plain our dependency on air travel and the relevance of the sublime, the crash of TE 901 was an unimaginable horror and a reminder that there is something sublime about air travel itself. The Erebus disaster not only demonstrated the profundity of a simple encounter with the material and elemental world, but also exposed an internal complexity within the system where rationality fell short. The increasing emphasis on a positivist notion of culture as that which is moving ever forward and upward, seems to have been fulfilled by new technologies, unknowable and thus terrifying as manifestations of a new sublime. As Jeremy Gilbert-Rolfe observed ‘technology has subsumed the idea of the sublime because it, whether to a greater extent or an equal extent than nature, is terrifying in the limitless unknowability of its potential’. (Gilbert-Rolfe 1999, front fold)

Applying art to a subject more typically science related – aviation, I have drawn attention to the aesthetic of the technological sublime – in this case the flawed construction of the technological sublime. In extending the critical element of art to the complex systems supporting air travel, the flawed nature of the system as a rational monolithic structure is exposed. Positioned alongside a set of theoretical concerns and empirical case studies, the artworks provide a poetic, emotional, subjective dimension giving space to the particularities and subjectivities that monolithic totality precludes. While we all know the air traffic system is not fool proof and does not work in every case, the art works add a palpable sense of the system as a human construction, as opposed to a foolproof digital system incapable of error.

Even though it has been over thirty years since the Erebus disaster occurred, the tragedy lingers in the public imagination as a source of grief, terror and apprehension. The positive good to come from the disaster’s aftermath has been the recognition given to the task of the public unravelling the most plausible truth for the reasons for the crash. Justice Mahon has been vindicated to the extent that the International Civil Aviation Organisation (ICAO) recognised the Royal Commission of Inquiry, and his post-crash analysis carried an important message about preventing future organisational accidents. The Erebus disaster was later cited in texts such as Beyond Aviation Human Factors (Maurino, Reason, Johnston and Lee, 1995) and the ICAO Human Factors Digest No. 10 (ICAO, 1993) as an example of the way in which actions taken close to the moment of occurrence had in many cases been seeded or compounded by events, conditions or the way of working months or years before. (Braithwaite 2008)

At the time of writing, Malaysian Airlines flight 307 has disappeared with 239 people onboard while en route from Kuala Lumpur to Beijing. Although there is a huge amount of speculation over what may have happened to the plane, there has as yet been no conclusive evidence that brings us nearer to the truth of what may have happened, other than the fact that the aircraft has disappeared. What has emerged however, is that two passengers carrying stolen passports acquired in Thailand were not terrorists but Iranian citizens likely seeking asylum in Europe. Therefore the disappearance of this commercial airliner has already revealed the traces of unregulated economies and human trafficking as well as how the intersecting of these activities involving far-flung locations, which knit together more tightly than we imagine thanks to air travel.

Conversely, the regulatory systems and protections that govern air travel, such as air traffic control, airport security checks and passport controls have been revealed as seriously flawed. Meantime, as to the whereabouts of the aircraft, those currently investigating the disappearance of MH 370 are insisting there is no precedence. At a time when more of the world has been placed on the grid — tracked, counted, enumerated and mapped — the idea that anything, let alone something as large and heavy as Boeing 777 aircraft, can vanish without trace carries a new valence of the incredible. Air France Flight 447, crashed in an area beyond radar coverage and it required five days of intensive searching before discovering the wreckage and a further two years to retrieve the 'black box' flight data recorder from the ocean floor. While we wait for the Malaysia Airlines plane to be found, this moment of the fearful unknown stands as a reminder that gridded, rule-governed airspace is not as totalised as we might imagine.

As the repository of an obscure mystery as well as a possible solution, the 'Black box' of Malaysia 370 contains knowledge desperately sought. Until this 'Black box' containing the cockpit voice and flight data recorders is found, the fate of whatever happened to MH 370 will remain unknown. In some way, not being able to find the aircraft or the voice and data recorders leaves us with a silence that represents both our helplessness in the face of forces beyond our understanding and our need to bring them under our control and to 'know'. In an age of ceaseless progress of scientific and technical knowledge, the disappearance of Malaysian 370 and the desperate search for the ‘Black box’ reveals the limits of our relationship to nature and might, if nothing else, act as a check upon hubris underlining our trust in our technological constructions. As the most recent of air disasters, the ‘not knowing’ of what happened to MH 370 reminds us of the very real terrors ignorance can induce in us. Perhaps it is not only what is learned from failure, but also how failures are processed back into the system, which will keep machines and people in the air, while inhabiting this planet.

The ethos of air travel, from its very beginnings, has been one of `freedom of the air' and `open skies'. Implicit in the rhetorical messages of aviation is the deeply utopian logic that `making the world a smaller place', will `make the world a better place'. Flight could be seen as participating in the dream of modernism and the agency of abstraction with the aerial being the means whereby the earth could become detached from itself. In the work of Russian artist Kasimir Malevich, the aerial view seems to have played it’s part. In some of his Suprematist compositions, abstract shapes were so arranged as to evoke light aeroplanes seen from above, twisting and turning in white space.

Malevich’s intent to liberate painting from the shackles of mimesis and representation raises it to a higher state and into greater spatial freedom. In the context of Malevich’s experiments, the development of abstraction might be compared to the view of the earth seen from an ascending aeroplane: ‘The familiar recedes ever further and further into the background … The contours of the objective world fade more and more and so it goes, step by step, until finally the world – everything we loved and by which we have lived – becomes lost to sight’. (Malevich 2003,68)

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