UNIVERSITY OF WINCHESTER

The Influence Automation is having on Air Traffic Control from the Controllers' End-User Perspective.

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Doctor of Business Administration

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ABSTRACT

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Advances in technology are changing the way expert roles are performed and how professionals are perceived by others within society. Developments in the field of Artificial Intelligence are now blurring the boundaries between the capabilities of people and those of intelligent autonomous systems, as well as improving the fidelity of the outcomes that can be achieved. Introducing autonomous systems to supplement and potentially replace roles that are currently seen as the preserve of highly trained and competent people presents challenges in terms of trust and acceptance. Informed and motivated by a review of the latest developments within the Air Traffic Control domain, a recent and topical example of the deployment of autonomous support recently deployed within NATS (the UK's main supplier of ATC services in the UK) explored the views and feelings of Air Traffic Controllers following of a technical innovation which changed how they provide a specific aspect of the UK air traffic control service. A phenomenological approach was undertaken to understand the experiences and feelings of Controllers who were required to use a new system that challenged previous concepts for safe service delivery. Potential linkages were identified between various recognised Change Management and Technology Acceptance Models and which offer the ability to help innovators understand how end-users could be effectively engaged in the future development and use of technology to support or supplement their roles, as well as help facilitate trusted relationships between those advocating the use of new technology and those who are required to use it. The research also points to the emotional aspects of such types of change and that seeking to understand possible impacts and outcomes from that perspective could help deliver more constructive outcomes.

Keywords: Change Management, Technology Acceptance, Automation, Artificial Intelligence, Air Traffic Control.

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1. Introduction

My research seeks to understand the potential influences that technical innovations within the Air Traffic Control (ATC) domain could have on Air Traffic Controllers (summarised for brevity in this thesis as Controllers). My interest is motivated by working as a manager within National Air Traffic Services (NATS) - the UK's major provider of Air Traffic Control service provider - and observing how some innovations that are being deployed are starting to change the role of the Controllers and wanting to see if I could try to understand what that might been to both the Controllers and the organisation.

The research explores a recent technical innovation that changed the way a specific group of Controllers provides the service, and which required them to interact differently with the systems they use and rely upon. The new concept, called Time Based Separation (TBS), is recognised within the industry as being "revolutionary" (International Airport Review, 2016) in both its application of technology and the way it is changing operational concepts. Such types of development, which start to use autonomous systems, are the first steps towards a greater role for automation within ATC and which is expected to become widespread as technology continues to develop. This will influence how those affected relate to and interact with such types of new systems.

My research starts to explore the feelings and attitudes of those affected by this particular innovation and seeks to give a voice to their lived experiences of the change. However, merely developing and deploying innovations will not fully achieve the desired outcomes, as these will only be realised when those using the new systems and capabilities fully embrace the opportunities they offer and start to identify new ways to use the technology. Acceptance or rejection of such innovations will require those affected (including Controllers) to be engaged in any process that changes how peoples' roles are performed.

1.1 Background

Technology has driven changes in the workplace since the First Industrial Revolution (Berlanstein, 1992). The introduction of automation to support manual work, such as robotic car production and the use of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) for the mass production of electrical and electronic systems, such as the robotic population of computer motherboards with electronic components in the 1970s/80s,

characterised a change in roles which were hitherto labour intensive and considered to be manual labour. The roles of the skilled blue-collar workers undertaking these roles evolved as they were initially supported, and then replaced, by robots and machines developed to replace manual and repetitive activities.

The key characteristics of such roles and functions were that they were deterministic (in terms of input, process and output) and repeatable, in so far as they could be exactly defined in terms of the sequence of actions to be undertaken to give the outcomes required. The advances increased productivity, consistency and reliability within a production line where the repeated delivery of bespoke products was required. Any issues that interrupted the production line would only require human intervention to resolve the issue and restart and monitor the process. There was no intelligence required to perform the activity, with the machine replicating what the human aimed to achieve, yet in a more continuous, predictable and assured manner. In this sense, the intelligence was vested within those who envisioned the new capability and delivered the change, as opposed to being considered as embedded with the new system.

Progressive advances in technology since the 1980s have enabled the more widespread use of system-support processes, whereby humans are supported in their roles by Decision Support Systems (Sprague, 1980), which can analyse and process a greater number of variables and potential scenarios substantially quicker more capably than humans can and which is not susceptible to lapses in concentration or distraction. More recently we have observed the automation of repetitive tasks under human supervision, enabled by the ability to accurately describe and define the actions required to provide repeatable outcomes. In this case, we are seeing a system, usually computer-based systems and sometimes operating machines that exhibit precise geospatial awareness and fine-tuned dexterity, replacing the activities of skilled operators, but with no intelligence or ability to stray from the predefined process nor to change the outcome. In this respect, the manual systems and processes that are being automated were deterministic and still required some level of human interaction and decision making.

Since c.2000, the deployment of concepts and capabilities considered to be under the general banner of Artificial Intelligence (AI) and Machine Learning (ML) have occurred, capabilities which develop these concepts further and to the point where the system can learn (within limits) from past performance and outcomes and can self-improve or revise what it does

(Daugherty and Wilson, 2018). The development and use of systems that are supporting and/or supplementing roles that require greater cognitive and intellectual abilities are being seen, roles which are characterised as professions and referred to as being white collar in their social status (Ford, 2015). Such professions almost always require an advanced level of academic qualification, training or pupillage supported by professional registration or accreditation, and significant post-qualification experience to enable best practice to be adopted and evidenced through repeatable outcomes (Susskind and Susskind, 2015). Such professions tend to be revered by society, being seen as providing services by only highly qualified, capable and trained individuals, such as engineers, air traffic controllers, clinicians, architects and lawyers.

However, this paradigm is changing. The use of computer processing power that can analyse vast quantities of information within datasets to identify patterns and trends associated with human behaviour, as well as human-human interactions and outcomes (referred to as 'Big Data') is challenging the precepts that only humans can undertake certain activities. Such developments are questioning the premise and constructs of the "grand bargain" (Susskind and Susskind, 2015, p.9). Such technical developments are fuelling the Fourth Industrial Revolution (Schwab, 2016), whereby the most recent advances are enabling the digitalisation and automation of previously manual processes and activities, and which can exploit internet-based systems to connect separate items or facilities to contribute to the outcomes required. Such systems support the ability to transfer and process vast amounts of data without the need for human-to-human or human-to-machine interactions, commonly known as the Internet of Things (Ashton, 2009). End-user applications and tools are now being developed to perform tasks that seek and obtain information from preceding systems, sometimes enabling executive decisions to be made without any human interaction or engagement.

Such developments are enabling fundamental changes on the concept of work, enabling the view to turn from how something is done to the outcomes achieved. For example, we are now observing changes to working patterns and concepts, such as virtual meetings enabled by real-time video processing capabilities and the concept of remote teams, enhanced by virtual reality systems to provide a greater feeling of actual participation, when in the past physical presence and participation would have been required or expected.

These advances are having a dramatic effect on society, both from the perspectives of those who provide specialist or professional services through their skills and capabilities and those

who receive their services, as well as changing how people interact with technology and how they react to the information they are presented (Autor, 2015). Further changes are being observed on how people learn and the level of trust they give to the sources they engage with. How individuals learn and the need to retain facts and knowledge is now being supplemented by knowing where to obtain immediate access to trusted and assured sources of information.

This also challenges the future concept of learning and therefore how people develop cognitive powers to interpret facts and analyse information to develop their own set of reasoned arguments, as well as developing skills to challenge opinions and perspectives, i.e. where will the creative thought be developed. One of the implications of such advances is how both laypeople and professionals view others' roles, their actual and perceived contributions to their organisation, and how it may influence what they do and the ultimate value of their contribution to their organisation and wider society. The conflux of these various factors is resulting in a wicked problem, difficult to solve and with evolving requirements that can be difficult to recognise. The identification and management of the potential outcomes and consequences present unique challenges for organisations to consider both in the workplace and elsewhere (Fry, 2018; McKinsey Global Institute, 2017a; McQueen, 2018). NATS is itself starting to recognise these issues and is exploring what possible avenues could exist in responding to the opportunities that such advances in technology are expected to enable.

My research recognises the importance of these issues and considers the potential changes on those whose roles will be affected, with a focus on how they are reacting to the opportunities and threats such developments present and how their reactions may help or hinder future developments within their field (Arntz et al, 2016). In doing so, my interest is steered towards professional and white-collar roles, characterised by highly capable and developed cognitive abilities and evidenced in individuals who are often at the forefront of their profession or specialism (Van Horn and Schaffner, 2003). Key to the development of such roles is a willingness to support and accept that the skills they have developed can now be understood, challenged and in part replicated by computer-based systems (McQueen, 2018). My specific focus is on ATC and the influences that future technology and automation could have on its acceptance by those whose role it will affect most – the Controllers. Acceptance of the changes that such advances could provide is underpinned by the recognition that the current situation will change and the belief that the future will still provide a secure and trusted working environment, with the concept of trust spanning both the motives for the change and

the capabilities of the technology used in the supporting systems (e.g. Muir, 1987; Merritt et al, 2012; Rivard and Lapointe, 2012; Rossi, 2018). Users' trust in both aspects is required to deliver the types of outcomes that can be achieved; mistrust in either could result in failure, partial compliance and sub-optimal performance outcomes.

The situation is further challenged by the fact that the types of actions and activities which will be provided by the type of innovations expected need the support and engagement of those whose roles will be affected. Those who need to be engaged to help develop future capabilities may feel that such developments are not in their best long-term interests, either personally or from a professional perspective (Ratcheva and Leopold, 2018). Whilst specialist developers and innovators can develop new capabilities to perform different functions, the true value of the capability comes from end-users making the right decisions when confronted with choices and having safe fallback positions when unusual or unexpected circumstances occur – situations where the users need to rely on experience, judgements and intuition. It is here that the input and commitment from those currently performing the role are vital. This presents a challenge as developing and delivering the most capable of systems require the support of those who may ultimately see that very capability as a threat and who may be suspicious of the motives for such developments in the first place. A key influencing factor in securing engagement from those affected is what they perceive to be the motives of the change, either positively to achieve a better outcome from their role or negatively from a concern that it could replace or dilute their role.

There are also more personal feelings and concerns that will influence the user's engagement and commitment: what might be better for an organisation from a commercial or service delivery perspective may not align with the individual's view on what may be best for them in their role in the longer term. Concerns over status and job satisfaction may influence the type and level of support provided, with hard-won reward, recognition and job security being threatened within the learned professions by advances that may dilute or even obviate their specialist skills.

1.2 How Technical Innovations are Changing Peoples' Roles

Concepts and applications of automation focus on how machines are supplementing physical processes by replicating and repeating established and deterministic human actions. There is no intelligence in the physical automation of known actions – the cognitive and intellectual thoughts supporting the underlying processes have been created and are applied by people. These are accurately and reliably replicated by machines or systems across a variety of manufacturing and construction industries, such as from the use of heavy machinery to support robotic car production, through to the intricate construction of electronic systems such as the population of Printed Circuit Boards with electronic components. The outcomes are not different to those that would be delivered by human operators but are more repeatable, can be achieved quicker, are more dependable and of consistent quality. Such operations are also immune to the vagaries and inconsistencies that may be exhibited by human operators and which can lead to human error. The drivers of such process and product development automation are primarily to deliver business efficiencies, such as reducing labour costs whilst increasing overall productivity (Sarter, Woods and Billings, 1997; Daugherty and Wilson, 2018) and to undertake tasks that reduce human exposure to danger, such as remote or robotic operation in hazardous environments.

Many systems and applications which are loosely described as being intelligent are actually 'dumb', they are in reality the automated replication of defined processes or actions, which have themselves been previously developed by human intelligence, i.e. the intelligence is vested within the human creators and delivered by their creativity, as opposed to such intelligence being exhibited by the machine discharging the task. Thus, to be able to set the research in the correct context it is valuable to distinguish between two widely used terms: *automation* and *artificial intelligence*.

Automation

There are numerous definitions and interpretations of the term automation and what it means in terms of supplementing or replacing human actions. Groover defines it as the "technology by which a process is performed with minimal human assistance" (Groover, 2019), a definition that is independent of the context within which it is used, nor reflects the various 'levels' of automation that others assert exists to provide an important discriminator in the capability of the automated system. Such a perspective also decouples the concept from any timeframe, with all four of the Industrial Revolutions seeing the automation of activities and processes in

one guise or the other, usually to replicate what humans do, yet in a more efficient, reliable and predictable manner.

The model of the types and levels of human interaction with automation proposed by Parasuraman, Sheridan and Wickens (2000) facilitates a framework to identify the types and extent to which functions or activities should be automated. Such positions were motivated by their view that automation does not simply 'replace' but 'change' human activities, including increased requirements for concentration whilst monitoring, such as for unexpected or infrequent events. They assert that automation can be proposed for four basic classes of functions: *information acquisition; information analysis; decision/action selection; and, action implementation*. Whilst other classifications and taxonomies have been developed and applied (e.g. CAA, 2016; Frohm, Lindstrom, Stahre and Winroth, 2008; Norman and Panizzi, 2006), the literature is consistent in the view that the use and application of automation within a human-machine system is not a Boolean, black and white, characteristic. This supports arguments that the extent to which a task could be automated should be set with a continuum of autonomous capability, with a delineation in the transfer of responsibility between the human and the machine, and with specific applications and uses being better aligned to a particular level that reflects the role of the human participant and to maintain an appropriate level of interest and engagement.

Finally, in seeking to understand the concept of automation, caution must be exercised to not expect automated systems to be a panacea to replace human operators. The Seven Deadly Myths of Autonomous Systems (Bradshaw et al*,* 2013) sought to bring some realism into what reasonable expectation of uses and benefits, including challenging the value of the concept of levels of automation discussed above, but rather considering it to be an entity in its own right:

> "autonomy isn't a discrete property of a work system, nor is it a particular kind of technology; it's an idealized characterisation of observed or anticipated interactions between the machine, the work to be accomplished, and the situation. To the degree that autonomy is actually realised in practice, it's through the combination of these interactions." (Bradshaw et al, 2103, p.56).

Artificial Intelligence

Although there is no universally accepted definition of the term Artificial Intelligence (AI), it is generally recognised to be intelligence exhibited by machines and systems, as opposed to natural intelligence shown by humans and animals. Such a view is underpinned by the concept of 'intelligent agents', whereby a system or device perceives its operating environment and develops its own course of action to maximise its chances of achieving its goals (Poole, Mackworth and Goebel, 1998). The term is used to describe a system that appears to show the types of cognitive powers and ability to learn from previous outcomes within a sensed environment to achieve a predetermined outcome, thus mirroring the need of living bodies to develop solutions to survive. A more nuanced definition is provided by Kaplan and Haenlein (2019) as:

> "a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation."
>
> (Kaplan and Haenlein, 2019, p.17).

The literature also points to AI being an evolutionary and fluid concept, requiring a definition and understanding that reflects the evolving capabilities of the systems that exhibit it. Capabilities that were once considered to be revolutionary AI, such as optical character recognition, are now routine and commonplace and the systems used to provide it are no longer considered to fall with the bounds of AI – it has in effect become normalised and expected within the capabilities of today's society, thereby challenging whether there is now any real intelligence in such types of system. This is recognised as the "AI effect" (McCorduck, 2004), whereby the behaviour is not considered to be real intelligence (Haenlein and Kaplan, 2019), rather the outcome is achieved through the ability using large-scale processing power and data to rapidly perform multiple simulations and scenarios covering all possible inputs until an acceptable solution set is identified. Daugherty and Wilson (2018) perspectives and applications of AI use the similar definition of "systems that extend human capability by sensing, comprehending, acting, and learning" (p.3), introducing the concept of extending human capability as opposed to competing with it.

The definition that I am most attracted to within the context of my research is "Computers which perform cognitive tasks, usually associated with human minds, particularly learning and problem-solving" (Loder and Nicholas, 2018). Such a perspective recognises that AI no longer

describes or defines a single type of technology, but rather can be a catch-all range of technological capability with a focus on observed/experienced outcomes as opposed to the technology used to host the applications. It also fits with my research which seeks to infer potential outcomes and consequences of automation and AI on people and their roles by considering the consequences of the outcomes on the end-users and not from the perspective of any particular technology. Furthermore, an outcome-based definition is also more agnostic of the type of technology that delivers it which will no doubt change in the short term as technical capabilities evolve.

There are two aspects of AI that are relevant to my line of research: i) the concept of Machine Learning (ML); and, ii) eXplainable Artificial Intelligence (XAI), both of which influence how end-users react to the outcomes delivered by AI systems and the trust they place in them, in effect working against AI if it is perceived as a threat or working with AI if it is seen as supporting/furthering their own particular goals. ML is the underpinning concept that supports AI, whereby computer algorithms can automatically improve through experience to achieve the outcome required (Lugar and Stubblefield, 2004). ML is thus one of the many ways to achieve AI, it being the ability of the system to learn from the data by analysing it in a variety of ways to examine whether trends exist or if any predictions being made are reliable and valid, as opposed to only using the data as an input source to use by predetermined algorithms, themselves developed by humans, to arrive at the outcome.

Understanding how the system arrives at the outcomes is a key part of whether those who use and rely on the information trust it: it is easier for a user to trust an outcome that they would have arrived at themselves (albeit it over a longer period) irrespective of whether they believe it or not, as opposed to being expected to trust and accept an outcome that appears inexplicable. This leads to the concept of Explainable Artificial Intelligence (XAI), whereby the results can be understood by human experts and recognised by end-users as being feasible and contrasts with the concept of the 'black box' where it is not possible to explain why a specific decision has been arrived at. The literature underpinning the concept and importance of the value of being able to explain AI system behaviour (to those who need to understand it to the required level of detail) has been critiqued by Adadi and Berrada (2018), who concluded that XAI is itself a "vital interdisciplinary research field in the AI ecosystem" and that considerable focus will be required in parallel with advances in AI to provide assurances that the outcomes are explainable and understandable.

As well as enabling trust to be developed by end-users, being able to explain the outcomes is vital if regulatory approvals are required for systems that use AI, such as within industries that are required to operate safety-critical systems or deliver safety-related outcomes (e.g. medicine and transport). If regulators cannot understand how solutions or outcomes are developed, they cannot be assured that safe and acceptable outcomes will be delivered under all circumstances and thus will be cautious about approving a system for use (i.e. that cannot approve unexplainable outcomes).

A further consideration within the domain XAI relates to what constitutes an acceptable or plausible explanation, linking into the numerous cognitive powers that those who understand something use to explain their views to others, and the same powers the recipients have to understand the messages. Such challenges have been explored by Miller (2019) who identified four key findings regarding explainable AI: i) explanations are contrastive (in terms of explaining why something happened instead of something else); ii) explanations are selective and therefore biased; iii) probabilities matter less than causality; and, iv) explanations are social, thereby presented in a manner that reflects both the explainer's and recipient's beliefs. Miller (2019) concludes that "explanations are not just the presentation of associations and caused (causal attribution), they are contextual" (Miller, 2019, p.3).

Thus, as well as just *explainability* the literature points to the need for *understandability* – with the level of understandability required itself not absolute, but rather placed on a continuum which reflects that varying uses and engagements will need different degrees of understanding. For example, a regulator whose approval is required to certify that a system is safe or fit for purpose may require a far greater level of understandability (and have cognitive powers to develop such levels of understanding) than a user of the system, who may be willing to trust and use certified and approved systems. Some end-users may have difficulty in trusting systems that deliver outcomes that can be neither explained nor understood, and that may lead to them being cautious in using and fully embracing their capabilities, potentially leading to resisting their use to support or supplement their roles, outcomes which are developed and critiqued in the literature review that followed in Chapter 2.

1.3 The Challenges of Delivering Technical Innovations

Projects that aim to deliver innovative change to supplement or automate people's roles have a chequered history of success, with reasons for failure including inaccurate or incomplete

requirements (Bjarnason, Wnuk and Regnell, 2011), scope creep (Elliott, 2007), a lack of end-user engagement (Schmitz et al, 2019) and being overly ambitious in what is achievable (Verner et al, 2008). Whilst all of these factors apply to projects within the ATC sector, insufficient consideration of the outcomes on the end-users is of particular interest to me as my experience within NATS has made me aware of insufficient Controller input in the past has led to projects being delayed and the capabilities needing to be improved to deliver workable solutions acceptable to the Controllers. The following examples illustrate how ineffective enrolment of the users of the new system can contribute to failure.

The NHS National Programme for IT (NPfIT)

The NPfIT was a major IT programme initiated by the Department of Health in 2002 to transform how the NHS used and managed patient records. The intent was to develop a system that would enable paper-based medical records held and accessed manually by local health bodies (e.g. at GP surgeries and hospitals) to be held electronically and be universally accessible from a single, centrally managed, facility. The capability would ultimately be able to hold the records of everyone in the UK registered with a GP, interconnecting over 30,000 GPs and 300 hospitals in the UK, with timely access available in a secure and auditable manner. Initially estimated to cost £2.3bn over three years, by 2006 the cost has increased to £12.4bn over 10 years (National Audit Office, 2008). One of the reasons cited for the failure of the system to deliver as expected was that clinical staff (the key end-user group) felt that they had not been engaged in the development of the system and thus their requirements were neither understood nor delivered by the systems provided, thereby finding the system unusable in many circumstances where time-critical, complete and accurate patient information was required. The inability to engage and secure the commitment from the most powerful group of key workers from an early stage meant that, once views and perceptions had been formed and positions embedded, further investment to address the numerous issues on a piecemeal basis was ultimately unsuccessful.

UK eBorders

Initially commissioned by the UK Home Office in 2003, the e-Borders project was established to develop a modern and efficient immigration and border control system. The project was estimated to cost £750M, with Raytheon contracted to provide the underlying IT system. One of the main drivers was to address the increasing queues and delays of passengers arriving at UK airports having to be processed manually by Border Control officers using a variety of disparate immigration and security information systems, and the perceptions this was having on the efficiency of the UK transport system. However, following a series of missed development milestones, the contract with Raytheon was terminated in 2010, resulting in a £150M out-of-court settlement (with terms and reasons not disclosed). To date, the activity has cost over £830M and delivered a system that does fully deliver against its original mandate, although an initial capability is now available at major UK airports for certain types of passports and passengers from specified countries. A review by the National Audit Office (2008) found that a major contributory factor to the failure was that many of the Border Agency staff who had to interact with the new system felt that they had not been fully engaged in the development of the system and that a fewer number of them would be expected to revert to manual operations upon system failure or when it referred arriving passengers for further (manual) additional checks. The lack of engagement from the outset resulted in mistrust from this front-line border & immigration staff, who felt that a solution was being imposed on them by those who did not fully understand the complexity of the task and pressure of the role (Alami, 2016).

The Federal Aviation Authority Advanced Automation System

The USA Federal Aviation Administration (FAA) provides ATC within US airspace. In 1982, the FAA launched a major technology update programme to modernise its ageing ATC system, the core part being the development of an Advanced Automation System (AAS). The programme was extensive and aimed to replace all aspects of the ATC system. It also sought to change how the service was delivered by seeking to automate many of the functions provided manually by Controllers. The project did not deliver to cost, specification or timescale. One of the main issues identified for the cost overruns and delayed delivery was an initial design that did not adequately consider and reflect the expectation and requirements of the Controllers resulting from ineffective end-user engagement, compounded by superficial assessments of

technical and programmatic risk and seeking to automate the Controller 'out of the loop'. To date, the concept of service delivery remains predominantly manual.

NATS New En-Route Centre

In 1988, NATS established a major project to design, develop and transition a new Air Traffic Control Centre to replace the ageing facilities at the London Air Traffic Control Centre. The New En-Route Centre (NERC) would be located on a new greenfield site and provide Controllers with the latest state-of-the-art ATC system to meet future demand. The new system would exploit new technologies that would be able to replicate the role of Controllers. The project had an O' date of 1996 and an initial budget of £475M. NERC was delivered in 2001 (some five years later than initially scheduled) and at a final cost of £482M (with additional undisclosed costs incurred by the main contractor under penalty clauses). A subsequent review by the House of Commons Transport Select Committee (1998) identified a lack of adequate engagement with the end-users (the Controllers) to understand and specify their requirements. When NERC opened in 2001, it replicated the manual capability it was intending to replace, but on a new platform from a different location.

A common feature in these four examples was the consequences of ineffective engagement of the end-users whose role would be changed through the latest technology prevailing at that time, resulting in solutions that were ultimately not accepted in the manner originally envisaged. A further factor to consider is how individuals reacted when they are confronted by change and how their experiences of previous change may inform their reactions. The literature points to understanding end-user engagement and support as being a complex situation, with those experiencing the change each bringing with them their lived experiences informed by the past and each considering how it could affect them personally and in their chosen role. It is within this context that I focused my thoughts on such types of changes within the ATC domain and in my organisation (NATS) in particular.

1.4 How Technology is Evolving the Controllers' Role

Organisational Culture within NATS

As well as the broader influence that technical innovations will have on professional roles, my research seeks to interpret any influences these may have on Controllers from both technology acceptance and change management perspectives. The workforce that will be most affected by the change (i.e. the Controller community) has high bargaining power within the organisation, is heavily unionised and cannot be readily replaced. The type of change required will see the development and use of a new system that will provide automated capabilities and provide an initial platform for specific AI concepts, thereby blurring the boundaries of accountability for decision making by transferring some of the skills required to perform the roles from the Controllers to the system.

Successfully engaging Controllers in the opportunities provided by new technology within a regulated environment will require the use of appropriate change management, technology acceptance and user-engagement strategies and which reflect the nature of the role and the high bargaining power they enjoy within the organisation. As such, the outcomes of this research are valuable to NATS as it will allow suitable engagement strategies to be developed as part of projects that seek to deliver innovative change that will evolve the Controllers' role. Other roles in NATS can be filled by those who would be more willing to engage in such types of changes to their roles and where a market for such skills exists, whereas the Controllers are the only group which is legally permitted by the UK Civil Aviation Authority to provide the service, as well as being a scare resource which cannot be readily replaced (Kreedy, 2016; Saraogi, 2020).

The types of changes envisioned through the deployment of automation and intelligent autonomous systems are expected to make the Controllers' role less complex, thereby providing greater opportunities to others to develop the skills required to perform the role, ultimately leading to greater opportunities to recruit from a wider pool. The Controller community is aware that this could influence their status and job security, yet are also aware that the new technology will only be successfully deployed with their engagement and support. Such a situation provides additional challenges to be overcome as new technology is developed and deployed, over and above the usual type of challenges faced when delivering major IT projects.

Trying to understand Controllers' lived experiences of change is informed by an appreciation of the prevailing organisational culture within which is it delivered. As with all aspects of air transport, ATC is highly regulated from a safety perspective to ensure that all risks are identified and mitigated to an acceptable level. Whilst NATS comprises numerous professional and support disciplines, the Controllers are recognised as the group which wields the most power as they discharge a licenced function that cannot be readily replaced, where demand for Controllers exceeds supply (not just in the UK but globally) and where any withdrawal of goodwill or contracted services has an immediate impact the performance outcomes required of NATS by the CAA (i.e. service delivery is highly sensitive to Controller availability). Manifestation of NATS culture (as observed by me as both an employee and the researcher) can be considered within the layers proposed by Schein (1992). Within NATS, culture is understood and accepted to be 'how we do things around here when others aren't watching' and is seen as the 'glue' which holds the organisation together.

Layer (Schein, 1992)	Manifestations in NATS
Underlying Assumptions	Structured and processual nature of developing knowledge and providing services; sense of security; expectation of a rewarding & satisfying role; expectation that all can and do make contributions to the organisation.
Espoused Values	Providing safe services is a given – regular safety surveys and internal campaigns; services provided offer value for money; a rewarding organisation.
Observable Behaviour	Observed as a professional organisation; employees expect and treat others with respect; united positions provided even though there may be underlying differences; management and Trade Unions are seen as working together to achieve common objectives and outcomes; respected by peer organisations; declared and seen as innovative and a thought leader within the industry. Employees are proud to say that they work for NATS; Controllers are proud to say they are Controllers.

Table 1: Manifestation of Schein's Layers of Culture within NATS (as observed by the researcher).

I have observed power discourses prevailing within the organisation between management and the most powerful and dominant workforce (the Controllers) which bear some similarities with Critical Theory in terms of power dynamics, and where Controllers sell their skills and capabilities to enable management to deliver upon management and business performance objectives. Anecdotal instances of the views emanating from the Frankfurt School perspective of critical investigation can be seen, as can a Marxist perspective where work just becomes work, with workers becoming the abstract labour force, with the control over work becoming a

management prerogative. In this case, the Controllers can be recognised as the workers, who use their skills in return for an agreed level of reward and compensation. To a certain extent, with rest of the workforce benefits from what emanates from those power-plays, including the management side, to ensure that a recognised hierarchy of reward is maintained across the organisation and which can be sufficiently attractive for Controllers to move to the management domain. The outcomes of such interactions are also in many ways self-sustaining, in so far as developing Controllers to deliver more or better services increase their capability to achieve safer and more resilient services, thus further cementing the reliance placed upon them and thereby resetting the management/Controller dynamic at a new equilibrium from which future interplays will be based. It is also valuable to set this into the current day context, from both organisational and research perspectives.

I am not suggesting here that Controllers are an emancipated group that needs to be somehow liberated, but I have observed a type of industrial relations environment that can be recognised within that context in terms of labour bought and labour sold since the 1980s. The dynamic is further constrained by the reality that management can only (by law) buy such services from licenced Controllers, and those Controllers can only sell their services to the employing monopoly supplier – there is no other market to buy and sell the type of labour required. The Controller community is also aware that they enjoy generous rewards for their services relative to other stakeholders in the air transport domain, and are sensitive to the need to avoid a situation developing where these could become more visible and possibly challenged to such an extent that a complete review and overhaul is triggered. Both management and Controllers are aware that they traverse a fine line that benefits both sides, yet at the same time need to be seen to secure the best possible outcomes for their respective stakeholders (i.e. shareholders and customers on one hand; employees on the other). Both sides are aware that they each have a lot to lose from any form of official industrial action that draws attention to the current employment conditions.

This power dynamic prevailing within the organisation will however change with the development of new technology that places lesser reliance on the capabilities of Controllers and which will start to automate some of the more complex actions they perform. Such innovations thus have the power to deliver a ‘soft reset’ of the role, challenge the value of its contribution, and thus the reward provided to Controllers when their skills will no longer be the preserve of the human. This too forms part of the backdrop to the development and use of innovative tools to support Controllers, and their potential willingness to support their

development and integration into the systems and services provided. Being aware of the prevailing culture and group power dynamics will help me as the researcher when I seek to induce knowledge from my interactions with both the Controllers and managers during the data gathering and analysis phases of my research. Such innovations will not be delivered into a power vacuum, but into a prevailing environment of a tense organisational culture.

Amaldi, Quercioli and Smoker (n.d.) concluded that the effective and successful implementation of highly integrated human-machine work systems is achievable only by managing power relations that influence the acceptance of the change:

> *"The path dependency that has influenced the evolution, when seen through a lens of power relations, clearly indicates that the barriers to implementation stem from the conflicting needs and understanding of what automation means."* Amaldi et al (n.d.).

Such views can be observed in NATS and may influence whether technical developments which seek to automate the Controllers' role are accepted and whether these could change the power balance in the future.

Being a Controller in NATS

Previous work (Hopkin, 1995; Jou, Kuo and Tang, 2013; Isaac and Ruitenberg, 2017) on those aspects which attracts people to become a Controller has identified certain characteristics and personality traits, including the belief that the role will provide a high degree of personal satisfaction and offer a sense of achievement in terms of solving real-time problems within a safety-related and intense, pressurised environment. Research of the Controller community has shown that intrinsic motivational factors such as a sense of achievement and the ability to experience the contribution of their role are reported as major positive features, as is the sense of being immersed with a real-time safety-related system under their control. As well as these intrinsic motivational factors, the Controller community is respected as a profession and attracts a sense of kudos resulting from how others perceive their role. Furthermore, the compensation package and job security are seen as major retainers, with other (non-operational) roles available for those Controllers who are unable to retain the licence due to medical reasons or for those who chose to experience different aspects of the business, and which can be undertaken on the previous (i.e. operational) terms and conditions, secured through effective TU negotiations. This provides the key challenge of how to engage

Controllers in the development and acceptance of new technology that will initially support but potentially replace them in their role, and in a manner that maintains their commitment to the service delivery performance outcomes required.

1.5 The Phenomenon Investigated

The aspect of the change explored in this research was the influence the innovation had on the Controllers who had to provide the service differently, as opposed to the science and technology that enabled that change. As such, it considered how the specific group of Controllers felt it affected them from their perspectives and lived experiences. The innovation which was deployed changed how a particular group of Controllers provided the service, from one where they were solely responsible for providing a specific function, to a concept where automated system support determined and provided the optimum solution to them. The innovation automated one of the more rewarding and stimulating aspects of the role, where their skills and capabilities were regularly exercised and tested, and which through repeated use under a variety of operating conditions kept them at the peak of their performance. For those Controllers affected, this was a major change to have to accept and develop and they had to revise how they interacted with the system. My research is rooted in the air traffic control domain and contributes to the ongoing discourses regarding the future role of Controllers and whether the industry-wide performance outcomes required can be achieved through the wider use of technology within ATC, and if so, how a change in the balance between Controllers and the technical systems they use can be achieved. As such, I am considering these matters from the Controllers' perspective as they start to embark on the types of changes to their role that technology will enable. Specifically, this research sought to:

1. Explore whether projects that have sought to use technological innovations to change the roles of the end-users delivered the outcomes initially expected.
2. Consider whether existing technology acceptance and user-engagement models could inform management in the progressions of the changes considered in this research.
3. Contribute to the existing body of knowledge on the user-acceptance of technology when it is deployed within the specific vocational setting and context that applied.

4. Provide NATS management with insights into the change from the Controllers' perspective and within the specific context of the phenomenon experienced by a recent technical innovation that changed how a particular aspect of the service was provided.

1.6 Overview of the Research Approach and Findings

My research adopted an interpretive theoretical perspective where I sought to induce or infer knowledge from the information gathered from direct interactions with the Controllers affected. My study was phenomenological, accepting that any social reality needed to be grounded in peoples' experiences of that reality and where the outcomes of the phenomenon are allowed to speak for themselves without preconceptions. Such an approach was supported by the fact that I am not a Controller, and whilst I have a basic understanding of how they perform their role, I am not of their "mindset" (Isaac and Ruitenberg, 1999) and thus am not fettered or influenced in my thinking. I sought to engage with those who had experienced the change by seeking to "step into their shoes" and by trying to immerse myself in how they internalised and socially constructed their feelings triggered by the change. Face-to-face semi-structured interviews were used to gather the information; a reflexive thematic analysis (Braun and Clarke, 2006) enabled me to infer six themes from the Controllers' lived experience of using the innovation selected for this research:

1. Limited awareness of the capabilities of technology and their influence on ATC and how it could be applied to ATC in general, despite working at the forefront of ATC service delivery using advanced technology, systems and facilities.
2. That ATC is too complex and unpredictable to be automated and advances in technology will not be capable of providing the service, with an underlying scepticism about whether it could ever be done. I inferred that there was an underlying belief that whilst other parts of the ATC service delivery chain could be (and would value from being) automated and may benefit from the concepts being mooted for AI and ML, the complex nature of ATC and the skilled nature of the task would prevent (or significantly delay) the use of any such technology in support of their specific role.
3. That technology could adversely affect the skill base required and the satisfaction Controllers experience by undertaking a complex role. However, there was some polarisation of views raised on the outcomes on the skill base the change would have, covering both concerns that there would be a reduction the core skills required to

provide the tasking (i.e. deskilling), countered by views that it would necessitate an increase in the skill base to match the increased abilities of the overall ATC system. A common message I inferred was that a different set of skills will be required and different capabilities developed.

4. Effective User Engagement in the design and development of the new capability. I inferred that the users recognised that they had been engaged in the formative phase of the development and that their views had been reflected in the ultimate capability provided.

5. Trust in both the integrity and reliability of the innovation and the motives for deployment the innovation deployed came across strongly. No mistrust in management nor any motives other than being to improve the service provided were inferred from the data.

6. An acceptance of the innovation within the operation by the Controllers, with strong support and acceptance of the new capability provided. The benefits in the performance to the overall ATC system and its ease of use was seen by the Controllers and the ability to observe improved outcomes helped develop their sense of acceptance.

No assertions of generalisability are made, although the inferences made regarding the specific innovation examined may help NATS management to consider whether such inferences could be valuable if the innovation is deployed for other airports.

1.7 Contribution

This research contributes to existing theories and practice in the field of technology acceptance within the specific profession considered (i.e. Air Traffic Control). Specifically, from a theoretical and academic perspective, this research contributes to the academic literature regarding technology acceptance by supporting the widely accepted dimensions of 'perceived ease of use' and 'perceived usefulness' within the Technology Acceptance Model (Venkatesh and Davis (1996) and the Unified Theory of Acceptance of Use of Technology (UTAUT) (Venkatesh et al, 2003). Furthermore, it provides anecdotal support to the models relating user acceptance, trust and resistance when users are obliged to use new technology within the work dimension. It also supports other research into the acceptance by Controllers of technical innovations (which enhance those enjoyable or stimulating aspects of the function and suppress those aspects which are less attractive or motivating (Bekier et al, 2011).

2. Literature Review

A theoretical literature review of relevant constructs and theories was performed to gain insights and help develop my understanding and knowledge around the research topic (section 2.1). This was followed by a review of previous empirical studies undertaken within the ATC domain to understand the findings of earlier studies on the type of change being investigated by this research (section 2.2). The review of existing knowledge and literature within the field of delivering innovative change and the detailed focus on ATC enabled the contribution that my research would make to be identified and justified (section 2.3).

2.1 Theoretical Literature Review

Recognised Change Management Models

Multiple sources of information and models exist to propose the various aspects or phases of organisational change, which either propose and describe the various phases that organisations or individuals go through (Lewin, 1947; Kubler-Ross, 1969; Bridges, 1991), or provide models or constructs that can be used to deliver change within an organisational setting (Peters and Waterman, 1982; Kotter, 1996). Rosenbaum, More and Steane (2018) classified the various recognised models and processes to support organisational change into three groups: i) governance approach, researched-based; ii) structural approach, researched-based; and, iii) practice-based organisational. Two recognised Change Models for each of the categories identified (Rosenbaum et al, 2018) is provided in Table 2. Such a categorisation enables the most suitable type of model to be progressed in the context of the type of change being considered.

As this research relates to a change in how Controllers perform a specific aspect of their role, the change experienced is 'functional' as opposed to 'organisational' and as such, is better set within the context of the "research-based, structural approach" and could point to findings being recognisable within the context of the Change Curve (Kubler-Ross, 1969) and the Transition Model (Bridges, 1991). These models also point to the emotions experienced and generated from lived experiences and may help set any emotional aspects which may be inferred analysis of the data in an understandable and recognised context.

Category	Change Model
Governance approach, research-based	• Planned Change (Lewin, 1947) • Eight Step Change Model (Kotter, 1996)
Structural approach, research-based	• Change Curve (Kubler-Ross, 1969) • Transition Model (Bridges, 1991)
Practice-based, organisational	• 7-S Model (Peters and Waterman, 1982) • ADKAR (Prosci Ltd, 2003)

Table 2: Examples of Change Models by Types of Category (Rosenbaum et al, 2018).

The Change Curve (Kubler-Ross, 1969)

Although emanating from reflecting on the various emotions experienced when grieving, the Change Curve (Figure 1) is also a recognised model when considering both organisational and personal change (Perlman and Takacs, 1990; Grant, 1996; Leybourne, 2007). Furthermore, as organisations comprise individuals, and as organisations change, then the Change Curve may reflect or align with the views and feelings of those subject to organisational change (Rosenbaum et al, 2018). Phases of the Change Curve may be more readily observable if the change experienced could result in unwanted outcomes, such as reduced status within the organisation or redundancy.

Although the model implies a flow across the stages, Kubler-Ross (1969) noted that the moving through the various phases were not discrete transitions, as individuals behave differently in the various stages and can stay in the phases for different periods of time. Furthermore, the direction of travel as depicted in the model from Denial to Acceptance is not always unidirectional: individuals can move back and forth between phases as part of an underlying direction of travel. In some cases, individuals can remain in a stage and not be able to move on, particularly when in the denial phase (Carnell, 1999). This is valuable to understand when considering whether the model is appropriate when considering organisational or functional change as it implies that some individuals may never accept the change and remain in a permanent state of denial. If such change is imposed or the outcomes are mandated, those remaining in the denial or anger stages may harbour feelings of resentment and become

"saboteurs" for future changes (Fenton-O'Creevy, 2001; Angela-Eliza & Valentina, 2018). Being aware of such possibilities will help inform an engagement strategy that seeks to reduce such outcomes to the extent possible. This could be relevant to my research as the Controllers were obliged to use the innovation provided to them, and as such were required to accept it as part of the enhanced ATC system. Realising that they had no choice or discretion in whether or not they used the innovation that was considered in this research (and more generally in the future) may result in a spectrum of views across the Controller community and which may become manifest in various ways.

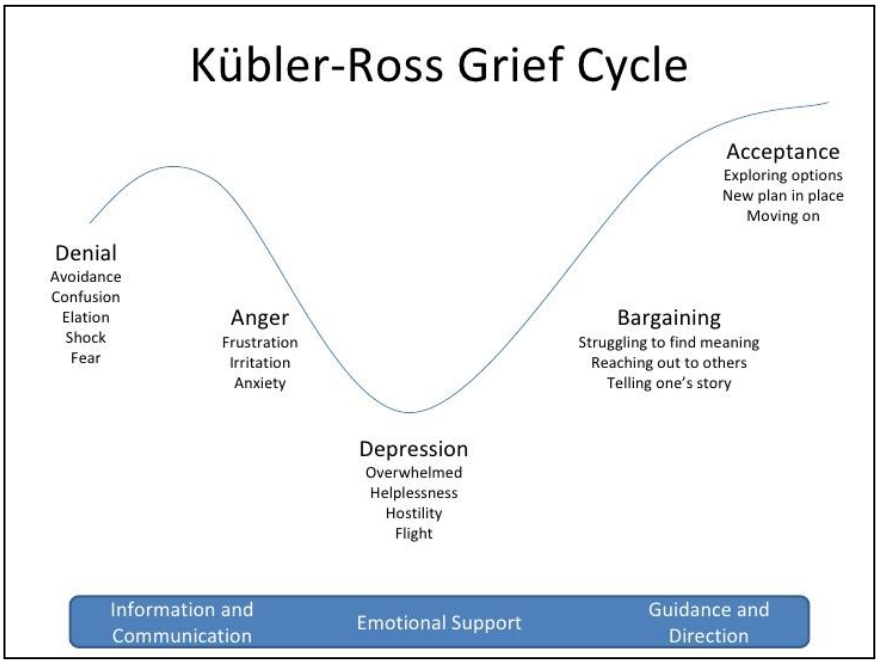

Figure 1: The Kubler-Ross Grief Cycle (Kubler-Ross, 1969).

Bridges' Transition Model

William Bridges (Bridges, 1991) considered the management of change from the perspective of 'transitions' between the various stages of personal events, as opposed to being in those states themselves, such as when activities start or stop, or when activities need to be performed differently. In this respect, Bridges' model has similarities with the feelings individual's experience in the stages of the Change Curve. Whilst organisational change can be managed using rational and understood models, an individual's *transition* between the various phases, irrespective of how they are modelled or defined, is a psychological process that is specific to the individual and is harder to rationalise and thus harder to pre-empt and manage.

In this sense, a transition could be "a process internal to the individual, slow and progressive, not demarcated in time and directly related to what the individual is living through" (Nortier, 1995, p.33). The difficulty individuals have as they transition depends upon the complexity of the interactions of the change to be rationalised and how they emotionally deconstruct it (Clarke et al, 2007). Bridges' conceptualised this as comprising three aspects: letting go; neutral; and, new beginning, with the various emotional states for each stage illustrated in Figure 2.

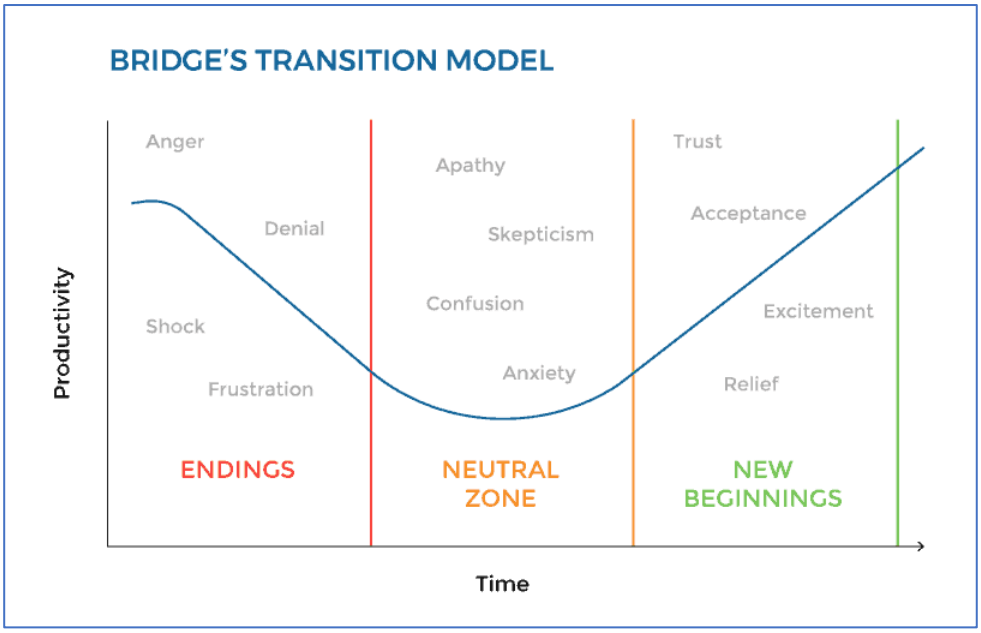

Figure 2: Bridges' Transition Model (Bridges, 1991), as illustrated/depicted by Plutora.Com

As Bridges' theory allows a focus on individuals' reactions to change, it may be able to be used to suggest and overcome any resistance that may be expected or observed by identifying those emotions that could lead to resistant behaviours and attitudes, possibly supporting the development of solutions or mitigating actions by those most affected, as opposed top-down impositions and expected outcomes.

There are some valuable similarities between the Change Curve (Kubler-Ross, 1969) and the Transition Model (Bridges, 1991) that may support their further consideration when looking at the functional change investigated by this research. Both set out thoughts and reasons to propose and explain individuals' emotions and feelings at the time of change, which can be valuable when seeking to raise awareness of the outcomes on those experiencing change (Stensaker et al, 2002; Leybourne, 2007). Understanding this could be valuable to those

seeking to implement change as providing emotional support to those affected can yield tangible benefits in support of the overall objectives of the change (Cunningham, 2006; Clarke et al, 2007).

However, in discussing such models I am not seeking to identify a solution or a construct that should be followed as part of an activity to secure end-user engagement. Nor am I trying to seek whether any specific construct should, or even could, be followed: that is not the purpose of this research. Firstly, there is no evidence that the engagement of end-users, and Controllers in particular, when faced with innovative change that will affect their roles can fit into any specific model or deterministic outcome. Secondly, the purpose of my research does not seek to fit people into any recognised change model to achieve any outcomes. It does however help develop my awareness as the researcher of an important point to appreciate and points to me reflect upon the possibility that that Controllers' experiences of the types of innovations envisaged may include an emotional dimension.

Although both organisational and functional changes have been thoroughly researched and the outcomes are extensively reported, many initiatives still fail to deliver the outcomes expected. Research has suggested that seeking to 'manage' change is itself a flawed concept (Beer et al, 1990; Kotter, 1995), some of which cites that about 70 percent of all change initiatives fail (Hammer and Champy, 1993; Beer and Nohria, 2000; Kotter, 2008; Senturia et al, 2008; and, Keller and Aitken, 2009). Whilst failures undoubtedly exist, the 70% figure has been challenged by Hughes (2011), who reviewed and critiqued the available evidence to conclude that:

> "Evidence-based change practice requires valid and reliable empirical evidence, which does not exist in support of the popular belief in the inherent 70 per cent change fail rate." (Hughes, 2011, p,462).

Whilst there remains limited empirical evidence to assert any quantity or rate of failure, the preceding citations do point to many instances of failure, either where the outcomes of the change did not deliver the type or extent of benefits envisaged when the case for change was initially made, or where unexpected and unforeseen negative consequences limited the ultimate value of the positive outcomes realised (Balogun, 2006). The examples of failed projects discussed in Chapter 1 all pointed to a lack of effective engagement of the end-users, and which resulted in an unwillingness to accept the innovation and to resist the changes that

would either deliver or impose it. Being aware of what might induce resistance could help inform strategies and plans to engage users in a manner where success, as perceived by those seeking the change, can be more likely.

End-User Resistance to Change

Many reasons for failure when delivering change have been identified, with resistance from those affected being cited as a major factor in the innovation not achieving the outcomes originally envisaged (Oreg, 2003; Bovey and Hede, 2001a and 2001b; Prochaska et al, 2001; Avey et al, 2008; Fuchs and Edwards, 2011; Erwin and Garman, 2010; Pieterse et al, 2012; Rafferty et al, 2013; Courpasson and Vallas, 2016; Amarantou et al, 2018; McCabe, 2020).

Hee-Woong and Kankanhalli (2009) specifically identify user resistance to information systems as "a salient reason for the failure of new systems hence needs to be understood and managed" (p.567), pointing "status quo bias" (p.569) as the causal factor, where individuals have a preference to remain with existing systems that they trusted and could use within their capabilities.

End-user resistance to changes in information systems has been singled out as "a salient reason for the failure of new systems hence needs to be understood and managed" (Hee-Woong and Kankanhalli, 2009, p.569), where individuals have a preference to remain with existing systems that they trust and which they feel confident to use within their capabilities. This also points to the perceived self-limitations of the users, who prefer to stay within their comfort zone of what they have learned and capabilities they have developed through use and experience.

Although there is no formal definition of resistance to change, it has been characterised as being complex and multifaceted, informed by a variety of factors (Waddell and Sohal, 1998), including: protection from adverse consequences (Fielder, 2010); fear or disappointment to management (O'Toole, 1995); a desire to maintain the status quo (Zaltman and Duncan, 1977); and, to counter perceived threats to established social relations (Bruckman, 2008). Peiperl's (2005) nuanced definition of resistance offers a perspective that covers the general characteristics suggested by others:

> "active or passive responses on the part of a person or group that militate against a particular change, a programme of changes or change in general" (Peiperl, 2005, p.348).

An individual's resistance to change is multidimensional, informed by what they think about the change (the *cognitive* dimension), how they feel about the change (*affective* dimension) and how they behave in response to the change (*behavioural* dimension) (Erwin and Garman, 2010).

Although much research considers the individual as the source of the resistance, positioning the individual as a resister to change in response to the imposition of a change in 'something' placed upon them, earlier work by Coch and French (1948) developed the argument from the perspective of the organisational context within which the change is affected as a contributory factor, asserting that:

1. Resistance does not emanate from the individual, but rather from the context within which the change occurs; and,
2. The way to achieve change is not by imposing it, but by enabling participating group discussion through Action Research.

Whilst such views may emanate from 1948, in my professional experience of observing both functional and organisational change within NATS, they still hold true today, with a common feature being those affected (i.e. individuals and end-users). However, there remains a body of opinion that whilst some individuals may be predisposed to resist any forms of change, it is the context and manner in which the change is delivered that can trigger and lead to increased levels of resistance, and the prevailing organisational culture within the organisation and relative power dynamics between the various stakeholders.

The extent of an individual's resistance cannot be considered to remain constant, but a variable that is informed by many factors, such as context, perceived fairness and justness. Thus whilst there are views that individuals are the root source of the resistance, there remains a contradictory perspective of evidence that supports the concepts proposed by Coch and French (1948) which offer an alternative approach regarding the role of the organisation and the context as the catalyst for resistance (Senge, 1990; Beer, Eisenstadt and Spector, 1990), complicated by the view that organisations are themselves complex social systems (Burnes, 2015). Such a perspective can envisage resistance to change arising from the complex interactions between individuals and the social characteristics of the organisation itself, with a powerplay emerging between the individual and the organisation, which itself comprises multiple individuals. In this respect, there are similarities here with the organisational culture and power discourses that exist within NATS and which may inform or support possible

research strategies and methods to try to understand the influences future innovations could have on Controllers, as set out in section 1.3.

Since Coch and French (1948) proposed their views on resistance to change in the late 1940s, four theories of resistance to change have emerged: *cognitive dissonance*; *depth of intervention*; *psychological contract*; and *dispositional resistance* – all of which seek to offer reasons to why some individuals may resist change and how these can be understood and reflected upon by those seeking to deliver the change and their 'change agents' (Lunenburg, 2010). Reflecting on such theories on resistance to change may help management infer how Controllers may respond to the types of innovations that will be deployed and inform the types of enrolment strategies that could be considered and are valuable to be aware of when considering my research methodology and method.

Cognitive Dissonance

Developed by Festinger (1957) in the 1950s, individuals experience cognitive dissonance when they hold at least two contradictory ideas, values or beliefs, or perform an action that runs counter to any of these, to such an extent that it could result in them experiencing psychological stress. The basic tenet is that people try to be consistent in their attitudes and behaviours, resulting in them doing what they feel to be right based upon the values they hold. When they experience a disconnect between their attitudes and behaviours, they will experience cognitive dissonance manifest through feelings of anxiety and frustration. Such feelings cause the individual to change something to redress the situation by altering those aspects that they see as now being out of balance, changing something to achieve consonance (Robbins, 1986).

The potential for cognitive dissonance can be considered in the context of organisational or functional change when the change is significantly out of step with the attitudes and beliefs of those affected. Changes that are more aligned to the individual's beliefs and views will generate a lower level of dissonance, as the influence on their behaviours and attitudes will be easier to rationalise and address. Burnes and Jackson (2011) suggested that there was an association between the level/amount of dissonance experienced and the extent to which the change disturbed the beliefs and values of those affected: the smaller the difference between the discrepancy in views or attitudes generated by the change, the lesser the level of cognitive dissonance and thus the extent to which the change is resisted, whereas a greater level of difference will cause greater dissonance and increase the level of resistance.

Depth of Intervention

Depth of Intervention seeks to address resistance to change by considering how change is managed within organisations, with a focus on the activities of appointed "change agents as opposed to the senior managers sponsoring the change, i.e. those tasked by management to drive the change (Schmuck and Miles, 1971). Schmuck and Miles (1971) main tenet of argument is that the level of an individual's participation in the initiative and how it affects them needs to be connected in the users' minds to reduce the level of resistance encountered. Furthermore, the type and level of resistance generated are influenced by the extent to which it challenges the individual's psychological makeup (Burnes and Jackson, 2011).

The theory thus asserts that resistance to change initiatives can be minimised when those seeking change adopt an approach that allows individuals with the opportunity to reflect on their behaviours and attitude to reconcile the outcomes of the forces delivering the change are countered by resistant forces seeking to retain the current situation. Reflecting on the type of functional change being considered in this research, this avenue appears to offer limited value in the possible issues raised.

The Psychological Contract

The 'psychological contract', initially proposed by Argyris (1960) and latterly more widely explored by Rousseau (1989 and 1995), explains the set of unwritten mutual expectations between employees and managers within an organisation that establishes a way of working based upon common understandings of behaviours and contribution. It is thus not defined by an agreed formula or contractual terms and conditions, rather by mutual expectations of what the parties feel to be reasonable and covers the less tangible issues such as trust, commitment, respect and objectivity. When expectations are in harmony, the relationship is stable, but when one group seeks to disturb the balance (for example to increase compensation or to increase productivity) then tensions can arise to reflect the consequences of the imbalance. The extent to which resistance to change initiatives will arise can thus be influenced by the prevailing psychological contract between the parties. However, like all types of contracts, there is the expectation of reasonableness, and the level of resistance to initiatives is also informed by the organisational context in which they are set – if individuals understand why the contract needs to be changed, they are less likely to resist the change, and once the new equilibrium is achieved, a new psychological contract will be established that reflect the revised expectations.

Resistance will thus not be determined by the change initiative alone but will also be influenced by the prevailing organisational context and the stability of existing equilibriums. Van den Heuvel et al (2016) found that, from a psychological perspective, addressing the 'what's in it for me?' question is a key determinant to an individual's attitude towards change. Considered another way, it can be thought of as someone asking what they will get in return for something they are giving up.

Their analysis further concluded that a focus on managing relationships by fulfilling the mutual expectations of the psychological contract will increase support and engagement of organisational change as opposed to progressing change as an independent activity, i.e. innovations and change that is done *with* people, as opposed to done *to* people.

In this respect, using the psychological contract as a mechanism by employers to show good faith by delivering in a manner which exceeds expectations could result in reciprocity by those affected (Coyle-Shapiro et al, 2002). Set within the organisational context and power discourses within NATS discussed earlier, the concept of the Psychological Contract may offer some form of basis to understand and contextualise any resistance that could be inferred or induced from the data gathered.

Dispositional Resistance

Dispositional resistance focuses on the individual as the main source of resistance to organisational change as opposed to broader institutional factors (Oreg, 2003). The extent to which individuals are disposed to accept or resist change varies, with those who are predisposed to be resistant to change (in any situation or context) are more likely to form negative attitudes to future change when confronted with it, as well as being less likely to ideate changes or initiatives that would disturb the status quo.

In an attempt to try to quantify resistance to change, Oreg (2003) developed a Resistance to Change (RtC) scale that sought to measure the extent to which an individual is predisposed to change, addressing those personality factors that he considers to be influential and formative: *cognitive rigidity* (the extent to which individuals are can flex they views and perspectives to be open to new consideration); *routine seeking* (seeking solace or comfort in maintaining a routine or fixed structure); *emotional reaction to imposed change* (acting emotionally as opposed to rationally); and, *short-term focus* (not being able to consider a bigger picture).

Oreg et al (2008) do not subscribe to a position that all individuals have some form of inherent or evolutionary resistive characteristic or trait; rather their analysis concludes that some individuals with higher dispositional resistance (as estimated using the scale) will be more likely to resist change that those with lower dispositional resistance. Subsequent research concluded that the extent of resistance can be influenced by the relationship with the change agent and that a strong relationship with the agent can reduce the level of resistance experienced irrespective of the measure of dispositional resistance (Oreg and Sverdlik, 2011). Understanding the level of dispositional resistance felt by those affected may reduce the level of resistance to change initiatives that may otherwise occur and thus increase the likelihood of success; such a possibility may be valuable to NATS when considering the deployment of future innovations.

Resistance as a Valuable Force

Although the preceding critique of the reasons for failure and change initiatives may paint a negative view on individuals' engagement with change initiatives, the literature also sets out relevant counter-perspectives of the value of resistance. Perren (1996) asserts that resistance to change can be a positive force within an organisation, describing it as a "natural survival mechanism within organizations, which tests, adapts and sometimes stops decisions made by fallible and often ill-informed senior managers" (p.24). Such views are supported by Waddell and Sohal (1998), who argue that resistance is often useful and should not be discounted as the expected actions of those who will be affected as part of some adversarial activity. The difficulties of progressing change initiatives can be exacerbated by the misinterpretation and mismanagement of resistance, ill-informed by change agents as the *de facto* opening position of those affected, thereby from the outset developing a situation that will be characterised by potential conflict. However, the lack of resistance from an apathetic or disinterested workforce can also be a cause for concern, as with resistance comes engagement, energy and a desire to tackle the underlying issues (Litterer, 1973). Resistance may not manifest to prevent or frustrate the change, but rather to steer the activities in a more appropriate direction to secure a more effective solution. Achieving a balance of resistive behaviour may result in maximising the likelihood of success – not just delivering the change but achieving it in a manner that achieves the ultimate outcomes required, noting that the change initiative is the vehicle, not the ultimate destination. Ford and Ford (2010) considered resistance as

"feedback" (p.24) which can result in better outcomes if considered constructively, seeing resistance as an expected and potentially positive and constructive feature, and using it as part of the change initiative will secure better ultimate outcomes:

> "Change planning and implementation can be made smarter, faster, and cheaper by listening to the feedback embedded in resistance." (Ford and Ford, 2010, p.35).

From a professional perspective, I recognise such thoughts. Many earlier NATS innovations that were ultimately successful were initially resisted by Controllers, but through their engagement and addressing their concerns, better outcomes for both sides were secured. Trying to impose the change would have been counterproductive, and if imposed into the operation, would not have resulted in the Controllers identifying the initially unforeseen and innovative ways to use the new capabilities provided. Thus there may be a 'sweet spot' of resistance: neither too much such that it becomes confrontational and adversarial, but nor too little such that the initial thoughts and solutions are not sufficiently challenged through counter perspectives which may result in sub-optimal outcomes.

The Influence of Trust When Delivering Change

Trust is a major factor when expecting individuals to do something different. One way to understand 'trust' is to consider how humans live and interact socially and consider how social interactions occur (Simpson, 2012). If trust can be considered as a utility, and it is valuable when placed in trustworthy activities or agents but costly when misplaced, it has to be placed intelligently, aware that actions have consequences (O'Neill, 2018). Such an explanation between two human agents is further complicated in a situation where one of the agents is a machine exhibiting artificial, as opposed to human, intelligence. Solomon and Flores (2001) assert trust come from "reciprocal relationships" (p,14), thereby calling into question whether trust could even exist between a human and the system being used. Further distinctions can also be made between trust and reliance, and how humans react to shortfalls in either of these two characteristics (Baier, 1986). A breach of trust results in a feeling of betrayal, whereas the failure of something or someone that was relied upon generates feelings of disappointment, pointing to the situation where trust and reliance are differentiated through an individual's reactions and expectations. Thus, the traits that underpin trust and reliance connect both to the rational and the emotional, where trust without experience of previous outcomes has to be based on feelings and intuition.

A further aspect of trust is belief: when we trust something or someone, we believe that the expected outcome will occur. This enables us to consider trust as being bi-directional and a reciprocal activity, yet reliance to be considered as only unidirectional. This will help inform my research and any inferences that may be made from the data gathered, generating thoughts of whether it is 'trust' or 'reliance' that could be induced from the analysis of the data, or maybe any possible inter-play between the two. Such a distinction may help develop an understanding about how Controllers will react to, and engage with, new and innovative ATC systems: will they need to 'trust it' or simply 'rely on it'? If, as asserted by Solomon and Flores (2001) trust is a reciprocal construct between giving and receiving agents, then Controllers' interactions with automated systems may be more influenced by reliance, with the concept of trust (in this context) being meaningless from the outset. Set within the context of my research and future innovative developments that affect Controllers, developing such a narrative may lead to Controllers not being expected to fully trust the ATC system, merely to rely on it. This may result in a disconnect between the current and any new future systems requiring such perspectives and may disturb the equilibrium of the prevailing psychological contract. A possible outcome could be that Controllers would need to learn to trust themselves to rely on the technology to help them deliver the service. If so, such a journey may be a necessary part of any engagement of enrolment aspect of the overall change programme. Much of the guidance on the development of human interactions with autonomous systems point to trust a variable that influences an individual's willingness to engage with a new system (Hoff and Bashir, 2015). Merritt et al (2013) found that individuals' implicit attitudes towards trust have important implications for trust in automated systems, more so than explicit (conscious) influences when autonomous systems are operating in an unexpected manner. The consequences of such views are that users may not be able to accurately report why they experience a particular level of trust in a system, necessitating the development of both implicit and explicit measurements to predict future behaviours. Trust is also a recognised influencing factor in whether and how individuals accept the use of new technology (Siau et al, 2004; Li et al, 2008). The concepts and antecedents that inform individuals' identified reactions to innovative technology and how these can help develop trusted relationships are summarised in Table 3 (Siau and Wang, 2018).

Trust Context	Trust Concepts / Antecedents (Factors that Facilitate Trust)
Trust in Information Systems (Li et al, 2008)	Trust is the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party. Antecedents: • Personality base – a faith in humanity and trusting stance • Cognitive base – cognitive cues, including categorisation process • Calculative base – a calculation of pros and cons/costs and benefits • Institutional base – a sense of security one feels about a situation due to institutional structures (e.g. regulations and guarantees).
Trust in human-automation interaction (Hoffman et al, 2013)	• Reliability, • Validity, • Utility, • Robustness • False-alarm rate.
Trust in applied artificial intelligence (Hengstler et al, 2016)	• Performance (i.e. operational safety, data security, privacy protection) • Process (i.e. cognitive compatibility, usability, trialability (reducing concerns by inviting users to test the technology)) • Purpose.

Table 3: Conceptualisations of Trust (extracted from Siau and Wang, 2018)

Of these three concepts, the work of Hofman et al (2013) that explored how trust is developed when end-users interact with automated systems and the facilitating factors proposed aligns more closely with the avenues explored by my research. Thus, antecedents including reliability, validity and utility may point to influencing aspects with Controller start to develop trust in the innovations being deployed, and which are aspects that are not uncommon within

when new concepts and systems are deployed within the ATC sector as a whole. Sian and Wang (2018) further propose that trust in technology is determined by human, environment and technology characteristics (and their respective antecedents), illustrated in Figure 3.

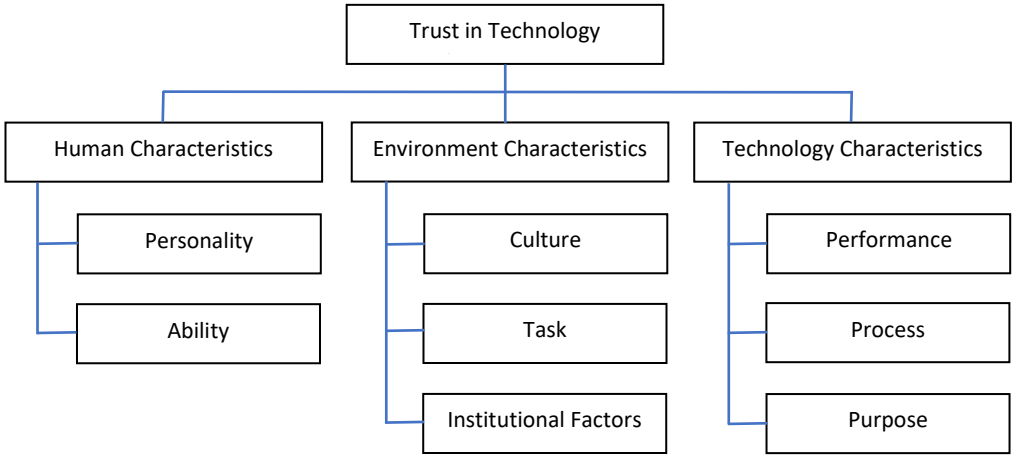

Figure 3: Factors and dimensions informing trust in technology (Sian and Wang, 2018)

All three of the characteristics proposed by Sian and Wang (2018) – i.e. human, environmental and technological – can be considered as relevant to the type of functional change enabled by the specific innovation deployed and being explored in my research. All such characteristics point to the potential value in developing an engagement strategy with Controllers which not only considers the technical characteristics of the use of advanced technology in future ATC systems, but also their personality, capability and the environment within which the trust will be developed and maintained.

Within the context of the specific technical innovation considered in this research, the concept of trust covers two aspects:

- trust in the *motives* for the change, with conflicting thoughts between the expected increase in productivity and safety level provided by the management side and the suspicion of reduced costs and lesser reliance on people from the Controllers' side.
- trust in the *capability of the technology* used to support the role and the confidence and willingness the Controllers may have to fully exploit the capabilities of the new systems when delivering the service using the new system.

Both aspects need to be considered and potential outcomes reflected upon for the change to fully deliver the desired outcomes. A new system that is trusted will be used in a manner that fully maximises its capabilities and could identify new, innovative, ways of use that may not have been anticipated at the outset. Trusting, or at least accepting, the motive for the change will help enrol the Controllers in understanding the importance and value of the technical advances in their formative stage of development, which itself will help them develop their thoughts on how they will interact with the new technology when it is deployed.

Engaging Controllers to help them develop trust in the new tools will help facilitate how they develop strategies to process the potential influences resulting from the change and start to accept it as being an embedded part of the new ATC system and how their role is performed. The literature points to some key concepts and models that can help developers and Change Managers understand how users could react to the types of innovative change that technology can deliver and how trust can help facilitate end-user acceptance of technical innovations.

User Acceptance of New Technology

How humans interact with technology is influenced by a variety of psychological, and social characteristics and factors (Taiwo and Downe, 2013). Theories and models have been developed to help explain how humans adopt new technology which seek to explain observed behaviours and aim to predict acceptance of and engagement with future products or systems. Understanding how users could engage with or react to the new technology and innovations early in the formative phase of the development lifecycle of a new product or application is vital when seeking to maximise the level of user acceptance required to achieve the desired outcomes. Some of the models previously developed to explain and predict acceptance when users either have the opportunity or are obliged to use with new technology and which could be informative in the context of this research are critiqued below.

The Theories of Reasoned Action and Planned Behaviour

The Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980) seeks to explain how an individual's attitude to a given situation and subjective norms together position their behavioural intention, which subsequently informs their actual behaviour. Recognised as one of the formative constructs which informed the subsequent development of acceptance models, the TRA predicts how individuals react when presented

with the need to use new technology which, when first proposed, was predominantly obligatory within the workplace and in an era preceding the advent of home computing and personal electronic devices. Figure 4 illustrates the relationship between the components within the TRA which combine to deliver the behaviour of the end-user.

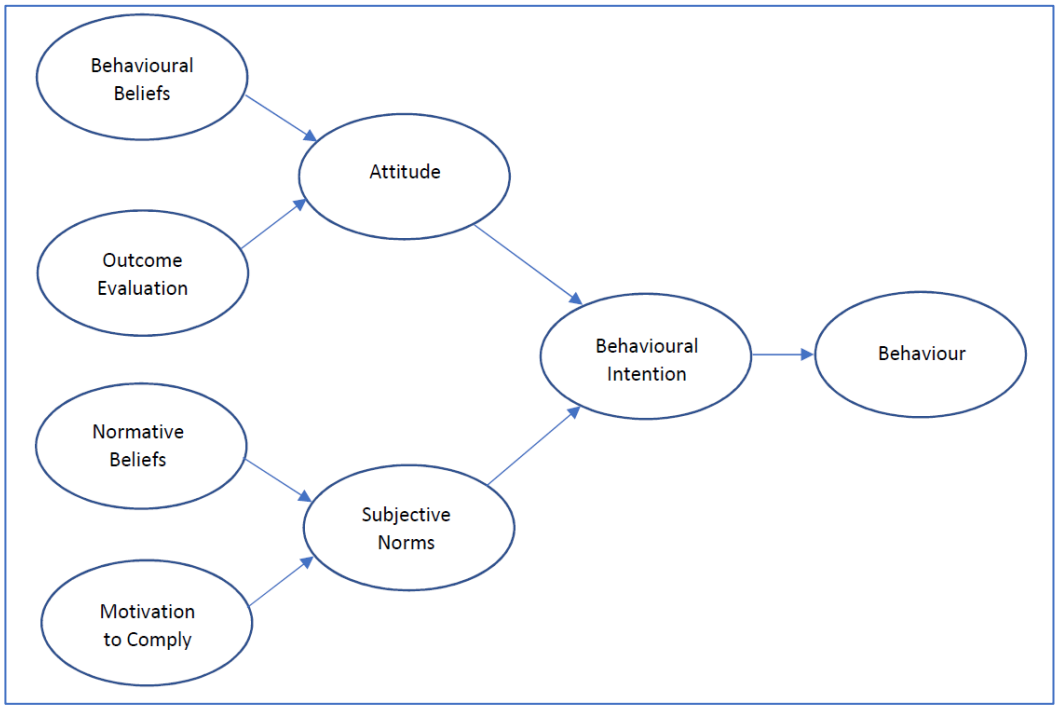

Figure 4: The Theory of Reasoned Action (Fishbein and Ajzen, 1975).

Despite proposing a recognisable set of antecedents that inform the behavioural characteristics of users when faced with the requirement to use new technology, a recognised weakness of the TRA is that it does not reflect an individual's ability to control their actions and behaviours. Such a limitation was addressed through the inclusion of perceived behavioural controls to reflect the differences that could exist between an individual's perceived and their actual behaviours, which is influenced by self-efficacy, reflecting the level of difficulty of the action, and controllability (the extent to which users feel they have control over their performance or whether it is constrained by external factors).

The subsequent development of the Theory of Planned Behaviour (TPB) sought to link individuals' beliefs with their perceived behaviours and to reflect how they, as users, respond to different situations. Proposed by Ajzen (1985), the TPB developed the TRA to reflect the influence on perceived behavioural control, proposing that, if the suggested behaviour is seen as positive and if they feel that significant others (e.g. colleagues or peers) will also want to

exhibit that behaviour, then this will result in a greater intention or motivation to perform that action (akin to a form of peer pressure). The influence of such perceived behavioural control may be influential in the context of this research and the nature in which Controllers engage with each other to discuss their different views as they construct their thoughts and position on innovations that affect how they perform their role. The TPB developed such concepts to reflect that, due to other circumstances, behavioural intentions do not always result in actual behaviour, in so far as there may be preventative constraints that influence the outcome and a desire to use the technology to achieve desired outcomes may be prevented by other factors (such as functional limitations or constraints placed upon its use). Figure 5 illustrates the relationship between the components within the TPB that combine to deliver actual behaviour.

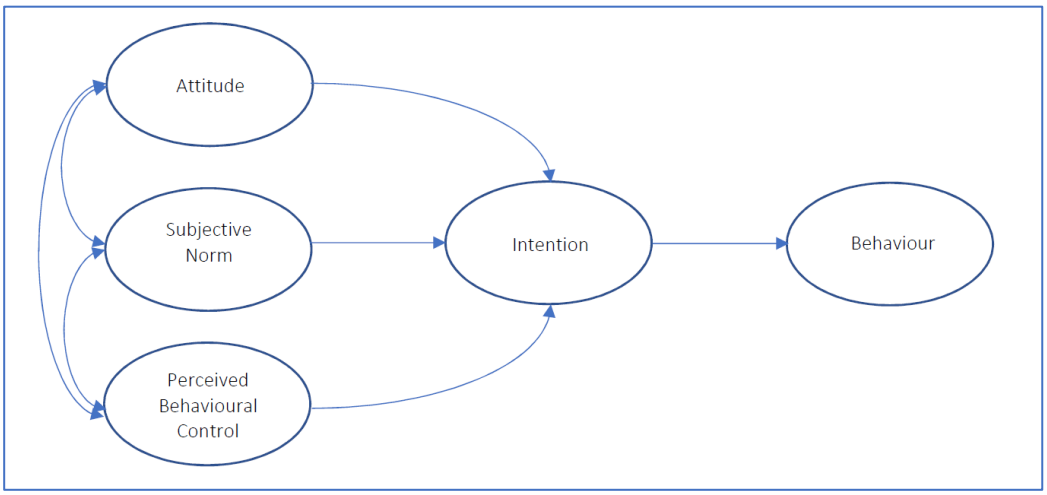

Figure 5: The Theory of Planned Behaviour (Ajzen, 1985).

The TPB has been used extensively within many sectors and service industries – such as healthcare, public relations, advertising – although a lesser body of literature provides evidence of its use directly within emerging technology considered in this research, which is better predicted using specific technology acceptance models discussed later. One of the merits of the TPB is that it covers non-volitional behaviour, which is not covered by the TRA, and that reflecting perception reflects any observed differences between actual and intended behaviours. Studies have suggested that it provides greater predictability when compared to TRA when applied to an individuals' health, such as the relationship with diet and exercise (Ajzen, 1989). Limitations of the TPB include the fact that it does not reflect the individual's

emotions at the point the decision is made and the variety of *a priori* situations that can influence the decisions made and how the behaviours become manifest. Another limitation is that it does not reflect the individual's *needs* before that decision is made and how that can influence the outcomes. The fundamental premise that behaviours and intents are informed by the three determinants - social norms; attitudes; and, perceived behavioural control – has also been challenged. Sussman and Gifford (2019) suggested that these determinants and peoples' intents are actual bi-directional (i.e. each influences the others) as opposed to being unidirectional as implied by the schematic used to summarise the model. It is therefore valuable to understand the relationship between an individual's belief and their behaviour when considering the implications of delivering change within organisations and reflect on any predispositions users and regulators may have to the type of technology that they will be required to use or certify. The establishment and development of technology acceptance models reflected how beliefs affected behaviour and could contribute to understanding Controllers' acceptance of the specific technical innovation explored in this research, with a particular focus on the recognised instances of the Technology Acceptance Model which have evolved to better model end-user acceptance.

Technology Acceptance Models

Models have been developed to predict users' ultimate willingness to engage in innovative technology and have sought to explain the variability between predicted and observed behaviours. The Technology Acceptance Model (TAM), in its various evolutionary forms, seeks to understand and predict how technology is used and will be accepted by new users. The TAM evolved from the widespread use of information technology systems to provide a framework of how users would adopt the new capabilities to innovate new concepts and ideas following the proliferation of personal computer systems within the workplace and the use of home computers. It links the actual system use to the users' behavioural intent, itself influenced by the users' attitudes and their general impression of the technology. The underlying concepts and framework which underpin TAM have evolved since its first instance to reflect a better understanding of how people's attitudes to technology have changed, in part influenced by changing demographics and socialising of technology, and how it has pervaded and influenced lifestyles and societal norms. Initially developed by Davis (1989), the TAM asserts that the extent to which users will adopt new technology depends on:

- How '*useful*' they perceive it to be – a perspective that reflects that users would be more attracted to understand how to use the new system if they could understand how it would achieve their goals or improve their performance at work (noting that in the timeframe when TAM was developed, access to new technology was substantially work-related and office-based); and,
- Its perceived '*ease of use*' – reflecting the amount of effort that would be required to achieve the required outcome once the users had been trained and were confident in their capabilities when using it.

The TAM evolved from the earlier formative work proposed by the TRA (Fishbein and Ajzen, 1975) by replacing the '*attitude*' dimension with two measures for the acceptance of technology – '*ease of use*' and '*usefulness*'. However both are underpinned by a behavioural assumption that users can develop the intention to act in an unconstrained manner, i.e. they are not fettered nor influenced by external variables, although in reality users do not operate or develop intents in a manner that is dissociated from the environment within which they find themselves (i.e. the intent to perform an action may not in itself actually lead to that action). Figure 6 illustrates the flow of behavioural constructs that deliver actual system use.

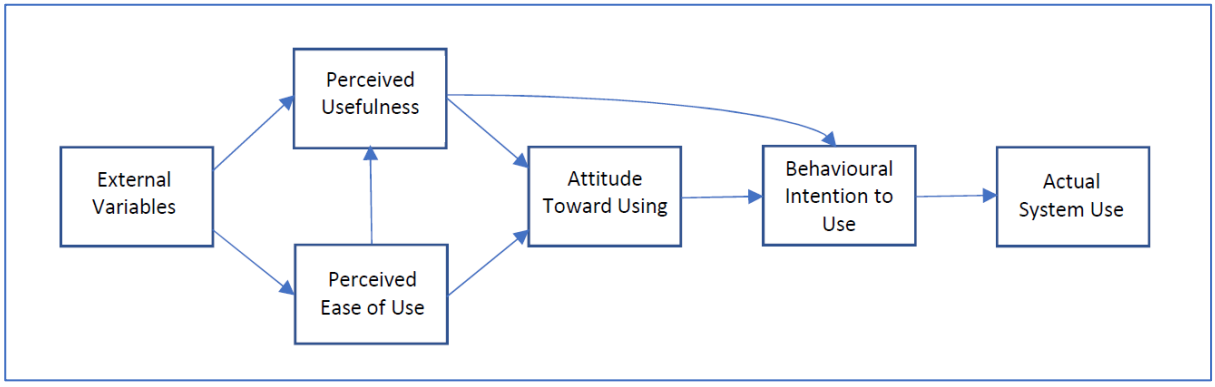

Figure 6: The First Modified Version of The Technology Acceptance Model (Davis, Bagozzi and Warshaw, 1989).

The final version of the original TAM (illustrated in Figure 7) was proposed by Venkatesh and Davis (1996) to reflect findings that both perceived usefulness and perceived ease of use were found to directly influence behavioural intention, thereby obviating the need for attitude.

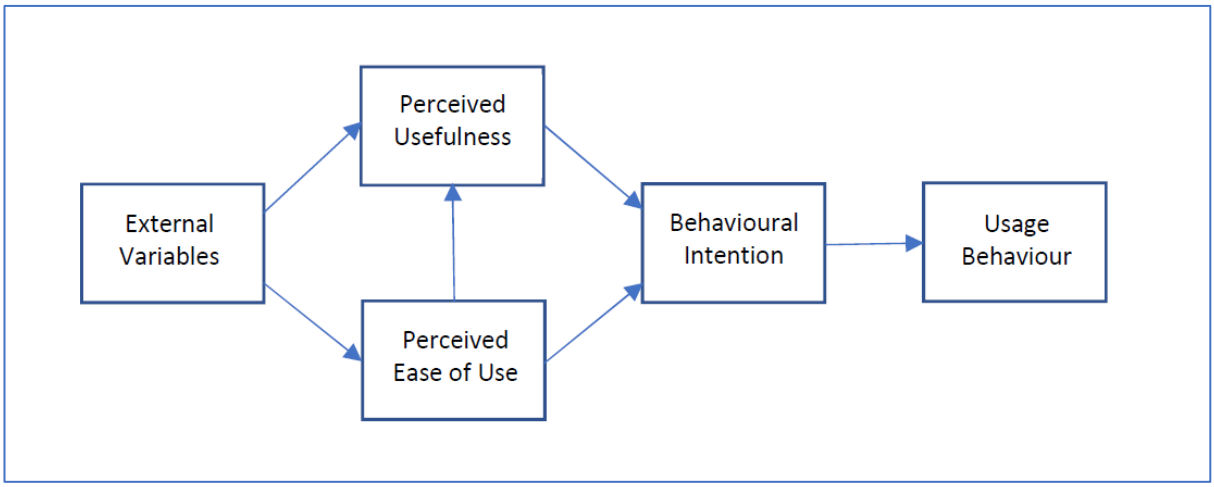

Figure 7: The Final Version of The Technology Acceptance Model (Venkatesh and Davis 1996).

Widespread use of technology over the 1990s in both work and home contexts, and the interest in how to better understand user engagement acceptance resulted in the need to provide greater fidelity to the input parameters, which resulted in the development of TAM2 (Venkatesh and Davis, 2000). TAM2 considers '*why*' users found a system to be useful at three points in time: pre-implementation; one month after implementation; and three months after implementation.

TAM2 reflects the viewpoint that a user's perspective that the relationship between important goals, and the consequences of performing tasks using the system, informs their perceptions on the usefulness of the system. Post analysis has shown that TAM2 provides a valid construct when systems are used in both mandatory (e.g. work) and voluntary (e.g. social or discretionary) situations.

Unified Theory of Acceptance and Use of Technology (UTAUT)

Further explanation of expected end-user acceptance is offered by The Unified Theory of Acceptance of Use of Technology (UTAUT) (Venkatesh et al, 2003), which seeks to explain users' intentions when using systems and how they use them (i.e. usage behaviour). UTAUT posits that four key factors exist that influence the users' intentions and behaviours: '*effort' 'expectancy'* (a measure of the level of input required); '*performance expectancy'* (the level outcome the user expects from the input required); the prevailing '*social influence'* (i.e. how individual behaviour is influenced by the environment); and, the *facilitating conditions* (i.e. the ability to adopt the desired course of action reflecting any barriers or preventative conditions).

The model proposes that age, experience, gender and voluntariness of use all influence the preceding four influencing factors. Venkatesh et al (2012) latterly developed UTAUT2 to reflect the value of 'consumer use' by supplementing the original independent variables with 'hedonic motivation', 'habit' and 'price value'. UTAUT2 retains age, gender and experience as input factors but no longer includes the influencing attribute 'voluntariness of use', in so far as the individual may have no discretion in whether the technology is to be used, which is more applicable in a work-related context. UTAUT2 is generally regarded as the latest model to explain and predict the extent to which users accept and are willing to use new technology when presented with that opportunity.

Reflecting on the context of my research, the preceding models would appear to be able to offer some insight into the various factors, attributes and characteristics that may influence whether Controllers accept the types of innovations expected within ATC. However, the future application of such models within ATC would have to reflect the nature of the role and the reality that the use of innovations is not optional and comes as an expected part of the role. In this respect, the earlier consideration of the psychological contract may provide some valuable mediating input to help develop Controller enrolment and engagement. A further aspect that may offer some constructive input is being aware of and sensitive to the feelings and reactions of users and empathising with the types of reactions that such changes may cause. The concept of designing new technology in a manner that reflects from the outset the potential influences on the end-users engagement may help to achieve their acceptance of innovations that may not naturally fit with existing perceptions and dispositions.

Designing with Empathy for the End-User

Alomary and Woollard (2015) suggest that end-user acceptance is also sensitive to how users are required to interact with systems at the point of use, known as the human-machine interface (HMI), and that being aware that positive or engaging interactions may help the users accept the innovation. Thus, whilst an engaging HMI is not in itself sufficient for user acceptance, one that dissuades users from engaging or requires a disproportionate amount of effort from the users' perspective will not facilitate the acceptance sought. Considering such potential outcomes early in the new systems or innovation's lifecycle will help designers identify those characteristics or attributes that will attract users and increase the chances of end-user acceptance. It is here that the concept of Design Thinking (Dorst, 2015) contributes

to the further development of acceptance models by developing attributes and characteristics that seek, from the outset, to innovate in a way that maximises the likelihood that the new technology will be both perceived as being 'useful' and perceived as 'being easy to use' (two aspects that form the basis of technology acceptance models discussed above). Design Thinking relates to the cognitive process by which design concepts are developed, including the innovation of new technology products and services (Dorst, 2015), and an awareness of such concepts may prove to be valuable when considering how to engage Controllers in the acceptance of future innovations which they may feel could challenge their role.

Such a concept can be valuable when seeking to address *wicked problems*, problems that cannot be sufficiently defined to ensure a solution can be developed from existing knowledge (Rittel and Webber, 1973; Buchanan, 1995). Engaging users to help develop solutions to wicked problems requires understanding their concerns and showing empathy to their situation and how they view the problem and innovative solutions (Kelly and Kelly, 2015). Such a situation can be seen in ATC, where business and performance outcomes sought cannot always be provided from existing technologies, and where competing stakeholders (such as management, designers and Controllers) come together as stakeholders to identify what may be possible. From previous observations of such situations, the extent of what may be possible is influenced by an awareness of what the outcomes on the stakeholder may be, such as changes to working conditions, with the extent to which the solution developed and how it is used being influenced by the varying levels of power held by the stakeholders and the extent to which both sides feel the developments remain within the changes considered acceptable by the psychological contract prevailing at that time. The aim is to develop an understanding of users' essential and desirable requirements, attributes and characteristics of the possible solution(s), seeking to understand the fears or concerns users may harbour in terms of how the solutions could challenge or threaten the status quo. When developing solutions to replace existing capabilities, users may be concerned that the replacement system will be harder to use or not be as beneficial in achieving the expected outcomes, with fears of a perceived reduction in engagement or productivity.

"Designerly Thinking" (Gasparini, 2015) proposes that developing and acting in a manner that empathises with those affected can lead to solutions that users are more willing to accept. Gasparini (2015) proposed two types of empathy – the emotional and the cognitive - to understand what a designer does in practice, setting out how five separate theoretical perspectives can lead to an understanding of the effects that empathy has on the design

process and how empathy is developed with those required to use the innovation developed (Table 5).

Empathetic design is thus broader than ergonomics and the discipline of Human Factors as it considers and uses as part of the development process the emotional and psychological needs of end-users, in effect trying to reflect their perspectives of the world as opposed to solely the designers', with linkages to reflective practice (Kolb, 1984; Schon, 1991), reflexivity (Archer, 2007) and the use of reflexivity as the practice of empathy (Katila and Merilainen, 2013). In this sense, the designer seeks to immerse themselves in the world of the user, not just from the perspective of how the system will be used, but how the users will truly engage with the purpose of the innovation to achieve the desired outcomes. Such actions are visible within the ATC community, where the views, feelings and engagement of the Controllers are apparent through the engagement of the wider user community by identifying influential individuals to present the collective requirements, views and constraints of the users. Such a type of engagement was adopted during the design phase of the innovation considered in this research, and as will be discussed later, formed one of the main influencing factors in its ultimate acceptance by the Controllers.

Theoretical Perspective	*Core Concept*	*Empathy*
Design and Designerly Thinking as the Creation of Artefacts	The science of the artificial	Emotional
Design and Designerly Thinking as a Reflexive Practice	Reflection in action	Cognitive and Emotional
Design and Designerly Thinking as a Problem-Solving Activity	Wicked problem	Cognitive (Holistic)
Design and Designerly Thinking as a Practice-Based Activity and Way of Making Sense of Things	Designerly ways of thinking	Cognitive (Constrained)
Design and Designerly Thinking as a Creation of Meaning	Creating meaning	Cognitive (Interpretation of context)

Table 4: Overview of Designerly Think and Empathy (Gasparini, 2015, p.3)

User-Centred Design

Understanding the value of empathy within user engagement also supports the concept of User-Centred Design (UCD), which seeks to understand and address users' essential and desirable requirements from the outset, intending to secure end-user acceptance of the solution ultimately delivered and outcomes achieved (Norman and Draper, 1986). The value is two-fold: not only does the solution provide a set of capabilities required to provide the service, it also develops a relationship with the end-user such that they feel their importance and value in the development process is recognised and accepted. Input is thus not solely physical, it is psychological, with the users feeling that they are making a valuable contribution to the activity and influencing the outcomes. The inclusion of end-users who fully understand their work context is a key determinant to successfully changing how end-users will engage with and react to the new system or interface (Winter, Rönkkö and Rissanen, 2014).

A limitation of UCD is the need for users to know the motives of the change and an awareness of the potential outcomes. If the users see these as a threat to a desire to maintain the status quo, it may influence their input such that the less desirable outcomes of the activity are not delivered, either at all to the extent that the outcomes can be fully realised. One of the unintended outcomes of adopting a UCD may be to strengthen or cement the position of the user and the centre of the design process thereby maintaining a high power of control and influence, whereas in reality better overall outcome could be secured by manoeuvring the users (e.g. the Controllers) to a slightly 'off-centred' position before opening such engagements. A knowledgeable and influential workforce will be able to engage in the concepts of UCD frameworks in a manner that reflects their intent to remain at the centre of the current and any future processes, with the extent to which such outcomes are achieved being influenced by the prevailing culture within the organisation and power balanced across the affected stakeholder groups.

For example, when developing a new ATC system, a UCD process may result in a greater level of engagement from Controllers to increase safety but at the expense of increasing productivity. Furthermore, those who see future automation and AI as a threat to their role (in terms of short-term value or longer-term security) may be tempted to provide input to the development of new capabilities and system which continues to require Controller input to deliver the performance outcomes required, thereby strengthening the level of power they hold in the relationship and thus increasing their leverage in future engagements and interactions. Such a situation is visible in NATS, although tempered by both management and Controllers seeking to achieve pragmatic outcomes acceptable to their stakeholder groups and which do not introduce risk nor reduce the resilience of the services provided.

Reflecting on the Theoretical Review

My reflections on the theoretical literature enabled me to conclude that relevant models and constructs may exist which may support and inform the direction of my research. Significant work in the field of technology acceptance is documented, covering its use in a work context where users are obliged to accept and use new technology, and in separate contexts such as social and entertainment where users have more discretion about the levels of use and acceptance. Within the work context considered in my research, the picture that has emerged sees trust and appropriate engagement on the end-users in the change as being influential in

securing users' ultimate acceptance. However, merely accepting the new technology can be considered as the first step enroute to its beneficial use. Hidden value and innovative use only come when the users have not just accepted the innovation but have truly embraced it and can see ways of using and further enhancing it which could not have been envisaged when the concept was initially considered, or if they were, were considered so ambitious and revolutionary that the thoughts would not have been able to secure any meaningful engagement of the end-users.

The findings and future direction informed by the literature can be readily applied to future developments of the ATC system and the future engagement of Controllers. The types of issues and challenges discussed when seeking to secure user acceptance apply to Controllers. How Controllers have been engaged in such types of technical & revolutionary developments and the outcomes observed are explored further within my review to see whether any specific engagement strategies can be observed and inferences of the success of the initiatives inferred. Thus in trying to see how to win the 'hearts and minds' of Controllers, concepts which seek to engage them in the developments of new systems which could be seen by them as changing how they discharge their role, the concepts of UCD and Empathic Design would appear to offer some relevant avenues to be aware of.

2.2 Empirical Literature Review

Studies into the influence and acceptance of innovative technology which Controllers are required to use to perform their role are not as extensively reported as innovative and technical change more generally within the workplace, such as business IT systems. The tasking is niche and only recently has the level of technology maturity enabled their use in the safety-related domain of ATC. Such innovations also can be commercially sensitive, and ATC providers are not as willing as organisations within other sectors to publicise or report the types of technology used, their plans for more widespread use, nor are many willing to share research into past failures in public forums. As such, there is more research into probable reasons for successful outcomes than failures.

Empirical research has found that Controllers are very selective about the types and levels of computer assistance they are prepared to accept despite its use being mandatory (Eurocontrol, 2000). As the accuracy of the support systems decreases and Controllers start to detect errors, their trust in and acceptance of the system dramatically reduces (Ruff,

Narayanan and Draper, 2002). Furthermore, as the level of automation increases, Controller performance deteriorates (Ruff et al, 2002; Wickens, Mavor and McGee, 1997; Wiener, 1988), resulting from the Controllers not being 'in the zone' and not being sufficiently focused on discharging the tasking to maintain the level of concentration required, nor being able to react as would otherwise be the case under system failures or abnormal situations. Research has demonstrated that trust in automation and job satisfaction are significant predictors in user acceptance (Muir and Moray, 1996; Lee and See, 2004; Hopkin, 1991; Lee, Rhee and Dunham, 2009). Similar findings have been found within the ATC domain (Bekier, Molesworth and Williamson, 2011), along with Controllers' age and experience. However, such predictors only offer partial explanations for the more general acceptance by Controllers of automation. Bekier et al (2011) recognised that traditional predictors of acceptance such as trust and job satisfaction only explained a small proportion of Controllers willingness to accept automation and sought to examine whether any additional predictors may exist. Their analysis found that Controllers would accept automation that supports their core tasks and which they find easy to use (with the attribute 'easy' needing to be set within the context of performing a difficult task). However, automation that was deemed distracting, not user-friendly and distracted them for their core tasks was not liked. Bekier et al (2011) concluded that ATC providers needed to be sensitive and selective of the various activities and core tasks that Controllers perform, with Controllers more likely to accept technology that automated those aspects of the job they find 'boring' and 'standardised' (Bekier et al, 2011, p.618). Innovations that automate part of the role should ensure that the Controllers remain cognitively engaged in the task to remain alert and able to react to unexpected circumstances. Finally, the automation needed to be well designed from a usability perspective and reliable to help develop trust, findings that align with the concept of UCD previously and the influencing factors proposed by the technology acceptance models discussed earlier.

Other research on Controller acceptance has considered how automation influences a Controller's psychological model, seeking to deconstruct the numerous thought processes and actions that define the functional structure of their developed cognitive system. One of the key functions identified and which could be disturbed by changes to the systems used to help them develop their mental model is Situational Awareness (Endsley, 1995), comprising perception, comprehension and projection. The reference model proposed by Histon and Hansman (2008) presented in Figure 8 sets out the inter-related nature of the various aspects of the tasking.

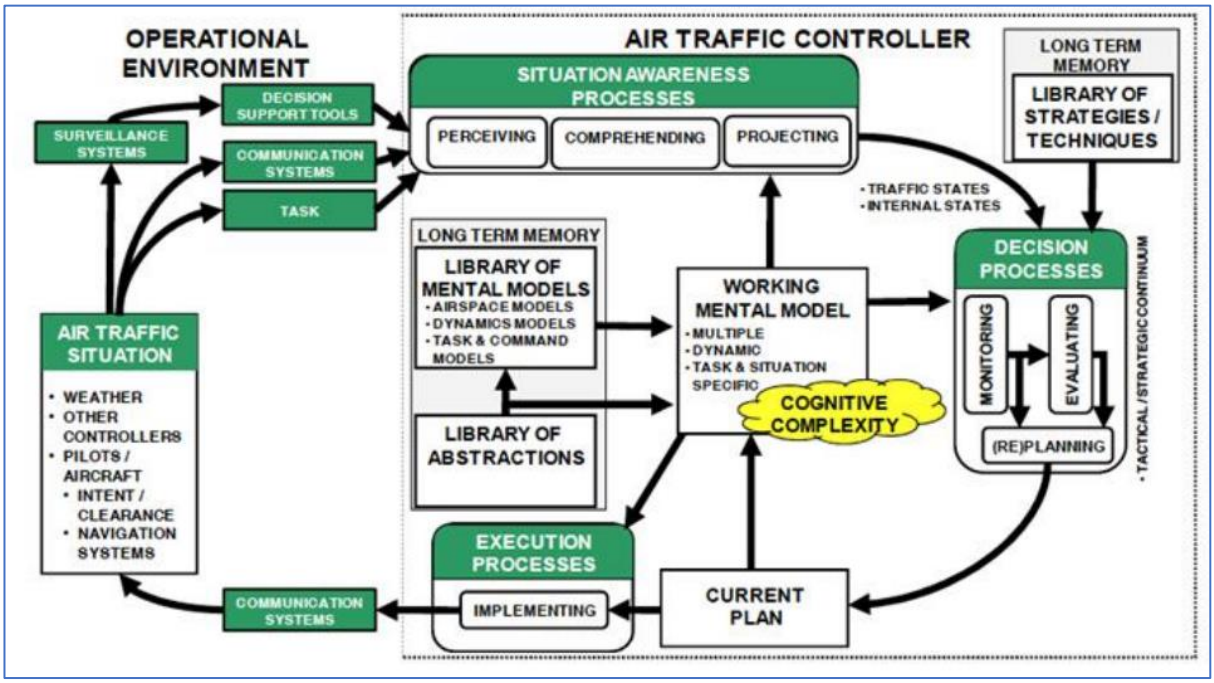

Figure 8: Functional Structure for the Controller's Cognitive System (Histon and Hansman, 2008)

The information the Controller receives from the awareness of the traffic situation is processed by using previous situations stored in the Controller's memory after experiencing and learning from previous situations, thereby enabling the Controller to understand the current situation being observed. The Controller then mentally projects into the future (by a few minutes) to predict how the traffic situation will evolve if no action is taken, and then make decisions about what actions to perform to correctly perform the task of changing the traffic situation.

This is a continuous process from which the Controller can become confident that they have developed an accurate mental model from which to continually base new decisions. Being fully aware of the traffic situation is thus a vital aspect of being able to safely and effectively perform the role – any dilution of this that may arise from sharing this with an automated system may reduce the Controller belief and trust in their own cognitive model of the situation.

The cognitive process associated with the tasks performed by Controllers can be classified as three processes: Situational Awareness (comprising perceiving, comprehending and projecting information), Decision Making and Execution (of an action or instruction). Any developments

that seek to automate any part of that cognitive chain may result in Controllers becoming wary of the trust they already place in the systems used and may result in dissonance if the information developed by the system and presented to them does not align with that which they might have arrived at themselves. Furthermore, exercising all aspects of the cognitive process enables Controllers to remain focused and sensitive to aspects of the traffic patterns which are not emerging as expected, with a concern that sharing responsibility for some aspects with the system may result in disengaging from other parts.

There is also a concern that the more motivating and stimulating aspects of the role may be those aspects that are transferred to the system, features which help counter the more mundane and less attractive aspects, such as monitoring for any aircraft non-conformances, thereby leaving the Controllers only the more mandate aspects of the role. Changes to the role that may result from automating the more challenging aspects might make it easier to train others to perform the function, potentially resulting in a greater number of people able to perform the role and thus disturbing the power balances that generally exist across the sector and are particularly visible in NATS (as discussed previously in section 1.4).

Further research has concluded that the use of automation to support Controllers can experience performance issues from not being fully included in the decision-making process, known as the Out-Of-The-Loop (OOTL) phenomenon, manifest through a lack of attention, loss of situational awareness and deskilling (Kaber and Endsley, 1997). Further automation is expected to increase the distance between the Controllers and the "loop of control" (Di Flumeri et al, 2019, p.3) resulting in Controllers feeling disconnected from the systems they use and rely upon. Understanding the causes and sources of the difficulties in the interactions with the system and exploring whether solutions could exist to avoid or mitigate adverse outcomes is valuable to management, designers and Controllers alike. Recognising the reasons and possible outcomes of Controllers being OOLT, Di Flumeri et al (2019) proposed the concept of Adaptive Automation (AA), whereby the system can adapt its behaviour to the needs and state of the Controller in real-time, based upon its perception of the level of the Controllers interest and engagement being observed. If the system detects that the Controller's level of engagement is declining, it allocates more tasks to maintain a level of interest required to ensure the Controller is kept 'in the zone' of engagement. If the Controller starts to become overloaded or starts to show signs of fatigue, detected through delayed reaction times of suspicious judgements or instruction, then the system will adjust the level of

interaction to assume a greater level of input to reduce the Controller's workload to achieve a more suitable level of interaction required.

Thus, the Level of Automation provided by the specific innovation used is not a fixed and static point, but rather can flex to ensure that the combined contribution of the Controller and the system is maintained at an acceptable level and where the Controller remains sufficiently exercised to retain focus, but without being overworked and experiencing mental fatigue. Thus, the concept of AA would be able to counteract the risk of the Controller being OOTL by modulation their workload to keep that at a safe and efficient level of engagement (Kaber and Endsley, 1997).

The ability to ensure that the Controller remains in the loop and continues to be stimulated and engaged in the activities required may provide some positive steps in seeking to address the issues hitherto experienced and which have led to Controller not accepting technology that seeks to automate their function. Ongoing research is exploring the use of electroencephalography, eye-tracking and near-infrared spectroscopy to continually monitor Controller awareness, drowsiness, stress and performance effectiveness to allow the AA to decide which activities to allocate to the Controller and which to retain and perform itself (Di Flumeri et al, 2019).

Reflecting on the Empirical Review

In summary, empirical studies into Controller acceptance of innovative technology to automate some of the core tasks point to contributory factors: role satisfaction; the sense of being 'in control' and not being expected to operate 'Out of the Loop'; reliability of the supporting system; and, credibility all being identified as aspects or attributes that support Controller acceptance. Of interest, none of the empirical evidence identified 'trust' as a contributory factor within the context of ATC despite it being identified as a relevant factor within the wider set of constructs and models critiqued earlier. If such a finding is valid, and whilst this would need to be explored separately, it could be that within ATC, trust in the systems provided is a given, and provided by Controllers more readily than trust in the motives for its use (i.e. trust in the technology but lesser trust in the reasons why management want it deployed). The concept of AA, whereby the ATC system can modulate the Level of Automation to keep the Controllers sufficiently engaged yet at the same time identify initial signs of reduction in concentration and fatigue, may provide future opportunities to contribute to

Controller acceptance as they may feel that as well as being a valuable safeguard, the level of automation will not be a *de facto* constant, but may be able to reflect the amount of support required.

2.3 The Opportunity to Make a Contribution

Both the theoretical and empirical literature considers a variety of models, theories and constructs which can help inform the influences that innovative change could have within a workplace setting and which can be expected to influence end-user acceptance. Common aspects that are evident from the literature when considering technical change are usability, trust and resistance. More specifically with the ATC sector, innovations which support the Controllers' role are more likely to be accepted if technologies enable them to focus more on those core tasks they enjoy and find stimulating (such as using all available information, training and experience to identify and deliver safe and efficient instructions to aircraft) by only automating those aspects of the role they find more mundane, and which are seen as peripheral or distracting. End-user engagement in the development of the new system to enable the feeling of a sense of ownership in the capabilities of the new technology through recognised concepts of UCD and, more recently, Empathetic Design is recognised as being valuable in achieving ultimate acceptance. The literature also points to potential consequences of such types of developments and the changes these could have on peoples' future roles, pointing to the emotional aspects of the changes, as those affected seek to internalise how the changes could have outcomes that are less immediate than simply a change in how they interact with a more capable system.

Furthermore, as well as being guided by the most recent journal articles reporting relevant research, it was valuable to understand the current topics being researched and the overall direction of travel and aspects currently being researched within this dynamic field. Thus, in addition to valuable input from my supervisors, my literature review also identified and engaged several Thought Leaders at other UK academic institutions who were able to share with me (in parallel with my literature review) the type of issues currently being explored. The main threads which were identified from this aspect of the review are summarized in Appendix 1. These conversations confirmed that understanding aspects such as trust, resistance and engagement when delivering innovative functional change are valid and topical, thereby

informing my thoughts on which of the recent changes within NATS that have affected the Controllers offers the most value for my research.

However, the types of change management and technology acceptance models identified in the literature do not fully cover the situation being researched and which will become more prevalent with the ATC sector, i.e. a specific instance of the use of technology to part automate a core aspect of a Controller's role, specifically the safe separation of aircraft in the final stage of the landing phase. Although the concepts proposed by the Change Curve (Kubler-Ross, 1969) and Transition Model (Bridges, 1991) may offer some valuable insights into possible influences on Controllers and the emotions they may experience when engaged in delivering technology-driven innovations, they do not appear to always cover the various influences and feelings which ultimately inform end-user acceptance. None of the Technology Acceptance Models considered appears to provide a level of coverage of the issues that may sufficiently inform Controllers' acceptance of the innovative change being considered within the ATC domain. As such, this research seeks to contribute to the field by exploring how a specific instance of technical innovation was accepted by Controllers and successfully deployed with the safety-related ATC operation. Whilst the engagement of other roles and skillsets will also be required, this research is focused on the Controller community as this is the most unionised and powerful within the organisation, and therefore the group whose support will be most critical to success.

In doing so, the research is not to seek to develop any deterministic model or solution that management or developers can use to increase the likelihood of success, nor does it aim to identify which of the existing change models or technology acceptance models might offer the 'best fit' for a particular project or investment to adopt. Rather, it seeks to infer from a recent example of a successful innovation the types of outcomes that may result when technical change is developed and applied in the manner observed. This research seeks to contribute to the field by exploring the outcomes from a recent and innovative development from the perspectives of a niche and skilled Controller workforce to provide knowledge to the wider discourses that exist within the field of technology acceptance, whilst recognising the specific cultural and power relationships that exist within the organisation between management and the Controllers.

3. Research Approach & Strategy

The research approach I adopted reflected how I would develop knowledge from the information gathered through seeking to understand the Controllers' experiences of the change. In doing so, I adopted a qualitative research strategy which allowed me to develop knowledge from my interpretations of the change they experienced. As well as being clear in my mind about the specific type of phenomenon I sought to investigate, I needed to fully understand myself as a person and how that could influence me when undertaking this research, as that would point me to a research strategy that was consistent with how I view the world and how I develop knowledge and understanding. How I approached my research reflected on who I am as a person, how I understand and develop knowledge and what assumptions I may have made to help me believe that the truth-stories I have developed are valid. I can recognise my philosophy here as aligning with post-modernism, seeing me reject the existence of a meta-narrative or grand theory, and believe that what we experience and observe in the world is socially constructed by myself and others. As such, I do not believe in absolute positions, rather I rationalise and try to understand what I observe and experience in relative terms which are set within a context that is itself developed by others. I do not believe that there is any single truth or a single unifying theory that can explain what I observe; rather I believe in various truth-stories, with others' belief in their truth informed by their own life experiences and ontologies. As such, I focus on the meaning that others ascribe to events, situations and outcomes, seeking to understand what is happening and using my own understandings and experiences to make sense of what I observe and experience. As such, I see myself as a relativist with thoughts, perceptions and inferences aligned to subjectivity, as opposed to being a realist with an espoused objectivity. Being who I am, the philosophy I hold and my interactions with the world influences how I develop knowledge and thus how I approached my research. This influences how I act and behave as a researcher and remaining true to my underlying feelings helps me rationalise the decisions and choices I make and how I relate to the validity of my findings. Such realities informed and influenced how I developed my research strategy and informed subsequent choices I made when conformed with options.

3.1 Justifying the Innovation Selected

The preceding literature review critiqued various aspects of the acceptance of new technology within the workplace, where its use is obligatory and where the extent to which end-users are willing to embrace the new capabilities to unexpected positive outcomes. Previous instances of change in NATS have shown that willing users tend to be more innovative in identifying and achieving unexpected outcomes than those not so engaged in the systems and capabilities. There are various ways to explore how such types of change can influence peoples' roles within an organisation and any change they may perceive it could make to the visibility of their contribution. The focus of my research was to understand how a small subset of the Controller community in NATS was engaged to deliver a new system (explained below) which changed the way a specific aspect of their role is performed and which was the first to blur the cognitive boundary between the Controllers and the systems they use. This change was the first that started to move the boundary of intelligence and decision making from solely the Controller to a combination of both the Controller and the system working together, and as such was seen as the first step towards greater automation within ATC.

The topic explored within this research related to a specific change on how a particular aspect of ATC is undertaken and which required the Controllers affected to place a greater level of trust in the integrity of information automatically determined by a new system. The innovation – called Time Based Separation - was deployed after extensive research and development of the potential safety implications of such a change. The first instance of this capability was deployed in 2015 at the Swanwick Air Traffic Control Centre to support Controllers provide the Heathrow 'Final Approach'[1] function; it was the first of its kind to be deployed globally within the ATC Sector. There were no earlier deployments nor use of the technology developed, nor had any research been undertaken on how the Controllers affected had responded to its deployment within the ATC service delivery chain.

The innovation was selected for this research as it provided the following unique aspects within the overall development of the NATS ATC system:

[1] Final Approach is that phase of flight that precedes landing and requires the Controllers to establish a continuous stream of aircraft, safely spaced behind each other to maximise runway capacity. It is a complex and intense activity that requires honed skills and experience, especially during peak periods, when controllers are establishing a stream that supports a landing rate of up to 45 aircraft per hour at Heathrow.

- It provided the first instance of the use of an automated support system within NATS that changed the boundary between the Controller and ATC system used, whereby the innovation provided a greater level of input to the overall delivery of the service, whilst not changing the accountability for safe and efficient service delivery, which remained with the Controller.
- It changed the Controllers thought processes from they alone developing a mental picture of a safe and efficient arrival stream by presenting a system-generated indication on their radar display of the optimal place within the landing flow, to which the Controller would manoeuvre the aircraft. In doing so, it removed one of the more motivating, engaging and satisfying aspects of the role, and one which provided Controllers with a sense of satisfaction and achievement.
- It started to deconstruct the Controllers' cognitive processes when delivering the service to provide real-time input, considered to be one of the first steps to automate the tasks provided by Controllers.
- It provided, for the first time, information of the actions of the Controllers that could be seen as being able to be used to assess the safety, efficiency and competence of the Controllers in how they performed the task, even though that was not the intention. By being able to see and record how effective Controllers are in positioning the aircraft to the system-generated moving marker the information stored could be used to see how competent the Controllers are to deliver both a safe and efficient service. Whilst NATS uses extensive automated real-time safety nets to maintain safety standards, this was the first system that a system could be used to also develop a measure of competence and effectiveness in terms of fully utilising (limited) runway capacity available at Heathrow.

Trying to understand the influences and possible outcomes that such an innovation could have on Controllers and inferring how they responded to such a development may contribute to NATS developing a better understanding of how Controllers may react when faced with such types of innovations, and automation in particular. However, in doing so, there was no intent to generalise the findings or to propose that other Controllers would respond similarly if they were required to use the new system. It did not seek to formulate a method or propose a solution to increase the likelihood of success of the deployment of similar types of innovations that may further change the Controllers' role. Nor did my research seek to develop some form of 'recipe for success' that may be able to be used when the concept is deployed at other

airports. Rather, it set out to infer knowledge from seeking to understand the Controller's thoughts and feelings as they experienced a type of change which has been made possible by more recent advances in technology and from which Controllers may be able to infer how their role will evolve in the future.

The phenomenon explored in this research was the change experienced by the Controllers in how they interacted with the system and how that changed the development of their cognitive situational awareness model. This resulted in a material change to the Controllers thought processes and how they viewed the systems used to support them and, as inferred by the literature review, may generate some reactions. Being obliged to use automated system support to replace such a challenging, yet satisfying, aspect of the function was a significant change to the Controllers' role. I wanted to listen to their thoughts on this; how they felt about it and how they reacted.

Providing the service in the new way required (i.e. used the concept of aircraft being separated by *time* as opposed to by *distance*) required Controllers to think and operate in a manner that ran counter to their previous training and experience. This presented a unique challenge in terms of the acceptance of both the maturity and integrity of the system that would be used and the motives for its development. Whilst aimed at improving service delivery, it could have been viewed as a way to continually assess their capabilities and performance. It would also change the relationship between the Controllers and the system and start to blur the boundaries of accountability and could point to issues of trust, reliance and acceptance.

3.2 The Research Approach Adopted

Developing Knowledge

The approach I adopted was strongly influenced by my understanding of how I develop knowledge and how I try to assure myself that it is valid. Although coming from an engineering background, later phases of my career resulted in greater staff management responsibilities and the need to develop softer skills when managing and interacting with others. Now towards the end of my career, I recognise myself as an epistemological subjectivist, whereby the only way I feel I can know about the social world is through the meanings that other people give to their world. I do not believe that there is a single truth out there to be uncovered or discovered, nor that there is a grand theory that I can seek to understand that provides me with absolute answers to those things I choose to explore and understand. I am not a distant and unaffected observer, seeing things from afar, nor do I believe that knowledge can be developed through neutral observation of the social world and the behaviour of social phenomena. Rather, what I perceive is influenced by me and my conceptual understanding of the world that I bring to bear in order to help make sense of what I have observed. However, as I explain later in my Personal Reflexive Statement (Chapter 10), this has not always been the case. My early life, education and roles within engineering resulted in me being more aligned to objective than subjective philosophies, with activities being more aligned to using quantitative methods. However, as my career developed and I interacted with others to seek to understand the more subjective aspects of human interactions both within work and social settings, I began to understand that the type of knowledge I sought could not be developed from being detached from the phenomenon I was observing as my interpretations of the situations were in part informed by my own lived experiences. Being aware of this informed me what theoretical perspective, research approach and methodologies, and data collection methods were valid to explore, and which were not appropriate and would question the validity of my findings.

The research strategy I adopted, and the choices made at key decision points, are explained and justified to help others understand the specific path I chose to understand and analyse the data gathered. Some avenues I followed were natural consequences of a subjective epistemology, such as adopting a qualitative interpretivist theoretical perspective and an inductive research approach. Others came from reflecting on the options open to me at each

decision point, such as what particular method to select to gather the data and what data analysis method to adopt.

Research Strategy Adopted

In seeking to explore and interpret the views of those Controllers who had experienced the change, I sought to try to stand in their shoes and immerse myself in whatever feeling and emotions that experiencing such a change may have occurred. I felt that engaging with the Controllers in a way where I could use my own experiences of change where the outcomes are uncertain would enable me to interpret their thoughts and allow me to induce knowledge in a manner that I could relate to. In doing so, I was also aware that how the Controllers experienced the change would be influenced by many factors, some common across the group such as training and education, and some specific to them informed by their own previous work and life experiences. I felt that each would have their own story to tell, and whilst unique to them, I may be able to induce some themes that pointed to shared and lived experiences.

An inductive philosophy and an interpretive methodology would allow me to explore the types of issues that would be valuable for me to understand and to develop knowledge for others (i.e. managers in NATS) to consider and use as they felt appropriate when developing further innovations that would change the Controllers' role.

Adopting an inductive philosophy to elicit the type of information sought is consistent with the literature on data collection and analysis (e.g. Smith, Flowers and Larking, 2009; Stokes, 2011; Peregrine and Yanow, 2012; Stokes and Wall, 2014; Gray, 2018) which identifies the value of being able to develop a richer picture of views through direct engagement and personal interactions with those affected.

3.3 The Validity of Adopting an Interpretive Theoretical Perspective

A key strength of adopting an interpretive theoretical perspective and an inductive research approach is that it naturally lends itself to being contextual, where information can be gathered in a real-life setting and an understandable and describable context, attributes and facets described by Bazeley (2013) as being intense, engaging, challenging, contextualised and highly variable. One of the aims of my research was to problematise the situations being explained in the specific example used and to identify and discuss any hidden realities that may only be identified through a direct engagement with Controllers. A qualitative approach can also be valuable when relatively little is known about the outcomes or phenomenon being investigated and thus provides an opportunity to ensure that all possible variables and antecedents are considered from the outset when considering the subsequent method, or to gain new views to build upon an initial understanding (Strauss and Corbin, 1998). Such characteristics can provide valuable insights when individuals are experiencing innovative functional change and where acceptance could be reached across the affected community at different rates.

Adopting a qualitative research method placed some important requirements upon me as the researcher which were valuable to understand and address throughout the research to ensure that the findings and conclusions can be asserted as being robust and valid. Bigby (2015) identifies some key issues that I reflected upon as I sought to understand the perspective being adopted and to help inform choices that I would subsequently need to make when considering possible methods to gather the data:

- An awareness of the theoretical position and philosophy ahead of developing the method, undertaking the fieldwork and analysing the findings to ensure that a coherent and valid approach across epistemology, research philosophy and method are adopted.
- Being sensitive to how the researcher will influence the research, as explained further in 'Influence of Self' and my reflexive thoughts.
- Being aware of and recording any changes to the design and application of the research method.
- Detailing how the information is collected.
- Capturing any material and relevant characteristics of participants (such as gender, experience and core skills).

Adopting a rigorous approach to understand the strengths and limitations of adopting a qualitative approach throughout the research helps support my argument that the methodology (and subsequent method and analysis) is robust and that the findings are conclusion are valid with the confines of the research and the context within which it is set.

However, whilst recognised as valid and valuable when used within an appropriate epistemological perspective (Stokes and Wall, 2015; Gray, 2018), an interpretive theoretical perspective and inductive research philosophy can be subject to various biases which, if left unmitigated or not recognised, may limit the value of the findings induced and conclusions reached. Confirmation bias arises when the researcher searches for or favours information in a certain way to support personal beliefs or views held before undertaking the research or gathering information (Plous, 1993). Unchecked, it has the potential for the research to be constructed and undertaken in a manner that simply seeks to confirm initial thoughts and views, with the researcher being selective in their hearing and understanding of those aspects of the information which support existing views, with the risk of creating their own subjective reality. Ambiguous information could be selectively misinterpreted through unconscious bias, as the researcher tries to 'read in' something that isn't there or maybe selective in their recall of information, being able to remember better information that fits with the researchers own mental model or suppositions already predeveloped (akin to selective hearing). A further risk comes from availability bias (or availability heuristic) where the researcher overly depends and reflects upon information that comes to mind or can be readily recalled, a misplaced view that if it can be recalled then it must be important to the matter being considered (Esgate and Groome, 2005). Such a bias can influence information gathered over time where more recent events or information can be recalled better than information gathered earlier in the process, such as when interviews occur over extended periods. Adopting an interpretive theoretical perspective required me as the researcher to be aware of such biases and how these could influence the validity of my findings, which I sought to understand and mitigate, but in a manner that did not prevent me from engaging with the Controllers to the fullest extent possible.

One of the influencing factors that I needed to be aware of when considering the implications of adopting an interpretive approach was how it could affect my thinking and approach to the research, and what influence that I, as the researcher, could have on the subsequent method adopted. Being reflexive in all aspects of my research is one of the key aspects of adopting the interpretive approach – it is me who is doing the interpreting and I need to be aware of the

influences I bring to bear on how I do this and the outcomes if could have. My research is underpinned by how I 'interpret the interpretations' of those who experienced the change (Alvesson and Skoldberg, 2017). How I do this will influence how I develop my knowledge from this research and how I convey it to others, who themselves will interpret my thoughts to inform theirs

It was thus vital that I reflected upon and considered how to address my pre-conceptions and potential biases relating to the research, rationalising my thoughts and motivations from the outset to ensure that I was aware and understood the potential influence these could have on the validity of the research. This was particularly important for the innovation selected as I was aware of the drivers for the change that had precipitated the innovation and had some relevant insights into the potential consequences on the roles of the users that the new technology had delivered, although I was not part of the project itself nor affected by the outcome. My reflexive thoughts when considering how to undertake the data gathering centred around what I considered to be my predispositions of how individuals react to change, the various forms of resistance that can frustrate or hinder change initiatives and the successes (and failures) of technical innovation within my organisation. I was also aware of the prevailing power discourses that frame the current industrial relations environment and that the relationship between the Controller community and management can be strained at times, manifest by Controllers' general wariness and suspicion of how they feel management perceive the value of their role.

My focus was to gather information on the various factors that facilitate or frustrate change in a manner that did not bias the information and subsequent analysis by developing a strategy that did not seek to give greater weight or credibility to those aspects of evidence or anecdotes that would support any previous beliefs or feelings that I may have harboured at the outset. Further explanation of how I assert I achieved this and justification for the various choices made are set out in Chapter 4 (Data Collection and Analysis).

4. Data Collection and Analysis

4.1 Ethical Considerations and Safeguards

Ethical approval for the research, including the research philosophy and method was obtained by the approving body (The University of Winchester) through approval of the Research Knowledge Exchange – Fast Track Review process. The basis on which the approval was provided did not change since it was granted and therefore remained valid throughout the research. The research was undertaken in a manner that is responsible and morally defensible and adhered to the latest ethical standards of the University (University of Winchester, 2015a and 2015b). The approach adopted sought to address the following main areas which underpin ethical research (Gray, 2018): avoiding harm to participants; securing informed consent; respecting privacy; and, avoiding the use of deception. As will be justified later, the data was in part gathered included the use of face-to-face, semi-structured interviews, informed by the following ethical considerations and safeguards.

Avoiding Harm to Participants

Going wider than just the physical aspect, the risk of harm also covers emotional aspects which may result from any distress or concerns at having to think about and discuss difficult, distressing or embarrassing issues (Sudman, 1998). Whilst the matters being researched were considered to be factual and all the participants were all considered to be both physically and mentally fit and resilient, the method used nevertheless reflected the possibility that some participants may have had better experiences and outcomes thannor reasons others, particularly is how well they experienced the change and how long they took to become competent in using the new capability. As such, participation in the research was voluntary and the interviews were performed in a manner that enabled me to detect any signs of distress and concerns, with areas of discussion being able to be changed or even the interview terminated at any point if any signs of distress were suspected or observed.

Informed Consent

Each interviewee was provided with sufficient and accessible information to make an informed decision as to whether to participate or not, with scope and coverage informed by Crow et al (2006). The interviewee was made aware of the purpose of the research, how the information would be collected and that their participation was voluntary, and that they were able to withdraw from the research at any point without being expected to provide any justification or

reasons. My background, my role within the organisation, and the motives of my research were provided to potential participants before the interview with the intent of providing sufficient information to allow informed consent to be provided. These were repeated and the ethical approach being adopted was explained before the interview started. The interviewee was asked to provide written consent by signing the Ethics Statement, which was then countersigned by myself as the interviewer and retained.

Respecting Privacy

Assurances were provided that the interviewee would be and remain anonymous at all times. Anonymity was assured with no statement, inference or opinion provided by the interviewee during the interview being attributable to any particular interviewee. Interviewees were asked permission to digitally record the interview to enable the matters raised to be transcribed. Only the interviewee would see the transcription of their interview, provided with a request for its subsequent use solely for the analysis. The interviewee would be able to redact any part of their transcript without justification. Only once written approval was provided to use the transcript it was eligible for subsequent analysis. During the data analysis, individual interviewees were allocated a unique identity number (ID) to allow the quotations used to be allocated to a particular individual to allow any commonality of thoughts to be seen. The transcript of an example interview is presented in Appendix 5.

No Deception

At no time during this research have any of the participants nor senior managers from my sponsoring employer been deceived regarding my motivation for undertaking this research nor how the information, findings and recommendations will be used. All participants were assured that the information gathered would be used solely for the purpose intended and as explained. To address all of these safeguards, all those interviewed had previously been provided with the Participants Information Sheet (Appendix 3) and provided with a Participant Research Ethics Statement (Appendix 4) which was signed by myself as the researcher and by the participant; an electronic copy of the signed Statement was provided along with the transcription of the interview for their retention. As well as enabling an ethical perspective to be observed and recorded, providing such assurances and providing anonymity supported enabled the participants can be more candid about their feelings and emotions generated by the change, thereby providing a richer picture for the analysis and strengthening the robustness of the overall research.

4.2 Identifying and Selecting Valid Data Collection Methods

The type and form of the data required are informed by the research methodology, itself influenced by the research approach (i.e. inductive). I selected phenomenological methodology to achieve this. It was clear in my mind that the phenomenon being considered was the change in the Controllers' thought process and how they now constructed their mental model as the result of having to accept and use the innovation, which now did much of the hard thinking for them. My earlier empirical review pointed to this aspect of the role as being satisfying and motivating, and as such, I considered that a phenomenological approach would lead to valuable knowledge being inferred within the appropriate specific setting and contextual description.

Phenomenology asserts that any attempt to understand social reality has to be grounded in people's experiences of that social reality. The key to adopting a phenomenological methodology is securing the subjective experience of the subject, seeking to put oneself in the place of the subject. In doing so, I sought to explore how the Controllers taken-for-granted world is experienced and how structures of consciousness apprehend their world (Holstein and Gubrium, 1994). I thus sought to understand, from the Controllers' various perspectives and experiences, how the phenomenon they experienced challenged or disturbed their taken-for-granted positions of both how they performed their role and how it helped them develop a sense of satisfaction and contribution. Thus, it becomes an "exploration, via personal experience, of prevailing cultural understandings" (Gray, 2018, p.25), where value and knowledge are not only ascribed to the interpretations of the researcher, but also to the subjects of the research themselves. Such an inductive approach seeks to find the internal logic of the subject, as opposed to using a theoretical model that imposes an external logic on the phenomenon. Adopting such a methodology was a natural extension of the qualitative nature of my research strategy and inductive research approach.

However, in selecting a phenomenological approach I was aware that other strategies of enquiry were available. These include the case study methodology, defined by Yin (2009) as:

> "…an empirical inquiry that:
>
> - investigates a contemporary phenomenon (the "case") within its real-life context, especially when

- the boundaries between phenomenon and context are not clearly evident".

(Yin, 2014, p.16).

My decision not to proceed with a Case Study approach was informed by the views of Gray (2018), who pointed to its usefulness when the researcher was seeking to uncover a relationship between a phenomenon and the context within which it is occurring, thereby seeking to "identify a causal relationship and not just describing a situation" (Gray, 2018, p. 262) and the numerous contextual variable that need to be taken into consideration. Furthermore, Case Studies benefit from the earlier development of a theoretical position to help inform data gathering and the creation of a focus through an initial definition of a research question (Eisenhardt, 1989). As such, the case study method tends to be "deductive rather than inductive in character" (Gray, 2018, p,263) which I felt did not fully reflect my interpretive approach.

A further possibility I considered was an ethnographic approach (Atkinson and Hammersley, 2019) to explore the nature of the specific phenomenon experienced by the Controllers, using the change enabled by the specific innovation as the case in point. However, this seemed to imply the need to participate in the event with those experiencing it, through overt or covert participation; this would not have been possible in the work setting available and I would not have been able to gather any data regarding their thought processes from observing what they were doing differently. Using grounded theory (Glaser and Strauss, 1967) could have provided a suitable strategy of enquiry as it provides an inductive yet systematic approach to design and data analysis, with the possibility that theories may emerge or could be discovered from the empirical data gathered. However, my research did not seek to discover or propose theories, rather it sought to try to infer how the Controllers reacted to a specific innovation that influenced how they performed their role, and how it may have disturbed their comfort zone.

My review of the possible avenues of the strategies of enquiry available enabled me to consider which would be valid and, from those, which could be justified under the circumstances and constraints of my research. As such, I feel that my selection of a phenomenological approach is both justified and valid and I progressed on that basis.

4.3 Options Considered to Gather the Data

Choosing Semi-Structured Interviews

I undertook face-to-face, semi-structured, interviews with the Controllers who experienced the change undertaken to gather the type of information sought. Interviews were chosen as these were an effective and appropriate way to understand the feelings, emotions and attitudes of those affected, and in a manner where their responses and reactions could be probed deeper when appropriate or valuable, as informed by the where they chose the direction of the interview to go. My intention when interviewing the Controllers was to see if any meaning could be ascribed to the phenomenon that the participants experienced, such as the specific and individual experiences that may have been triggered by the innovation. The intention was to understand their 'lived experiences' to see whether common aspects or themes would be distilled and the meaning they make of that experience (Seidman, 2013), reflecting that:

> "The best stories are those that stir people's minds, heart and soul and by so doing, give them new insights into themselves, their problems and their human condition" (Reason, 1981, p.50).

Interviews also enabled the Controllers to express feelings and views without the formality of putting them in writing and may be more willing to share information verbally and face-to-face once a rapport had been developed, with anonymity assured, which they feel would be too difficult to commit to or express in writing when uncertain who may later read and reflect upon their views. Furthermore, having the opportunity to directly explain the motives of my research, explain the ethical safeguards developed and provide assurances of how the information would be used, helped me develop a trusted relationship and provided a more assured basis for participants' engagement and how they would be willing to open up and express their feelings.

Semi-structured interviews were used to provide the type of information sought, using an *aide memoir* of the various aspects to be covered were identified and a set of questions developed to provide a basis for the conversation. The structure I followed to help develop a flow when conducting an interview is presented in Appendix 4. This provided a framework to cover the various aspects I sought to hear about when conducting an interview, without being so rigid or inflexible to prevent valid avenues from being discussed and explored. This was important and valuable as it enabled the subjective meanings that the interviewees ascribed to the phenomena experienced. In several cases, such an approach also enabled new and

unexpected avenues to be explored that were specific to some participants and which may not have been uncovered if a more restrictive rigid or structured approach has been adopted.

The method selected to gather the data also needed to reflect the fact that access to the Controllers was limited to when they could be released from operational duties and this needed to fit in with their rostered shift pattern. The nature of the shift pattern and roster meant that only five of the total population of the 25 Controller who experienced the change would be on-site at any one time, and from those five, only one could be released from operational duties to be interviewed, with a one-hour slot identified within that day's roster. A consequence of such a constraint was that I was only able to engage with one Controller at a time, thereby preventing data collection methods that would require group discussions. The interviews were undertaken at both quiet times of the day when traffic levels were at their lowest (early morning and early evening) and a quiet time of the year (i.e. winter traffic schedules). This reduced the possibility of the Controller who was being interviewed being unexpectedly being called back for operational duties. A further influencing factor was that, within NATS, surveys or questionnaires suffer from a notoriously poor response rate, and as the population of Controllers who had experienced the phenomenon was small when considered across the entire Controller community in NATS, a poor response rate would have yielded little in the way of meaningful information. Such a limited number did however lend itself the opportunity for direct face-to-face engagement on an individual basis and in a more manageable manner over a relatively short period on time over January to March 2020.

14 Controllers were individually interviewed over January to March 2020 at the Swanwick Area Control Centre. The interviews occurred whilst the Controllers were rostered to attend for operational duties and occurred during a one-hour rostered break. For many of those interviewed, this was the first occasion that they had been provided to discuss their experiences of the whole change and provided them with an opportunity to reflect on their various thoughts and emotions, from when they initially heard that the capability would be developed, through to the transition of its use to the current steady state when it is been in use for c.18 months. I could not influence who volunteered to be interviewed, nor did I decline any offers to participate. I did not personally know any of those who volunteered to participate, nor was I aware of their capabilities as a Controller nor any thoughts they may have had on the innovation that was the focus of my research. The number of years of experience as a Controller in NATS (including the training period) was recorded. As there is no maximum recruitment age restriction within NATS to become a controller, it is not possible to

validly associate a Controller's experience with their age, which would mean that no findings could be reliably attributed to their age, although some inferences may be possible from being aware of the length of experience they have in the role. Furthermore, the Controllers' gender played no part in any of the research nor in any of the findings (which for completeness were 13 male and one female). The high-level findings from the interviews are summarised in section 5.1, with thick descriptions of the themes induced set out in section 5.2.

When I selected face-to-face interviews to gather the data, I had expected that I would also be able to observe and reflect upon the interviewee's body language and intonations when I analysed the transcripts. However, this transpired to be far harder to do than I had envisaged, and I found that all my concentration was taken up in listening to the interviewee's response and thinking about how to develop the conversation. Whilst some emphasis on particular points could be heard on the recordings when the interviews were transcribed, these were insufficient to warrant inclusion in the analysis. Upon reflection, I feel that I may have set expectations in myself too high: this was the first time I had used interviews to gather data and I had underestimated how difficult it would be to observe and use non-verbal information and clues. In retrospect, understanding the difficulties of trying to achieve this has been one of my learning experiences.

Card Sorting

Each interview was supplemented with a Card Sort activity. Card sorting is an interactive research method that seeks to identify how participants understand concepts to enrich the quality of interviews and the data gathered. Set within the context of the social sciences, card sorting is a participatory research method that aims to engage participants in the identification and development of conceptual categories and definitions (Conrad and Tucker, 2019). Typically set with a context of information architecture, it is considered to be a quick, inexpensive, and reliable method for optimizing a system's usability (Spencer, 2004). Card sorting aims to reveal the mental models of those using an information system, or "how participants relate and categorize concepts" (Goodman, et al., 2012, p. 202). As such, I felt this would be a valuable way to supplement and either challenge or support the data gathered from the interview.

The Controllers were also presented at the end of their interview with 12 cards, each with a single adjective, and asked to select up to three that they felt reflected their thoughts on how

advances in technology may affect their role within the profession. The intention was to see if the words suggested related to their views and in a way that provided an opportunity to focus on specific feelings, as opposed to the more descriptive and narrative nature of the interview. It also provided the opportunity for the interviewees to reflect their overall feelings of the potential changes that technological innovation would have on their role as Controllers in just a few keywords that they were free to select, thereby requiring them to take a step back from the detail of the conversation and summarise their thoughts.

In many cases, the selections were explained and justified, and in some cases and linked back to examples or anecdotes raised earlier during the interview. In other cases, the opportunity to see words presented to them which they may have used during the interview provided a way to encapsulate their feelings, and where this was the case, provided me with the opportunity to test my understanding of any further avenues that could yield data. The words I selected for this were informed from my theoretical and empirical literature review.

In doing this I had to reflect these words were my interpretation of some aspects or characteristics that may be associated with the type of changes that technology is expected to ATC informed by my experiences from working within the industry and also informed by my preceding literature review, and that the Controllers may have different interpretations of both the context and the meaning. I considered it to be a valuable supplement to the interview and which would allow them to reflect on a type and level of change to their role that they felt new technology could enable. At the end of their interview, Controllers were presented with 12 cards with the following words and asked to select up to three: Excited; Relaxed; Dubious; Comfortable; Cautious; Enthused; Worried; Apprehensive; Encouraged; Nervous, Inspired; and, Sceptical. The cards were presented to the Controllers in a random and ungrouped way. The analysis of the card sort is presented in section 5.3.

Securing Valid Data

Whilst seeking to develop a robust method, I was aware of several limitations that could have affected the way the data was were collected. Whilst I sought to make the interviews as 'valid' as possible (Arksey and Knight, 1999), as the lived experience of the change was unique to the individual, and expressed in their own manner, each interview was slightly different in terms of the depth of how some questions were answered and subsequent lines of enquiry developed. I did not see this as a weakness or a limitation – my intent in choosing to

undertake interviews was to develop as rich a picture as possible of their collective experiences, accepting that some avenues my enquiry would be of greater relevance and importance to some than others. Furthermore, my research was not seeking to develop theory nor to generalise the outcomes to enable them to be set within a different context. An early concern that I had was the extent to which Controllers would be willing to volunteer to be interviewed, being aware that I wanted to talk to sufficient to allow a valid data set to be asserted. Due to the specific nature and use of the innovation (i.e. it is only used to support the Heathrow Final Approach Control function), I was aware that only 25 Controllers were now using the innovation, thereby limiting the total number of interviewees to that number. Rowley (2012) suggests that aiming for around 12 interviews of around 30 minutes or six interviews lasting around an hour can be considered as a suitable basis to develop external validity, views supported by Guest et al (2006) who suggest around 12 interviews when the aim is to understand common issues of a relatively heterogeneous sample. Similarly, Kuzel (1992) recommends between 12 and 20 interviews when aiming to identify the maximum variation in the data or to identify any disconfirming data. I interviewed 14 Controllers (out of a possible total of 25), each for between 40 to 60 minutes. I thus considered that I had sufficient data to be able to provide a valid basis for the subsequent data analysis.

Finally, in addition to the data being gathered from the Controllers, a group of senior managers (comprising Change Managers, Senior Leaders and Technology Innovators) were engaged to discuss their views and perceptions of how Controller react and respond to innovative change more generally, and outwith the tight focus of the specific change used as the example in this research. The purpose of this was for me to try to hear the views of others in senior positions whose role it is to manage the delivery or development of technology-enabled change within the ATC operation (be it technological, processual or organisational). In doing so, I felt it would be valuable to hear the views of others who have observed Controllers experiencing change and their views on how this has contributed to the power balance and competing narratives within the organisation, although none had had direct engagement with the development of the specific innovation that was the focus of my interviews with the Controllers (as that particular Change Manager had left the organisation before the interviews were undertaken, although not for reasons in any way associated with the delivery and outcomes of the innovation).

Limitations of the Data Collection Method

Despite best endeavours to explain, develop and use a robust method, the following influencing aspects remained:

1. Being a senior manager of my sponsoring organisation, some potential participants may have felt dissuaded from volunteering to be interviewed, as they may have felt uneasy about sharing their views on the new tool in case these were viewed as a criticism of how the change was managed or the suitability of the new capability being used. Despite anonymity being assured, there was a possibility that some may have not been sufficiently persuaded that their views would only be used for the purpose described.

2. Unintentional interviewer bias may still have fettered some aspects of the interview and either taken the conversation down a line of limited value or might have prevented an unexpected nuance been heard or understood at that time, thereby missing an opportunity to explore something unexpectedly raised. On some occasions whilst undertaking an interview, I found myself thinking about how best to develop the conversation, as opposed to giving my full attention to the particular answer being given. Recording and transcribing the interviews mitigated this to some extent, but this does not rectify any missed opportunities that may have occurred to probe deeper. I was also aware that undertaking interviews would influence me as the researcher, in so far as my interpretations and initial (pre-analysis) thoughts from preceding interviews may influence my thinking and lines of enquiry in later ones.

3. There is a risk that I may have been biased or expecting certain threads to be developed from the Thematic Analysis, in part informed by my previous experiences within the organisation and observations from previous technical innovations and change management initiatives. Being aware of such risks enabled me to challenge myself that the themes which I was detecting were based upon the evidence and could be attributed to particular comments or examples provided by the participants.

Overview of the Data Set

All of the interviews with the Controllers were recorded and transcribed. Each Controller was provided with the transcript within 10 days of their interview with a request to confirm that it presented their views and that they remained content to participate in the research. Each Controller was provided with the opportunity to redact any views or responses that had been recorded. None of the Controllers withdrew and no redactions were made. The recordings were retained and used along with the transcripts to perform the analysis. As has been assured, once the analysis has been undertaken, the recordings were deleted, leaving only the approved transcripts. The Controllers were each provided with the transcript of their interview. The transcripts also included the words they had each selected from the card sort; no changes or additions were requested. The average length of experience as a Controller in NATS (including training) of the group interviewed was 15.8 years, with a standard deviation of 5.9 years. There were no gender nor demographic groupings. Each of the 14 controllers interviewed was allocated an identification number to enable quotes to be presented anonymously and which would allow the outcome of the card sort to be set in the context of their interview.

ID	Experience (years)	Card Sort Words Selected	Words Added
1	20	Dubious, Cautious, Apprehensive, Worried, Nervous, Sceptical.	-
2	16	Relaxed, Comfortable.	Interested
3	27	Dubious, Sceptical, Apprehensive.	-
4	10	Enthused, Apprehensive, Inspired.	-
5	11	Worried, Nervous, Sceptical.	-
6	16	Cautious, Apprehensive, Dubious.	-
7	27	Comfortable, Excited, Cautious, Apprehensive.	-
8	17	Dubious, Relaxed.	-
9	16	Apprehensive, Excited, Cautious	Concerned
10	10	Relaxed, Cautious, Comfortable.	Apathetic
11	10	Sceptical, Dubious, Cautious.	-
12	6	Sceptical, Comfortable, Relaxed, Cautious.	-
13	15	Cautious, relaxed, Encouraged.	-
14	18	Apprehensive, Cautious and Relaxed.	Positive

Table 5: Data Set and Words Selected from Card Sort

4.4 Options Considered to Analyse the Data

Selecting a Suitable Data Analysis Method

Gathering data from interviews results in a large amount of textual material that needs to be analysed to see whether any relevant information can be developed and knowledge inferred. The data analysis method selected needed to break the data down into smaller units to reveal any characteristic elements or structure (Dey, 1993). The analysis of the data needed to go deeper than merely a description; it needed to "interpret, understand and explain" (Gray, 2018, p.690). Various methods exist to analyse the data to arrive at the level of understanding necessary to be able to fully interpret the meanings, including: Content Analysis; Thematic Analysis; Grounded Theory; and, Interpretive Phenomenological Analysis. After understanding the various merits and attributes of these, I chose to undertake a Thematic Analysis on the data gathered by the interviews, informed from my review of other potential methods:

- Content Analysis (CA) can be considered to be more deductive than inductive (Gray, 2018, p.690) and requires a measure of objectivity through the creation of specific rules called 'criteria for selection'; I had not assumed any *a priori* criteria relating to my data. I was also guided in not selecting CA by its recognised limitation that it cannot explore associations and causal relationships between variables (Flick, 2014) and the conceptual structures that CA imposes on the data could mask some of the interpretations that may have otherwise been induced from other methods of analysis.
- Grounded Theory (GT) offered a method to analyse data relating to a phenomenon through systematic data collection (Strauss and Corbin, 1998). Applicable to both objectivist and interpretivist approaches (Locke, 2001), locating GT in a particular research paradigm can be difficult. As a novice researcher and undertaking my first Level 8 research alone, I reflected that GT presented a complex method and one which I did not feel able to grasp to the level required, a view informed by it being reported as being "bewildering complex" (Partington, 2002, p.138).
- Interpretive Phenomenological Analysis (IPA) could have been used and applied to the phenomenon investigated set within the context experienced (Smith, 2011, Gill, 2014). Its use would have been applicable as it would have accorded with the data collection method and the open-ended enquiry enabled by semi-structured interviews. Idiographic in nature, IPA has a focus on both the unique characteristics of individual participants and on the patterning of meaning across the participants, whereas

Thematic Analysis is primarily focused on patterning of meaning across participants. IPA seeks to explore in detail the processes through which participants make sense of their own experiences by considering their account of the processes they have been through and seeking to utilise an assumed existing universal inclination towards self-reflection (Chapmans and Smith, 2002). In retrospect (i.e. post completion of the thesis), I can see that IPA would have offered a valid and suitable alternative to the TA that I undertook and could have yielded different outcomes. However, as this was the first qualitative analysis I had undertaken, I was steered by what I observed as a greater amount of literature pointing to Reflexive Thematic Analysis than IPA, as well as being aware that that the outcomes of performing TA and IPA can often be very similar (Braun and Clarke, 2019).

Despite the relative value and unique perspectives of these methods of data analysis, I am content with my decision to undertake a Thematic Analysis, which sought to explore whether any patterns or common themes could be identified or patterns recognised from the qualitative data gathered. Thematic analysis is a method of ascribing, analysing and reporting patterns or themes within a data set, as well as enabling various aspects of the research topic to be interpreted (Boyatzis, 1998). Rather than viewing this as a passive activity whereby themes simply emerge from the data, understanding and reflecting upon my role as the researcher is vital, as it is me as the researcher who identified possible themes and selects them for further analysis and reporting within the known context and environment. I considered a theme to be something that identifies something raised or considered which, in my judgement as the researcher, contained something important about the data in relation to the research topic.

I could not do this in a manner that was detached from those I interviewed nor from the data that was gathered. Both my data gathering and data analysis methods required me to be reflexive in my thoughts and actions which arose from them. In essence, when interviewing the Controllers, I was not a neutral observer in the data gathering process, nor when performing the thematic analysis - I was “implicated in the construction of knowledge” (Gray, 2018, p.689). Ongoing and repeated critical reflection of my feelings and reactions as I read and interpreted the transcripts of the interviews with the Controllers as part of the thematic analysis enabled me to be satisfied that I was inducing relevant and valid themes which were justified from the data gathered. Whilst undertaking the analysis, I found myself having regular internal conversations (Archer, 2003) when interpreting the data and induced themes,

reflecting on my own thoughts as to whether I was observing and developing something that I felt to be genuinely valid and which would lead to robust and valid conclusions, or whether I was considering something that did not actually exist but which I may have prepositioned myself to expect from previous experiences or early work in the theoretical and empirical literature reviews. In doing so, I was conscious that my reading around previous failures (as discussed in section 1.3) and associated literature review on change and technology acceptance has raised my awareness and sensitised me to possible avenues. Whilst this had provided a basis to develop line interviews, I had to be informed and steered by using the data I had gathered when performing the analysis.

Selecting a Specific Approach to Thematic Analysis

There are numerous approaches to thematic analysis available to consider: coding reliability; reflexive; and, the codebook styles. My decision to adopt the reflexive approach as developed by Braun and Clarke (2006) was informed after considering the process and the extent to which they reflect my research strategy.

The coding reliability approach (Boyatzis, 1988; Guest et al, 2012; Joffe, 2011) places a greater emphasis on the reliability or accuracy of the coding by using a structured codebook and multiple independent coders, with a measurement of the agreement between the coders informing a position on the overall reliability of the coding. However, the use of such a reliability score across the coders is underpinned by the realist/positivist premise that there is a reality to the data which can be accurately captured by the coding.

This differs from the Braun and Clarke (2006) reflexive approach, which is more flexible and organic, whereby the coding evolves through the coding process, bearing some similarities here with initial coding used in grounded theory (Charmaz, 2006). The Braun and Clarke (2006) reflexive approach recognises (and leverages) that coding is an active and reflexive process and as such reflects the mark of the researcher, pointing to the position that there is not a single, accurate, way to code the data, and as such, the concept of inter-coder reliability as exhibited by the coding reliability approach disappears. A further influential difference between the reflexive approach and coding reliability approach is the conceptualisation of the themes as analytical inputs in coding reliability TA rather than analytical outputs from reflexive TA. Themes are developed early in the analytics process when performing a coding reliability

TA, whereas they are analytics outputs created from codes and through the researcher's active engagement with the data.

The codebook approaches are typified by the concepts of template analysis (King and Brooks, 2017), framework analysis (Ritchie and Spencer, 1994) and matrix analysis (Miles and Huberman, 1994). If codebook reliability was to be located towards the positivist end of the spectrum and the reflexive approach at the other, interpretivist, end, then the codebook approaches would sit somewhere between them. They exhibit the same type of structured codebook and conceptualisation of themes as analytic inputs as the coding reliability approaches, but not the positivist aspect for measuring coding reliability.

Undertaking the Reflexive Thematic Analysis

The reflexive thematic analysis followed the six phases of identification, analysis and development developed by Braun and Clarke (2006), summarised as:

1. Familiarisation with the data by reading the transcripts and listening to the recordings to pick up or detect intonations and inflexions, most notably pauses and changes of pace and tone of delivery as the respondents thought back and reflected on their experiences, taking the interview as an opportunity to think deeper about their feelings, emotions and views and convey these in a safe environment where anonymity was assured.
2. Generating an initial coding, by identifying common words or views in the material.
3. Searching for themes by collating the codes into potential themes, reflecting that there may be a hierarchy of themes and some overlap, as well as causality (i.e. one theme may have emanated from or been triggered another theme).
4. Reviewing the themes to see whether they are valid in relation to the extracts and overall information set.
5. Naming the themes to define them as recognisable entities that can be understood from the data set and setting out how these fit into the overall context of the topic of the research.

6. Reporting the themes by selecting extracts that clearly link back to the purpose of the research, linking the finding and conclusions to the supporting literature, with assertions being able to be evidenced from the base information.

Maintaining and reviewing a diary when undertaking the analysis helped enable me to record and later reflect on my own feelings as I sought to interpret the data. When re-reading the transcripts at a later date, I was able to also reflect on my diary entries to consider how I was arriving at the themes, and the extent to which I was maintaining my interpretivist approach. The complete set of diary entries also enabled me to reflect on my own engagement in the analysis.

Seeking to Validate the Findings on the Analysis

The findings were provided to the Controllers who had participated in the research with a request to consider whether they could recognise the themes and descriptions I had developed. I was also keen to offer the Controllers the opportunity to read 'my interpretations of their interpretations' and to provide them with an opportunity to provide any reflections on these. In doing so, I would also be interested in what responses they provided and whether any felt that being able to reflect on my findings triggered any further thoughts that they may want to make. The views of those Controllers who provided their thoughts on the analysis and the views on the Senior Managers are in sections 5.4 and 5.5 respectively. One of the Controllers who provided feedback is also influential in the Guild of Air Traffic Controllers and was able to provide both feedback on the analysis from the viewpoint of someone who was affected by the change and also from the perspective of how it could influence and be accepted by the wider Controller community.

4.5 Connecting the Research Elements

This is an appropriate point to recap on the research strategy I adopted and provide a reminder of the avenues I took when choices of approach were available.

The research adopted a qualitative research strategy which would enable me to induce knowledge from their lived experiences of the complete lifecycle of the change. The phenomenon explored in this research was the change experienced by the Controllers in how they interacted with the system and how that changed the development of their cognitive situational awareness model as the innovation changed the way they had to interact with the system and the information it provided. Face-to-face semi-structured interviews were undertaken with Controllers who had experienced the change, supported by a card sort activity. A Braun and Clarke (2006) reflexive thematic analysis was performed to explore whether any themes could be identified.

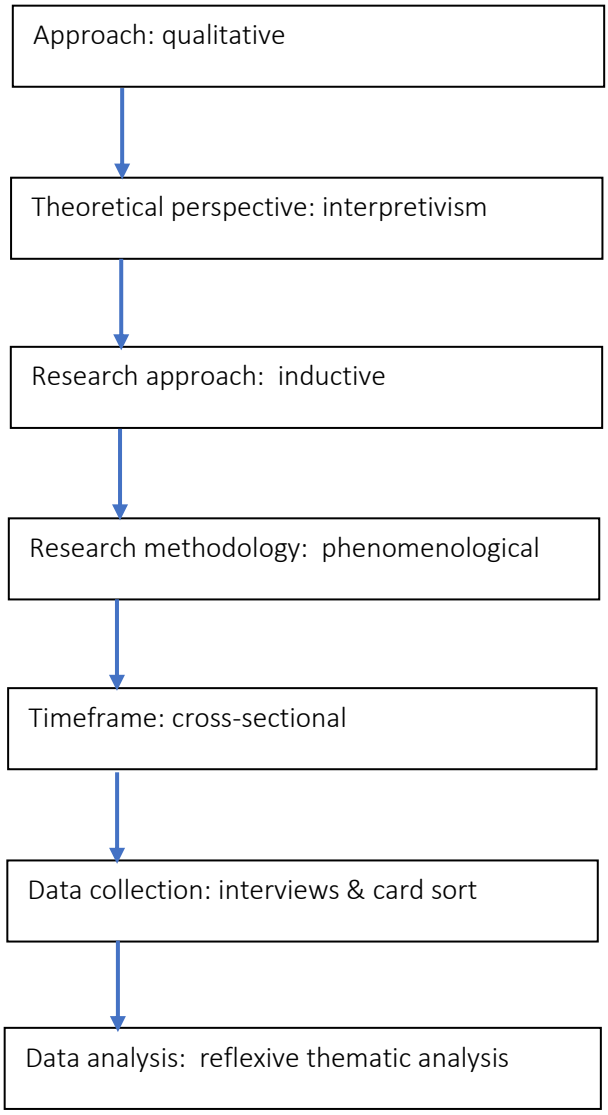

Figure 9: Flow of Research Strategy (as adapted from Crotty, 1998)

5. Analysis of the Findings

5.1 Overview

The analysis of the interviews enabled me to induce and develop six themes, three of which appear to be more applicable to the influences of automation and the use of innovative technology within ATC in general (themes 1 to 3), and three which appear to be more specific to the particular innovation which was considered (themes 4 to 6). These are summarised in the thematic map in Figure 10. The complete thematic map is presented in Appendix 6.

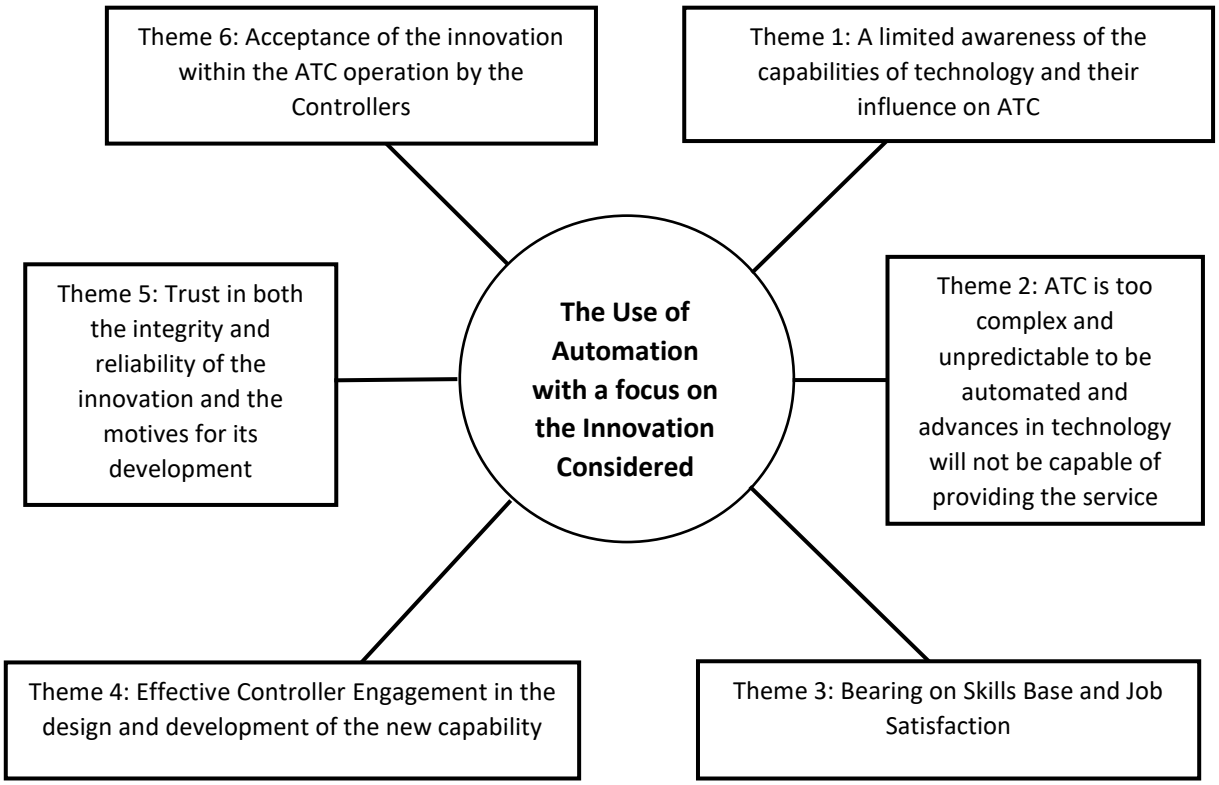

Figure 10: Summary Thematic Map Developed from the Analysis

The six themes which I inferred and was able to develop from my reflective thematic analysis were:

- Theme 1 - A limited awareness of the capabilities of future technology and its possible influences on ATC. There was little offered by the Controllers in terms of their awareness and knowledge about how technology which already exists and is used outside ATC could be developed to supplement their role.

- Themes 2 - That ATC is too complex, variable and unpredictable to be automated, and advances in technology will not be capable of providing the service. I inferred that there was an underlying belief that whilst other parts of the overall ATC service delivery chain could be automated and may benefit from the concepts enabled by AI and ML, the complex characteristics of ATC and the skilled nature of the task would prevent, or at least significantly delay, the use of such technology in support of their specific role.

- Theme 3 - That technology could have a bearing on the skill-base required to perform the functions required and reduce Controller job satisfaction. However, there was some polarisation of views raised on how the skill-base could change, covering both concerns that there would be a reduction of the core skills required to provide the tasking (i.e. deskilling), countered by other views that it would necessitate an increase in the skill-base to match the increased abilities of the overall ATC system. A common message I heard was that a *different* set of skills will be required, with new capabilities needing to be developed. I inferred a concern that the automation would perform the more satisfying and rewarding part of the role, and leave the Controllers to progress those aspects which were considered to be boring or repetitive, leading to a concern that the role may evolve from 'controlling' to 'monitoring'.

- Theme 4 – There had been Effective User Engagement in the design and development of the new capability. I inferred that the Controllers recognised that they had been engaged in the formative phase of the development and that their views had been reflected in the ultimate capability provided, and that this had provided them with some comfort and assurances on the useability and robustness of the new tool provided.

- Theme 5 - Trust in both the integrity and reliability of the innovation and the motives for its use. No mistrust in management nor any motives other than being able to improve the service provided were inferred from my analysis of the data.

- Themes 6 - An acceptance of the innovation by the Controllers. The benefits in the performance of the overall ATC system and its ease of use were seen by the Controllers and the ability to observe improved outcomes helped develop their sense of acceptance.

Each of these themes is developed further, with my thoughts, inferences and assertions informed by excerpts from the interviews presented in italic text. As anonymity was assured to the Controllers and as the sponsoring employer will review and use this thesis, the quotes have not been attributed to the specific participant, but rather to a unique participant ID number. Extracts from the interviews that enabled these themes to be induced are presented in Appendix 7, which presents extracts for the themes identified.

5.2 Developing the Themes

Theme 1 – A limited awareness of the capabilities of advances in technology and how these could influence the development of ATC

Overall, there appeared to be a general lack of awareness among the Controllers interviewed of how technology could change their specific role (i.e. Heathrow Final Approach) and the wider opportunities that technology could provide to the ATC sector in general. Open-ended questions that sought to identify and discuss their awareness or understanding of existing or emerging technological developments within the sector did not elicit an awareness of future possibilities that, only an understanding of current tools and systems.

"Self-driving cars, yeah, it's been on the news, but the finer detail on it, not really". (ID.1)

"I wouldn't know unless you said or gave me examples then I might have some knowledge but nothing springs to mind. Maybe my fingerprint on my phone?" (ID.2)

"I've seen stuff like that but not paid that much attention". (ID.3)

"I know there's many issues for artificial intelligence, it can be used in all manner of industries, I suppose day-to-day we see Alexa, Google, and up to, I suppose, don't know, you've caught me on the hop here, and then you see the high-end stuff I suppose with the talking faces and all that kind of stuff. I know it's used in Trading Floors, that's pretty much it". (ID.5)

"I'd say not a lot of detailed knowledge, but quite a lot of interest in what's happening and how it's interacting with us, I guess one of the examples might be when you're on a website and you get a chat-box come and you think, is this a person or is this a computer? And I've noticed now that lots of companies are making it clear that what you're interacting with is just potentially artificial intelligence kind of programme, so interested, definitely, and from a professional point of view as well". (ID.6)

"Fairly limited, only so much as you read in the papers, see on TV and in films". (ID.7)

"To a degree, I guess as much as the next person, not any specific knowledge of it but I realise it has its place and it's coming in more and more". (ID.8)

"Not a great deal, only what you see in the movies". (ID.10)

"Only like an interest. I saw that Google thing where they built a system to beat the top Go player in South Korea, that was quite incredible, they used Machine Learning and things like that, so yeah only through watching documentaries. Not so much how it works but I know it's coming. Still can't quite see it personally". (ID.11)

"I know a bit because when I did my MSc in Electrical Engineering back in the 90s, I worked on neural networks so I did so a bit on artificial intelligence which makes me wonder whether we can have artificial intelligence here yet, or whether it's just automation. It's probably not unique but it's in the minority". (ID.12)

"I've read a couple of articles about that type of thing but nothing particularly in-depth. There's a passing interest but nothing more than that I think". (ID.13)

"No really, no, I hear little bits and pieces and just on the news but it's not something I really follow, no. Interested in it though". (ID.14)

Only one Controller (ID.12) recognised the possibilities that automation could provide and saw how it could support the Controllers' role, with perspectives informed by his education and previous roles in advanced communications systems engineering. The knowledge, awareness and interest exhibited by ID.12 was unique across those interviewed. None of the other Controllers responded to the initial positioning questions with more than superficial knowledge and a basic understanding of the capabilities and possibilities, nor how these could be used to support their current or future role. Developments that are exploiting the capabilities of such types of technology, such as the use of driverless cars, the use of drones to automate parcel/package delivery, facial recognition technology to support crime prevention and detection and advances in the medical field, all of which are topical and reported items, were not raised by the majority of participants. Such a situation would appear to be in direct contrast with their ability to accept, engage with and confidently use advanced and innovative technology when providing the ATC service.

Whilst the interviews were able to elicit a general awareness when prompted with suggestions or topical examples, only one Controller (ID.12) identified future possibilities in an unsolicited manner; the rest did not consider nor present arguments of how it could affect them, nor how the organisation and wider industry could exploit it. Whist they had awareness of how they use technology in their daily lives, such as social media and mobile technology, I was left with the impression that, from a vocational perspective, they felt it was 'out there somewhere' and

somehow separate from their role and professional activities, despite that fact that technology provides the cornerstone of how they currently provide the service. It was as if some had not made, or chosen to not make, the leap from what they use and rely on socially and outside the work environment to how it could affect their role at work. This may be driven by the discretionary nature of engagement with technology outside work (i.e. choosing what to engage with, how and at what pace) and the non-discretionary nature of its use when discharging their role to provide the service (i.e. the Controllers have no choice in how to use the tools and systems that they are provided). The safety performance outcomes are predicated upon the correct and complete use of the ATC facilities safety nets provided – there is no scope to 'opt out' and not use all the facilities provided, nor to use them in a manner that does not fully exploit their capabilities and performance.

However, despite the vast majority of Controllers showing what I interpreted as an overall lack of awareness of the potential implications on their role (with the exception of ID.12), this did not manifest in fear or any prepositioned views that would suggest that such advances would be rejected or resisted. I inferred a common position that the participants appeared to be willing to keep an open mind; none left me with an impression that they were averse to understanding how new technology could help them to provide a safer and more effective service.

Theme 2 – A prevailing view that ATC is too complex and variable to be automated, and that the advances in technology will not be sufficiently innovative and capable to deliver the performance required.

I was able to infer a theme that future technology, and AI and ML in particular, would not be able to replace Controllers in their role. Whilst there appeared to be a recognition that it would be able to provide further automated system support, the prevailing view was that the task was too complex and subject to unpredictable external factors, such as weather conditions and emergency situations, to be able to be fully explained and described to the extent required to enable the development of autonomous systems capable of performing anything other than basic, deterministic and repetitive of functions.

> *"If it makes it easier, it's fine. I can't see there ever being a complete replacement". (ID.1)*

"I think we'll get more tools, whether they aid us or not I don't know, whether they're there to take over or not, I don't know, but for the reason I said before, I don't see it evolving that rapidly". (ID.2)

"I think it's too dynamic, I think the planes are too close together, the impact of things outside controlled airspace and weather situations just to name a couple, without going into emergency situations etc, etc. I think there's too many variables for what a computer could do". (ID.2)

"I don't know, I don't know because, well it depends what kind of things come through, the last couple of years there's been a lot of change, a lot of change together, so how much more of that can change in the next ten years I'm not entirely sure. What else they could do to support what we do I'm not entirely sure either. I suppose I'm sceptical in a way, maybe because I've been doing the job for longer". (ID.3)

"I'm sure there's plans in the pipeline – I'm sure there are - it will hopefully be a long time after I retire and hopefully after I stop flying". (ID.3)

"I think it probably will become more automated, that just seems to be the natural progression of everything at the moment – how much more automated that can be I don't know". (ID.3)

"I thought about this years ago. I thought at some stage we'd be made redundant basically by artificial intelligence. Having seen the pace that NATS moves at bringing new projects and stuff in I think I'm definitely getting a career out of it. Beyond that I don't know, we'll see". (ID.5)

"I think we're almost a special case in that it takes so long to train us, and it is a difficult job so not everyone who wants to do it can do it, even after training. I think there are lots of factors here at play, I think there could be things brought in with a view to getting rid of us eventually". (ID.9)

"I think it will definitely support it – I don't think it will replace it. They've tried a lot of different methods of, like telling us when we need to turn the planes, letting planes do it on their own, and not one of them yet has managed to come in, it can't understand the intricacies of what it is we do and the fine margins to which we work, so, it's quite

difficult for something to come in that can cover all eventualities, so yeah I'm sure there'll be stuff that comes in that will support us in that, but in terms of replacing our job, for the next, well as far as I can see, I'm going to be safe until I retire". (ID.10)

"I think that's the main stumbling block of any form of project that we do of that nature, just trying to systemise and standardise things, the need for flexibility but also predictability, there's a conflict there that's difficult to manage". (ID.13)

A further perspective that I induced related to instances of system failure, whereby an intelligent autonomous system was providing a level of service (in terms of the number of aircraft being managed) that was greater or more complex than Controllers would be able to manage upon reversion to manual operations following a system failure. I inferred three separate aspects in support of such a view.

Firstly, when acting in a monitoring role (i.e. monitoring an operation that is being performed by a machine), the Controllers would not have developed their own 'mental model' (as discussed in sections 1.3 and 2.2) to create safe and efficient traffic patterns and thus will be unaware of the prevailing traffic situation in the event that they needed to take over from the automated system, or following what they consider to be an unsafe situation that the machine would be unable to address.

"I find that some of the stuff that is automated, although it's helpful, it needs a lot of help, it doesn't work on its own – there's still a lot of human input for it to be used". (ID.1)

"The problem with that is when it stops working – it's then going back to is it still possible to do it without them or has it become so automated and helped by our computers that when they stop working, the whole system stops, whereas where there is less automation it's quite easy just to keep it going?" (ID.1)

"Would you get on a plane that has no pilot and would you get on a plane that has a pilot who is not being spoken to by somebody on the ground? People weren't too sure about that – so that is the leap". (ID.4)

"I think long term it's a threat, I don't necessarily think it's a threat for me because I've got less than 20 years left, I'm 43, so the reality of something that significant happening between now and the time I retire is pretty slim". (ID.9)

"I think artificial intelligence is used as a buzz-word, but it's not really artificial intelligence that we're going to see in the Ops room or in Control Towers or even in the cockpit. Definitely not yet, we're a long way away, because we were already working on neural networks in the 90s and we don't even see that in some of the areas of wireless communications I used to work on". (ID.12)

"Yes, it does currently, it's a difficult one because, especially new technology, trying to introduce it is always the difficult bit, sometimes they help, but more often we work around them, we make them work by getting used to them rather than being supported by them, depends what it is, depends how robust the training is, depends how robust the systems are, there's a lot of variables". (ID.13)

Secondly, concerns were raised over where ultimate accountability would be vested in the event of an unsafe traffic pattern emerging or the occurrence of a safely-related event. The concerns raised considered the scenario of a Controller operating in a monitoring role observing what he/she considered to be the emergence of a potentially unsafe situation caused by the automated system and what obligations this would place on them. Concerns were raised regarding where ultimate accountability and responsibility would lay if a safety-related incident occurred as a result of either intervening and assuming control of the situation, or not intervening and a safety-related incident subsequently occurring.

"From that point of view I think you need to be careful in this profession of just going gung-ho, automated everything and then have the controller, yes they can work ten times more traffic, but actually more often than not there is something unusual going on, whether it's weather or it's an emergency or whatever to deal with, so you know artificial intelligence is always going to struggle at the moment with the surprise element". (ID.6)

"I think the difficulties will be the liability and where that lies, so if the system is for example deciding a descent, if the system decides there's a confliction, to resolve it if it needs a descend but it's not going to work for any reason, then where does the liability

lay? Is it with the engineers, the software developers, the air traffic controller? Who's responsible for that monitoring?" (ID.11)

"You can't have a system that is not safe but a controller whose job it is to make it safe, it just wouldn't be acceptable. Not just for my employment or my job, probably for the airlines themselves have to bear that risk as well" (ID.11)

Thirdly, the complexity of developing protocols for accountability between the Controller and an intelligent autonomous system capable of providing the service was seen as being unsurmountable in the short to medium term. The task has become progressively more complex as new operating procedures have been developed to meet the increased traffic levels that have occurred. The absence in the past of the type of technology now becoming available has resulted in the current method of operation being human-centric, with the Controllers using highly developed and honed cognitive skills and processes to deliver the operation to the required levels of safety and efficiency. As such, incompatibilities between complexity and the development of deterministic solutions (required to facilitate automated delivery) may be self-perpetuating. Thus, perspectives or views on how the service is currently delivered cannot be automated are understandable and may be valid when considered within that specific frame of reference and context (i.e. seeking to automate the manner in which the role is currently performed).

"It's always struck me that there are so many variables all the time for the job that we do, it's always very difficult to put that into a computer, and to have a learning computer and to learn and make its own decisions would I guess be a massive step forward, but I can't imagine we are even close to that at the moment". (ID.7)

However, a different perspective that can be explored is whether the same overall service delivery outcomes can be achieved in a different way, such that new technology is not simply integrated (somehow) into the current or future type of operation, but whether the types of capabilities that will exist in the future will enable the task to be achieved in a completely different way, possibly without direct human involvement and in a way that cannot be currently envisaged. The realisation of such possibilities could result in the role of Controller ceasing to exist in the manner which it does today, resulting in an evolution of the role from

'active controlling' to 'passive monitoring' but trained to be able to take over control if or when intelligent autonomous systems fail. If this becomes the case, not only could there be expected to be a reduction in job satisfaction, there is a risk that Controllers will not be able to immediately use the types of cognitive processes required to take over, known within the operation as 'being in the zone', where the Controller feels fully in control, is able to concentrate for extended periods to maintain and develop their mental model of the continually evolving traffic situation, and feels confident that they can immediately respond to any unforeseen circumstances to maintain the safety or efficiency of the operation (e.g. an aircraft emergency situation, thunderstorm activity or the unexpected closure of a runway)

> *"If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job". (ID.5)*

> *"I think it's inevitable that there will be more automation of tasks, but with that comes the usual caveat that comes with aircrew as well, you know, if you just become a monitor of automated systems, when that automated system comes across a situation it can't deal with or doesn't like, then it hands over to the human element, and the human element is then left with perhaps less of an idea of what's going on than they might have had, had they had more involvement". (ID.6)*

Theme 3 – A Bearing on Skill Base and Job Satisfaction

Whilst there was consensus that the new tool would result in a change to the skill level required to perform the task, this was polarised between a view that it would either reduce or increase the skills required. One view was that the automated support provided would deskill the task as the cognitive processes hitherto used to determine and create the arrival stream of aircraft landing at Heathrow would be replaced by automated algorithms to help perform that

task for them. Such a view was informed by the fact that the skills developed and honed through experience and repetitive use would degrade over time if not continually exercised.

"It can make you feel deskilled". (ID.1)

"Well it's now on the screen in front of me so I don't need to learn it – it's fine as it works, but having less knowledge I don't think is a good thing - I feel I should know it". (ID.1)

"Well, I think it would deskill, mainly because you'd no longer need to remember the distance the aircraft are required to be apart – because it tells you on the radar". (ID.1)

"To me that doesn't seem too great a leap to have those planes talking to each other, sort of next generation, to almost take us out of the loop". (ID.1)

"What does concerns me is if we are being deskilled, that's what concerns me, not how people think about it or how people perceive air traffic controllers". (ID.3)

"When I look at trainees coming through now, I think well, how are they going to do it if it's broken, will they know how to do it, what will happen to the landing rate if it breaks and we can't use it?". (ID.3)

"I guess it would take away some of the decision making that I have, but with that I think it would also deskill controllers, I think that's what I've noticed already". (ID.3)

"I think there's a danger of it decreasing situational awareness, certainly with TBS one of the points that I noted fairly early on is a loss of awareness sometimes of the wake vortex categories of the aircraft, well not a loss of awareness, a loss of the awareness of the usual space you might be applying behind a particular aircraft and slavishly sticking to the TBS marker might you know, "is the marker correct?"." (ID.6)

"Yeah. One, we'd be slightly less accurate just naturally as we might now have the skills, and you're talking about a small margin, and two, we wouldn't want to push ourselves too far until we'd built up that skill and experience. I mean, if you go, if I was on leave for two weeks, I came back and I was doing the Final Director, I wouldn't expect myself to hit the same spacing as I did if I'd been in for the past 3 weeks, there's an automatic, you're more defensive, it's a skill level that you build up to, so yeah". (ID.7)

"Judgement wise, it's probably not too dissimilar to what we were doing it's just that element of the unknown of what actual gap we're going for, so certain skills have been degraded, but are they critical skills? Probably not, and you can get away with it anyway, so it's not a huge degradation of skills". (ID.8)

"I see more and more, now, people doing things they would never have done on paper because it's electronic so they take it more as a written and that is correct as opposed to the system having any fallibility in that somebody's just written something incorrectly on the strip, so technology leads you to cut corners in a way because you're more reliant on it and you believe its technology so it can't be wrong but its misleading you". (ID.8)

"I think there's an element of that already, whenever there are certain aspects of the job where automation comes into it, then you do get deskilled, as a natural consequence of that, I don't worry to the extent that we're not going to be required". (ID.13)

A further concern was that whilst the consequences such a deskilling may not manifest during normal operating conditions (i.e. when all the technology was operating as specified), Controllers may not be able to respond as effectively as previously to instances of unexpected failure to provide continuity of service as they would not be able to retain the level of unconscious competence previously held and regularly exercised.

"I think that like most tools we have, for 85, 90% of our time, it's made our job easier, but for those sometimes when it's not working or there are some other aggravating factors it's made it much harder, because maybe we have lost those skills a little bit, so yeah there's a lot of tools in air traffic like that, but when these tools fail, we're very good at cutting the flow rates right down until they're back in place". (ID.7)

"Me personally, it will definitely deskill me, but to the extent of a person who comes in who hasn't experienced controlling the way I have in the past, for them, when the system does break, which it would, it will be catastrophic, compared to, because they'll have no experience or knowledge to fall back on as to how to do it". (ID.8)

"You are effectively deskilling a controller who then has to pick up the pieces when it all goes wrong and then he'll be the one to carry the can at the end of the day because he's been unable to". (ID.9)

"I think it would both necessarily be more or less, just differently skilled about understanding how they work and knowing whether they are working according to how they're designed and what is right and what is wrong and how to deal with it if they suddenly stopped working, so not more or less skilled, just different more of an understanding I guess". (ID.10)

However, such views were countered by a perspective from some others that the automated support would actually *increase* the skills required to perform the role, as Controllers would need to anticipate the information now provided and respond it to by managing the conflux of arriving flights to achieve the optimal stream and spacing determined by the system. Not only would achieving this be more challenging, it would also (now) be visible if this could not be regularly and repeatedly achieved, with a fear that it would lead to both peer pressure/comment and potential management intervention. As such, some Controllers felt that it would require them to 'up their game', and in so doing, would raise the overall skill level required to perform that particular role.

"If anything, it's probably improved. Because I'm chasing a marker, if I turn on to a base leg and a marker appears at a certain place, I'll be turning on to Final Approach at a slightly different time than I would have done if that marker wasn't there. Because the marker's there it gives me a little more assured confidence as to turning on, whether that turn on is ahead or slightly behind, and if I'm going to be slightly ahead, I won't turn on I'll go another sweep or two and then I'll turn on. So, if anything it's improved my ability to do FIN to a slightly better standard, but it's one of those thing's, it's a tool to help us and I believe that it does". (ID.4)

"For myself, holding two validations, it means that on a different sector – I work on a sector that doesn't have TBS and I work on a sector that does have TBS – so having the two doesn't really deskill me, by having it or not having it". (ID.4)

"No really, you've still got to use your experience and judgement to stay on or behind the marker, all you need to know are a basic set of rules that you have different markers for different scenarios and you have certain rules attached to these markers, so to begin with you'd be a little bit more cautious, because you're not quite sure how the aircraft is

going to be against the marker, once you get a feel for it, you let it get closer and closer until you've reached that finite point where you're not happy anymore. So it's no different really, we're just providing a set distance or a calculated distance of compression to touch down whereas before we did it to 4 miles, so there's not a massive difference in the way we operate and in very strong wind conditions it can actually help us a lot". (ID.9)

"No, I don't think so. I think you still need the skill to get the aircraft on the marker, you still need to make a judgement call as to how close". (ID.11)

"I don't think I'm a better controller from using it, but at the same time it's definitely not deskilled us, because it's more difficult, so it hasn't made it easier and it hasn't taken skills of us, because we're still using those same skills and it's harder to put those skills into practice as we get less information". (ID.13)

Some Controllers raised concerns about whether increasing automation may reduce the satisfaction they currently experience in their role, with concerns that some of the more challenging, engaging and satisfying aspects of the role may be automated and undertaken by the system. This led to a concern that the role could become less satisfying. A further concern was that this could reduce the level of situational awareness required to be fully immersed in their interactions with the aircraft traffic patterns and a concern that they would be unaware of what course of action the machine may be planning to execute next. I inferred a sense that if they were to become 'out of the loop' (as discussed in section 2.2) they would not be fully in control of their thought process and would not be able to develop and maintain their own mental model of the continually evolving situation. There was also a view that the role would be less satisfying as the more complex and challenging parts would be performed by autonomous processes, with the risk that their role would evolve from 'controlling' to 'monitoring'. One controller (ID.14) posited that such developments may lead to an opportunity where fewer controllers are required to perform the role.

"If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys

in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job". [ID.5]

"The problems that we had, I mean that we were monitoring, when something went wrong, the work rate was huge, so you have the problem whereby if you put the workforce to monitors rather than say people that are actually proactively working, then the work rate, then the knowledge, the experience goes down, and when you suddenly have to ask them to work in peak periods for example when weather is an issue or there is an emergency when there is something that really focuses you, bad or strong winds that computers can't cope with, you'd then have a huge drop in movement rates because the controller were not sharp, as sharp as they could be, that would be sort of one of the issues". [ID.7]

"It would certainly change the job and it's hard to say how my view of it may change but certainly you may not get the same satisfaction, you may not get the same enjoyment, you may not get the same salary, if you're in just a monitoring-type role. There may be a lot less of us required". [ID.14]

Theme 4 – The Controllers had been engaged in the design and development of the new capability.

The Controllers felt that they had been fully engaged in the development of the new tool, both in terms of its concept of operation and the HMI. The establishment of a 'core team' which included Controllers to represent the views and raise the concerns of the wider community provided a conduit for the flow of requests and ideas between the end-users to the system developers. This resulted in a view that the change of operational concept was being done *with* the Controllers, as opposed to being done *to* the Controllers.

"Whenever I've been involved in a few projects, TBS being one of them, and yeah, your views are taken into account". (ID.5)

"Yeah, through experience and having some involvement in the initial development and the human interface basically". (ID.6)

"I was quite heavily involved in the project itself, so from quite an early stage I was involved, had quite a lot of input". (ID.13)

As well as feeling as being part of the solution and being able to see and experience how their requirements and requests had been addressed, it appeared to help develop a sense of trust between those developing the new capability and those who would be required to use it.

"I think because I was involved with the project, I had no issues with it, because I was chatting to the engineers, several times a week, I totally trust it and that was it. I was thinking that, and maybe it's a bit of naivety, that if I'm told that this works, and it's approved by the CAA, right I can do it, and that's it and I take that as read, I just worked it and that's it". (ID.5)

"It obviously takes different people different amounts of time to learn to trust the tool or whatever, I personally, I was like, the tools been built, I trust the engineers, I trust the fact that it's been approved, I'm just going to work with it and that's it and I get it on the indicator and just let it go". (ID.5)

"You can go to the project leaders if it's a project and they'll listen to your concerns and they'll try and allay any fears if you've got any, they're always encouraging ATCOs to get involved in the development of the project so if there was something that I was particularly interested in then I could get involved that that I'm sure, but no, for me, you know, for me, these tools come in and I'll deal with them and if they don't then I won't have to, so I'm really quite indifferent about them". (ID.10)

The Controllers were also engaged when planning, undertaking and reviewing outcomes of the safety analysis, thereby providing assurances about its integrity and reliability in a transparent and auditable manner. None of the participants stated nor suggested that the opportunities provided by the user engagement channels were misused to usurp the activity or frustrate the motives by using it to make unreasonable demands on the system, such as by arguing for functionality or an HMI that could only be provided at excessive cost solely to make the

investment financially unviable. None sought to abuse the power and trust provided by the management to help develop a solution that would be ultimately supported by the end-users.

Theme 5 – There was a trust in both the integrity and reliability of the innovation and the motives for its deployment.

My interpretations and review of the data resulted in me inferring two sub-themes within an overall theme of trust: i) trust in the capabilities and reliability of the system being used to support the Controllers; and, ii) trust in the motives for its deployment and its usefulness and value, itself linking to the 'perceived usefulness' dimension within technology acceptance models critiqued in the literature review. Trust in the system was supported through a focus on end-user engagement (discussed in Theme 4) to develop a system that operated in a manner that is attuned to the thought processes used by the Controllers and how the service was previously provided, yet not in a manner that replicated or perpetuated human limitations, fallibilities or variability.

> *"…no, I think I rationalised that stuff fairly well and my rationale for that is that there are people far more intelligent that I that have designed these things, looked at thousands and thousands and thousands of pieces of data that are the same – that's why computers are so good at that task – so I had no problems with it – I knew the rules, I still know them, and I was happy that I'd been told that as long as I'm doing that, that's my role fulfilled, ultimately I suppose you could say "Well you'd have to stand up in a court of law" I'd be happy to stand up and say that, that's what was signed off, like I said at high level people that kind of responsibility on, so at my level I'm quite happy". (ID.2)*

> *"No, no I don't not trust it". (ID.3)*

> *"But every time we questioned it we we're told "Trust the marker, you have to trust the marker, you have to work to the marker. That's quite a jump, but you think that's what the marker says, and you're told you have to trust it – all the algorithms have been done, it's had thousands of hours, so you trust it". (ID.3)*

> *"We trust that technology, to a degree. There are certain parts of the technology that we trust more than other. Parts of those are borne out of experience – parts of the distrust are borne out of experience as well. If a new piece of equipment comes in it will take you a long time to trust it, but once you've used that new piece of equipment for a*

long period of time, it will just become part of the ordinary. If it got taken away, you'd find the job a lot harder – but that's obviously a backward step in a way". (ID.4)

"For me in aviation, it's not the technology, the leap is the trust in the technology to ensure that it will work". (ID.4)

"Yeah – huge trust, there has to be, because you couldn't work without that trust". (ID.11)

A key factor in being able to trust the new capability provided was that it was approved as being safe for use by the external safety regulator – the UK Civil Aviation Authority (CAA) – thereby providing an independent assurance that provided users with confidence that it would facilitate safe operations. In some cases, this became visible by Controllers abrogating responsibility for concern, citing that if it was approved by the CAA, then it could be considered as a trusted system and used without concerns.

"Again, it's building up the trust, I think everyone was allowing point 7 of a mile, and now most people are point 3, point 4, I would do, so, I'd say, yeah, there is a little bit of trust, but it's not just trust in the system, it's not just trust in the marker, it's trust in yourself, it's trust in how the aircraft are responding to your feedback regime, the way you're looking at it and the information you're receiving is different and you have to build up some experience level with that". (ID.7)

"It sounds quite petulant in a way, but the marker is there because of a system that is designed by NATS, now if it's wrong, it's NATS' problem, not mine. They've trained me to be next to that marker and trained me what to do if I'm inside the marker, so if the marker is in the wrong place and causes vortex issues, I cannot be held responsible for that because I'm doing what I've been trained to do. So, trust issues? No". (ID.8)

"…that's the equipment we've been given to us, so trust issues? I don't even think about trust to be honest". (ID.8)

"Yeah, through experience and having some involvement in the initial development and the human interface basically". (ID.8)

"The system has been certified [by the CAA] *and is safe to be in operation, then we just follow the rules and go by the system, otherwise nobody knows what rules we're applying so maybe at the beginning yeah there was a bit more of maybe being cautious, looking at the marker a bit more and trying to get a feeling for what the values were, because, as you said, the marker might look too close because you have a heavy and a medium and its now 4 miles as opposed to the 5 that we used to do with distance". (ID.12)*

None of those interviewed challenged the concept that trust can only be a bi-directional construct and reciprocal relationship as advocated by Solomon and Flores (2001), as discussed in section 2.3, who asserted that trust has to be a two-way process that included the recognition of mutual vulnerability thereby both parties exhibiting agency and cognitive awareness. Rather, the theme I was able to develop was one whereby the Controllers gave themselves permission to trust in the reliability and integrity of the information being provided, enabled by assurances that they were using a new tool that was assured as being safe by NATS and approved by the regulating authority. Such assurance provided the necessary level of clarity regarding where ultimate accountability lay if the correct use and application of the information provided by the new tool subsequently resulted in a safety-related incident occurring.

"It obviously takes different people different amounts of time to learn to trust the tool or whatever, I personally, I was like, the tool's been built, I trust the engineers, I trust the fact that it's been approved, I'm just going to work with it and that's it and I get it on the indicator and just let it go". (ID.5)

"…and even now in a day of strong winds, when TBS is saying you can really squeeze them up, it does look odd, it does feel strange, but we've been told, we've been assured that, you know, to trust the technology". (ID.14)

"Yeah, absolutely, those questions did come up in training and in the Ops Room, when it was introduced, there were those questions and queries, but I think we've all just learnt to trust it". (ID.14)

Trust in the system was further supported by it delivering explainable outcomes, with the Controllers feeling that the markers were in a credible location on the radar display and in the same vicinity that they would have placed the aircraft unaided, albeit not as close to the preceding aircraft. Such feelings are consistent with the concepts of 'explainability' previously discussed in section 1.2, whereby individual's find it easier to trust something that is explainable, as opposed to something that might be correct but cannot be deconstructed through logical thought process and experience.

Being able to trust the new system was in part enabled by the Controllers trusting those who had developed it, which is where the bi-directional nature of trust can be set in a more understandable context. As well as expert input from a selected group of operational Controllers to represent the views on the wider user community (both directly and via the recognised Trade Union arrangements) and to act as a two-way conduit as the technology was prototyped and developed, gathering evidence to support the safety case and undertaking the pre-operational analysis required to develop the safety case was undertaken 'in house' by recognised experts within the NATS Research & Innovation and Analytics teams. The impartiality and robustness of the research analysts used within NATS to investigate and validate new operational concepts are known and respected by the Controllers; trust in the system was in part enabled by trusting the scientists and engineers who developed it and undertook stringent safety assurance analysis to assert that the new system would meet its safety requirements.

> *"For me there's a lot of people more knowledgeable than me that have done a lot of research than I have and you've just got to trust these people. They've put the research in and it's going to be safe". (ID.10)*
>
> *"…and I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it". (ID.13)*
>
> *"Not so much, I was involved in the project in the early days and also, before it came in, I've got the years of experience to fall back on, so I know what the new requirements are, the big reductions were just a reclassification, rather than a systemised reduction, so you can always fall back on what you knew previously to make a judgement call as to whether it's roughly correct or not, so I don't have trust issues in that regard, I would*

realise if it was badly wrong, and I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it". (ID.13)

The second sub-theme of trust related to the motives for the change and whether these were to improve service delivery performance, as stated during the development of the new capability, or whether it was also the start of active performance measurement and management, intended to provide evidence of a spectrum of skills and capabilities for subsequent consideration and use. Until the deployment of the new tool, the development of the optimal spacing of the arrival stream was performed solely by the Controllers on the Heathrow Final Approach position. As such, provided that a safe and efficient flow was established, there would be no opportunity for other Controllers, supervisors or management to readily identify inefficient practices that were in effect sub-optimal (i.e. the arrival stream was not as spaced as close as safely possible, thereby reducing runway utilisation).

The deployment of the new tool provided a visible marker that identified the optimal trajectory of aircraft on Heathrow Final Approach, thereby providing (for the first time within the operation) what could be perceived by Controllers as a 'performance baseline' that could be used to compare Controllers in terms of the safety and efficiency of the service provided on that complex and busy position. However, none of those interviewed considered this to be an issue, neither did it restrict nor fetter the Controllers' engagement with the development, transition and use of the new capability.

"A lot of our debriefs and personal ones you have with your colleagues happen over a coffee, and a number of people I heard were unhappy about it, they felt it was going to be a performance-based review towards the work we were doing, are they going to be monitoring how far behind the marker you are on average as a controller, are they going to be monitoring it as a Watch, morning shifts versus afternoon shifts, and I think there was a big concern about whether it was going to be used as more than just a tool to help the controller but a tool almost to punish the controller". (ID.4)

"There was concern amongst my peers, but I've never been concerned, I've always been of the view that if you're doing your job properly then there's nothing to worry about anyway". (ID.10)

"We've been told it won't be used to gauge performance because it's purely a safety tool, there was the initial concern that people were going to be looking at it and saying, 'well this guy, he's not performing to the required standard because he's always this far behind, and it's all there', we've been assured that that's not going to happen". (ID.10)

"There were some discussions at the beginning, that the management were going to monitor the spacing for their own purposes to ensure that the landing rates were as expected, to monitor the performance, so the controllers were a bit worried about their personal monitoring and assessment". (ID.11)

"That hasn't been the case and I think we trust the management above us enough for it not to be an issue for me, with regards for bringing it in, a Heathrow there's always motivations to land more aircraft, it's just the way it is, I don't have trust issues over that, no one is pretending it's any different". (ID.13)

The underlying message that I inferred from the interviews was that the Controllers' trust in both the credibility and understandability of the information provided by the new tool, their trust in the motives for its use, and the ability to observe its usefulness to improve the service delivered were all influencing features in helping achieve Controller acceptance.

Theme 6 – Acceptance of the innovation within the operation by the controllers

No issues or concerns with the acceptance of the new technology were identified, nor with how it was expected to be used to achieve the performance outcomes anticipated. Despite it resulting in a material change of how the service was provided, from 'distance based' to 'time based' rules and criteria developed to support by the new system, all the Controllers accepted that they would need to provide the service differently. The thoughts and experiences raised by the Controllers aligned with the various evolutions of the various technology acceptance model critiques earlier, whereby both usefulness and perceived ease of use are the key determinants in user acceptance (as discussed earlier in section 2.6). All participants understood how using the new capability would deliver benefits to customers by sustaining the landing rate at Heathrow Airport during strong headwind conditions and saw value in using the system to provide a more efficient service, and in a manner that improved safety through automated system support.

Acceptance was further supported by the system automatically generating information that is considered as a guide to assist the Controller (i.e. identifying the optimal safe place to manoeuvre the aircraft to) as opposed to being considered as being the mandatory location irrespective of the Controllers views and judgements. In this respect, whilst using the system is mandatory (as it comes embedded in the radar display system), the information it provides is considered by the Controllers as providing support information to provide the most efficient service possible. Understanding the purpose of the system and accepting that it had been developed as a support tool made it easier for the Controllers to accept it as a positive feature within the existing array of tools available.

"If anything, it's probably made it a little bit easier by the fact it's calculating the winds for you". (ID.5)

"I know there was a lot of fear around when TBS was coming in from a lot of the controllers, I actually, for the most part, I'll take things as face value, I wouldn't say I embraced the change but I didn't fight back against it either, so whenever TBS came in, you're still doing the majority of the role in what the FIN controller used to do". (ID.5)

"I don't think the job has changed massively although in the fact that we're landing more aircraft now, which is fun, you know, because actually it's a little bit harder, you're a little bit busier, and so, my opinion, it's more fun now". (ID.5)

"…it's been a huge benefit, for the resilience of the landing rate. We used to land, if there was a tail-wind, we could land 48, 49 and hour, if there was a strong headwind the landing rate would be down to 32, so you have a 17 per hour range which is, you know, you can't schedule for that, it's ridiculous. Now we land sort of 39, 40 every hour of every day, which is great". (ID.7)

"…you've got a much more resilient landing rate because the spacing's going to be accurate, much more accurate than we could do at the moment". (ID.7)

"I think it has made it easier, there's definitely an element of it's not as difficult, you don't have to visualise a gap without a marker, you can see it with one glance". (ID.11)

5.3 Review of the Card Sort

Tables 6 and 7 presents the outcomes of the card sort. Twice as many cards (30) were selected with what I perceived to hold more negative connotations than those with more positive connotations (15). Such an outcome is aligned with the thrust of the arguments made during the interviews: whilst the Controllers were open-minded to the types of changes that the use and application of future technology could bring to their role, they were generally cautious about how to approach it and portrayed an apprehensive undertone about what the future could hold. Six out of the 14 Controllers picked words that all had what I interpret to convey negative connotations; only two Controllers picked words that had solely positive connotations. Overall, the card sort set out a more cautious approach to how the Controllers views the use and influence of future technology on their role and closer represented the three themes I inferred from the analysis as Limited Awareness, Scepticism and Bearing on Skill Base. There were no instances of the cards selected by a Controller implying a perspective that ran counter to the views expressed during their interview. Table 6 sets out the cards selected by each of the Controllers and with reasons provided.

ID	Cards Chosen	Additions	Narrative / Explanation
1	Dubious Cautious Apprehensive Worried Nervous Sceptical	-	No justifications or explanations offered; no additional word/s identified.
2	Relaxed Comfortable	Interested	"I'd say I'm **Relaxed** about it because what will be will be so that's my attitude towards it, it's probably easy to eliminate, I'm not worried, I'm not caution, I'm not dubious, I'm not nervous, I'm not apprehensive. Am I excited about it? No. I'd say I'm **Comfortable.** Enthused? No. I'm not inspired because it's just a bit like papering over the cracks, do you know what I mean some of this stuff, that whole change that I was involved in, invested in. Am I encouraged? No because it's the same as the others. Am I sceptical? No. I'd say I'm comfortable and relaxed. Yes, I'll write one down, which is **interested**".
3	Sceptical Dubious Apprehensive	-	"All very negative – any additions would be more of the same – anything else would be semantics".
4	Enthused Apprehensive Inspired.	-	"I probably couldn't come up with anything better than those, this company other than companies I've worked for in the past is quite inspiring, by that I'm **enthused** by it, but with that there is **apprehension** about my job but also the jobs of people I am bringing on now as new trainees and bringing them through".

Table 6: Summary Outcomes of the Card Sort

ID	Cards Chosen	Additions	Narrative / Explanation
5	Worried Sceptical Nervous	-	"Okay. I'd probably be, unfortunately they're probably all going to negatives I'd say, I'd probably be **worried** in the fact that as I said before the job going to be pretty boring, worried, I would be probably a bit **sceptical**, I would have thought, that's in my nature anyway. It's funny I'd be worried about how boring that job would be, but I'd also be pretty relaxed about as well as they'd only bring it in it works. Probably going to have to go for **nervous**. I think you've probably nailed it there. I'd only say my worry, there I go again, worry, is that the job would become boring".
6	Cautious, Apprehensive Dubious	-	"I can probably feel a pattern here. I'd say that one, **Cautious**, I'm going to say **Apprehensive** as well actually, and I'll go with **Dubious**".
7	Comfortable Excited Cautious Apprehensive	-	"I can't think of any particular words. I'd just say that I am 50/50 with having reservations but at the same time anything that improves our performance, then I would welcome with a little be of caution, I'd be happy to welcome. I don't see it as a threat to the profession, I don't see it, even if things were slightly deskilled, it would be changing the job slightly in the same way that I believe AC controllers feel much more like the monitors now rather than proactive controllers, they're just as important and just as valuable, but maybe they're achieving more efficiency through automated systems, so, yeah, if that's the case, bring it on".
8	Dubious Relaxed	-	"I'm definitely **Dubious** about it, probably fairly **Relaxed** because I don't believe I'll experience much of it in my career, I've only got 19 years to go and I know how slow paced it is. I wouldn't say, I mean probably enthused is, because I don't mind technology, as much as dubious, I know it's got to come in, I know it will change, I wouldn't say I was excited about it, but I think it has its place and I have to accept that no matter how I feel about it, it will come in because I'm sure it will make things ultimately safer in a way".
9	Apprehensive Excited Cautious	Concerned	"**Apprehensive**, **Excited** if done properly and **Cautious**. The first one that jumped out at me was dubious, but it's not that I'm dubious, I'm err, probably **concerned**, yes concerned.

Table 6 – Outcomes of the Card Sort (cont.)

ID	Cards Chosen	Additions	Narrative / Explanation
10	Relaxed Cautious Comfortable	Apathetic	"I'd probably be contradicting myself here - Relaxed, Cautious and Comfortable - I'm pretty much like what will be will be kind of guy, so **apathetic** might be one, if it's going to happen it's going to happen, and there's nothing I can do to change that, so you might as well accept it".
11	Sceptical Dubious Cautious	-	"**Sceptical**, definitely, **Dubious** and **Cautious**".
12	Sceptical Comfortable Relaxed Cautious	-	"**Sceptical** would be one of them, but at the same time I'm **Comfortable**, I'm not worried, that's the problem with me, I mean I've had a career before, I've worked in different companies, whatever happens I'm not that worried, it's still a good place to be and if it operates slightly differently, that's fine, in fact given the fact that we have remote towers now, maybe I should get a Tower rating and try that, so I don't see it as a threat. If it's done wrongly, then it will be a threat, not just to me but to the industry, but personally whatever happen we'll get there, so sceptical, comfortable, and maybe relaxed, maybe cautious. All these positive ones, I've seen all the hype from years ago, about the industry and we're still in the same place 20 years later, even though we were going to change everything 20 years ago, that's why I can't be too excited"
13	Cautious Relaxed Encouraged	-	"Yeah, a bit of a balance. I'm not averse to new things coming in, it's well worth trying, things that could be achieved. I think there was a good range there".
14	Apprehensive Cautious Relaxed	Positive	"I'd say I'm certainly a little bit **apprehensive**, mainly am I going to be able to work with the technology, am I going to be up the task of working with it, operating with it, getting older every year, technology and the progress of technology is inevitable, and so keeping up with is something I suppose I'm a wee bit **apprehensive** about. It's inevitable in every area of our life. Maybe a little **cautious**, in this environment, you certainly have to be **cautious**, but I wouldn't go as far as saying dubious or sceptical, so **cautious**. **Positive** would be a word rather than excited. Pretty **relaxed** about it. Yeah, I'd say **relaxed** about It".

Table 6 – Outcomes of the Card Sort (cont.)

Cards Selected by Interviewees (ranked in order of occurrence)			
Positive Connotations:	**Count**	**Negative Connotations:**	**Count**
• *Relaxed*	6	• *Cautious*	9
• *Comfortable*	4	• *Apprehensive*	7
• *Exited*	2	• *Dubious*	6
• *Enthused*	1	• *Sceptical*	4
• *Inspired*	1	• *Worried*	2
• *Encouraged*	1	• *Nervous*	2
Total	**15**	**Total**	**30**

Table 7: Card Sort of Controllers' feelings about the influence on their role.

For completeness, the outcomes of the Card Sort and all quoted extracts from the interviews with the Controllers is presented in Appendix 8.

5.4 Controller Feedback on the Analysis

All controllers were provided with the analysis and asked for their views on whether they could recognise the themes I developed from their recollections of the change and interviews; only one controller provided feedback (ID.12).

In summary, ID.12 reflected in written feedback to me that he felt that I had:

> *"…captured quite well the views of the controllers and how they feel about automation coming. There is a comment in the text from the point of GATCO[2]/IFATCA[3]. I think the main difference is that, as GATCO/IFATCA, we are looking at the bigger picture and how the approach to introducing automation can be changed at high level to get better buy-in and engagement from the controllers. There is always going to be a certain element of distrust between the workforce and management but there are ways of reducing or eliminating that (but you do need managers to buy into that join human-machine system approach)".* (ID.12)

More specifically, regarding Theme 3 (Bearing on Skill Base and Job Satisfaction), my inference that automation would perform the more satisfying and rewarding part of the role was challenged by ID.12. The feedback provided was that such a thought now seems to be *"changing slightly within the industry, with Controllers (in general) talking more about collaborative approaches, task-sharing and effectively a joint human-machine system"*. The Controller who provided that feedback cited one of the sessions planned for the upcoming GATCO-BALPA[4] Controller-Pilot Symposium (in October 2021) that will look at a project of EUROCONTROL where the controller could delegate tasks to the automation to be supported by it. Such views were informed by the fact that the new concept of 'digital towers' is not taking away the rewarding tasks from the controller and the dynamic nature of an approach environment makes that unlikely there too, although less complex and dynamic tasking such as high-level enroute control is a completely different matter, where the concepts of service delivery are more predictable and less susceptible to unexpected variability. There is clear evidence to show that the potential influences of automation within the industry is being actively addressed by both the Controller and the Pilot communities.

[2] The Guild of Air Traffic Control Officers.
[3] The International Federation of Air Traffic Controllers Associations.
[4] British Airline Pilots Association.

Specific feedback was received by ID.12 in respect to a comment raised by ID.11 (re-represented below) regarding where ultimate liability lays when the system fails:

> *"I think the difficulties will be the liability and where that lies, so if the system is for example deciding a descent, if the system decides there's a confliction, to resolve it if it needs a descend but it's not going to work for any reason, then where does the liability lay? Is it with the engineers, the software developers, the air traffic controller? Who's responsible for that monitoring?" (ID.11).*

ID.12 recognised the challenges regarding liability when using automation to provide a safety-related service:

> "*This is a great point and one GATCO and IFATCA has raised on a number of occasions. Automation is not God-given, it is developed by humans who will make the same mistakes we do not want controllers to make but introducing automation. That should certainly be a consideration and engineers/developers would need to be much more aware of the safety-critical nature of their work. It is not the same to provide support tools than to provide decision-making tools*". (ID.12, in response to the comment made above by ID.11).

A further point raised by ID.12 was the use of references made by the Controllers to self-driving cars, and how developments in the safe use of such autonomous systems may provide Controllers with experience of starting to trust autonomous systems. This may be able to provide assurances that such advances can be delivered safely and may allow Controllers to understand how analogous developments within ATC could start to be deployed.

5.5 Review of the Conversations with Senior Managers

The conversations with Senior Managers supported the themes I had developed. The positive views of the Controllers on how the innovation was developed and deployed aligned to the overall view that this is seen within the organisation as a successful investment; it has been accepted by the workforce and is delivering the benefits anticipated at the outset. It has not caused fear or uncertainty within the Controller community affected, nor within the wider community about what future advances in technology could bring.

Key issues such as caution and scepticism were immediately recognised as being observable behaviours when engaging the workforce in any type of change, and not unique to ATC, especially those which require a change in role enabled by technology. The views of the Senior

Managers reflect the prevailing (pre-pandemic, early 2020) industrial relations climate with the organisation and what can be seen as 'opening positions' when change is raised, as if informing some form of negotiating position. Such views align with the prevailing power discourses discussed in section 1.4 and are an expected feature of all types of change within the organisation, not just those which relate to technology, although the possibility of a change or dilution in the Controllers' role makes those types of change more challenging.

As well as discussing the possible rational impacts and influences of technical change, the Senior Managers also reported they had observed an *emotional* dimension of structural and functional change within the organisation. Such views were informed by observing reactions to change that those affected may have been unable to observe or identify in themselves, and from a position where the potential influences on a group of Controllers could be observed from a detached position to understand their lived experiences and subjective perspectives. Whilst Controllers are recognised as being an intelligent workforce with the role requiring education and vocational training to Level 5 within the UK educational framework, little research has been undertaken within NATS on the emotional characteristics or psychological traits of those that are able to perform the role. Understanding Controllers' emotions when they experience change may prove valuable in seeing whether future feelings and reactions can be predicted, and mitigating actions and coping strategies developed where the type and extent of future change, be it organisational or functional, is known and where any consequences on those affected can be proactively managed. This possible avenue is explored further in the Discussion and informs one of the recommendations made.

Another outcome from these conversations was the impression I gained that the Senior Managers did not see the prevailing industrial relations as being a barrier to engaging the workforce in the opportunities that automation and the early deployment of systems that use AI and ML could deliver to ATC, nor to the wider industry. They did not consider it to be a threat to the Controllers role, nor something that would inevitably replace them, but rather saw the opportunities it could bring to provided Controllers by enabling them to provide a more strategic (as opposed to immediate and tactical) service. As such, there was a view that technology could evolve the role from 'Air Traffic Control' to 'Air Traffic Management'. The challenge that was recognised was the need to win the 'hearts and minds' of the Controllers, supported by their Trade Union representatives, and that the type of engagement activities used to successfully deploy the specific innovation considered in this research (in terms of UCD

and establishing a Core Team) offered a basis to build upon for more challenging developments.

Finally, none of the Senior Managers reflected to me their thoughts on what such advances could mean to them, as leaders of the organisation. Whilst they expect to remain in management and leadership roles, they did not convey how evolutionary developments among the core workforce may require them to manage and lead differently. None had considered that their roles and contribution may also need to change as technology evolves and the types of supervisory, management and leadership skills required may also need to evolve to match the changing skills, capabilities and expectations of the workforce. In this respect, I inferred a similar perspective to that I inferred from my interviews with the Controllers, that advances in technology that change peoples' roles are inevitable, but that it is easier to think about how it could affect others' roles.

6. Discussion

The analysis identified some specific aspects of the change investigated from the Controllers' perspective, and some more general observations and thoughts from subsequent conversations with the Senior Managers. My analysis and interpretations of the outcomes aligned with some of the constructs identified in the literature review and bore some similarities regarding previous outcomes of change where innovations have been deployed within other ATC organisations.

6.1 Relating the Themes to the Theoretical Literature

The limited awareness of the capabilities of new technology within ATC and the possible influences that this could have on the future role of Controllers may present some challenges for NATS. If the findings from the example selected is representative of the wider Controller community within NATS, there is a possibility that the community as a whole may be cautious about such advances simply due to a lack of awareness of such technology (e.g. fear of the unknown), and might initially mistrust innovations that use or exploit such advances. Such preconceptions may result in a lack of user engagement when new capabilities are identified, with potential fear of the unknown somehow conditioning the Controller community to consider such developments as a threat. This may result in surprise or denial when they realise and understand the capabilities of intelligent autonomous systems and system-support applications using AI and ML algorithms, and how these could be used to supplement, augment or even replace their role in the future. Any such feelings of denial that technical advances exist, or a lack of awareness that they are already being actively being explored (e.g. within the European Commission Horizon 2020 programme), or views that their role is too complex to be replicated, share some similarities with the Denial phase of the Change Curve (Kubler-Ross, 1969) and the Letting Go phase of the Transition Model (Bridges, 1991). When considering future developments that seek to more fully exploit the capabilities of AI and ML systems with ATC, recognising that such a perspective could exist within the Controller community will be an important early activity when identifying when and how best to engage those affected. This is not to say that all Controllers could align with denial, but that it will be valuable to accept that such views may be held by some and that developing appropriate awareness, education and coping strategies may provide some help to move to subsequent phases, ultimately to try to secure end-user acceptance. Being aware of such a possibility and developing mitigating strategies and tactics to manage such views will also help NATS Senior

Managers and Change Managers to understand how the views and feelings of the Controllers can be understood and managed.

When developing the new capability, the system designers and developers were aware that the Controllers would need to be able to accept and become 'unconsciously competent' in using it (Flower, 1999). There was recognition and empathy that there would be a spectrum in the rate at which Controllers learnt to interact with and accept the new tool, with some using the information that it provided to support the development of their own mental models more readily than others. There was thus a conscious decision by both management and the project team to understand the Controllers' requirements as end-users and to demonstrate how these had been delivered. Such a strategy of empathic design and UCD accords with the findings of Norman and Draper (1986), Winter et al (2014) and Kelly and Kelly (2015), as discussed previously in section 2.6. The constructive manner in which the Controllers engaged with the motives and trust shown by the management team to empower the users demonstrated a mature approach by management to end-user engagement, and one which has previously been used within NATS to develop major IT projects which have changed Controllers' roles. The interviews did not identify any behaviours by either side to disturb the balance of that trust, which was (and remains) a key component of the employer/employee relationship within NATS and which underpins changes enabled by its technology development programme.

The reasons set out by the Controllers' in their acceptance of the new tool bore similarities with the UTAUT (Venkatesh et al, 2003), as discussed in section 2.6, with associations inferred from analysis of the interviews regarding the model's various aspects summarised in Table 8.

Aspect of the UTAUT	Supporting evidence identified from the interviews
Effort Expectancy	• UCD and Empathetic Design constructs/processes enabled a design and application that required no additional Controller input. Information was presented in a manner that reflected appropriate HMI standards.
Performance Expectancy	• No additional Controller input was required to be able to use the information provided. Information provided by the tool is credible and reliable, enabling Controllers to fully exploit its capabilities to provide an optimal service.
Social Influence	• Norms within the working environment were already developed through the use of trusted technology, thereby providing a controlled and moderating environment of collective support from the Controllers of the new tools (i.e. the use of technology was not a new concept to them). • Controllers were heavily engaged in the 'core team' moderated overall expectations and provided a conduit for two-way influence between users (in terms of functionality and concept of deliver) and managers (in terms of expectation and acceptance and use). • The information provided by the tool was agreed as providing 'guidance' of the optimal location/trajectory.
Facilitating Conditions	• The information provided was considered by the Controllers to be valid, useable and reliable. Post-implementation reviews and coordination of updates provided by assured software development commensurate with providing a safety-related service provider user confidence. • Opportunities to raise issues or concerns in a transparent and auditable manner were provided.

Table 8: Aspects of the UTAUT (Venkatesh et al, 2003) observed from data analysis.

As well as the themes that were developed, one aspect that might have been expected to be inferred was *Resistance*. Such a theme could have been expected to be inferred from the feelings that some Controllers raised that it would deskill the role, thereby feeling their role could become easier, or by others who felt that it would make the tasking harder. Under such circumstances, some Controllers who may have already been operating at, or close to, their cognitive limits and skills may have felt the new technology would increase the difficulty of the task, potentially to the extent that they may not have 'validated', i.e. been certified as being competent to provide the service using all the ATC facilities required. Irrespective, no evidence of User Resistance to either the revised operating concept or the capabilities of the technology was inferred from the Controllers responses. Nor were there any feelings of resistance generated by concerns that their actions and controlling skills would become more transparent and thus their actions and judgements could come under greater scrutiny; they did not see the new tool as a threat to what they did, how they did it, nor how their role would be viewed by others.

There were no indications when developing the themes of any instances of cognitive dissonance (Festinger, 1957), dispositional resistance (Oreg, 2003) nor was any breach of psychological contract (Argyris, 1960) suggested. The fact no resistance was detected could have resulted from mutual expectations that exist between Controllers and management. ATC is a complex activity, for which Controllers are recognised as being well rewarded. However, undertaking such a rewarding role also confers expectations to help evolve the way the service is provided to exploit the benefits and to be open to innovative ways to improve safety and increase the efficiency of the service provided. As such, there may be an unwritten acceptance that change is expected to occur, supported by an expectation that Controllers will support and engage in the development of new and innovative ways to enhance the ATC system used. However, it is possible that not being able to develop such a theme may be due to the participants being aware of how such perspectives or behaviours could be adversely viewed, thereby being cautious to suppress such opinions. It is also possible that this was the result of a line of questioning or lack of challenge by me as the researcher when undertaking the interviews to elicit such views, in which case that would be a weakness in the content and structure of the interviews.

6.2 Relating the Themes to the Empirical Literature

Concerns raised in the interviews (Theme 3, ID.5, ID.7 and ID.14) about how technology could automate the more satisfying aspects of the Controllers' role and result in it becoming less enjoyable and more standardised resembles the findings of Bekier et al (2011), as reported in section 2.2, who asserted that Controllers are more likely to accept new technology if it does not remove those aspects of the role they find stimulating and motivating. The value of adopting UCD may offer some value in identifying which aspects of the role could be automated whilst still providing a stimulating and motivating role for the Controllers.

Further similarities with the empirical evidence were inferred from the concerns raised by a Controller (ID.6) about how technology could reduce their Situational Awareness (Endsley, 1995) as the automation would obviate the thought processes required used to develop their mental model of the situation and result in them being unaware of the traffic flows and trajectories being planned by the system. Such a situation could result in Controllers feeling that they are 'out of the loop' (as raised by ID.1), as their ability to remain fully engaged in the task is adversely affected by a reduction in situational awareness (as identified by Kaber and Endsley, 1997 and Di Flumeri et al, 2019). The concept of AA (Di Flimeri et al 2019) may offer some contribution here, to help understand how automation can be deployed in a way that reflects such potential outcomes and allocates tasks between the Controller and the system to keep the Controllers focused on the task but without overloading them.

6.3 Considering the Findings in a Broader Context

The example selected focused on the use of a recently developed intelligent autonomous system to enable the Controllers to perform their role under more demanding operating conditions (i.e. strong headwind conditions). The success of the development was in part supported by the acceptance by the Controllers of the new capability, itself enabled by an awareness of perceived usefulness, ease of use and trust in both the integrity of the information provided and the motives for its deployment. As such, the change to the operational concept generated by the new technology was not seen as a threat to the Controllers' role, and whilst some raised concerns about the potential risk of deskilling, others recognised the additional support it could provide to supplement their cognitive skills to maintain performance in the face of increased workload. There was a clearly defined and understood level of intelligence in the capability provided by the new tool and as such the Controllers were able to consider and accept its contribution within that limited context of its

use: it was not seen as a threat. More advanced applications which could reduce the Controllers' autonomy may be seen as a threat and thus may trigger a different set of reactions and responses.

There is thus an opportunity to identify and raise awareness of the beneficial outcomes that technology can provide to the role, not solely in automating existing procedures which rely on the analysis of dynamic flight information, such as the automated replication of manual activity, but to develop air traffic management strategies and tactics which Controllers, irrespective of capability and experience, are unable to.

The views and input from the Senior Managers raised the importance of being aware of the potential emotional dimension that change can have on Controllers, especially when they perceive it to change their role. If the types of advanced changes foreseen in the ATC sector occur and greater automation is deployed to support Controllers, it may be valuable for NATS to start to consider the possible emotional influences that such new technology may start to generate. It is here that it may be useful to reflect on whether the Change Curve (Kubler-Ross, 1969) and the Transition Model (Bridges, 1991) explored in section 2.3 may be able to offer some value in trying to understand the Controllers' feeling as the new system are developed and deployed.

Whilst Controllers are recognised as being an intelligent workforce with the role requiring education and vocational training to Level 5 within the UK educational framework, little research has been undertaken within NATS on the emotional characteristics or psychological traits of those who perform the role. Understanding Controllers' emotions and feelings when they experience change may prove valuable in seeing whether future feelings and reactions can be inferred. If so, mitigating actions and coping strategies may be able to be developed and proactively managed. Vakola et al (2004) found a relationship between personality traits and an employee's attitude towards change, a view which aligns with the earlier work of Huy (1999), who suggested that '…well channelled emotional dynamics can the to the realisation of radical and second-order change' (p.326). Fiol and O'Connor (2002) similarly identified that emotional energy is required to sustain radical change. Whilst their primary focus was on the relationship between emotions and organisational change, such avenues may be able to contribute to the types of changes delivered by the introduction of intelligent autonomous systems. Should that be the case, understanding Controllers' individual 'emotional make-up'

may provide valuable insight when considering the types of changes to ATC that will be delivered through the use of intelligent autonomous systems.

My analysis points to effective and constructive end-user engagement as being influential in the Controllers' acceptance of the innovation. However, unlike the issues experienced by the IT projects discussed in the examples given in section 2.2 where a lack of effective user engagement was seen as a contributory influence in the failures identified, it is not possible to assert here that the effective end-user engagement seen in this project resulted in overall success: as well as the possibility of other influencing aspects, a less effective engagement strategy might not have resulted in failure, although its ultimate acceptance may have taken longer. It is however reasonable to suggest that the Controller engagement strategy adopted was considered as constructive and contributed to the Controllers being able to develop trust in the integrity of the technology and the motives for its deployment, which ultimately contributed to their acceptance of the new capability within the ATC system.

7. Conclusions

The literature confirms that inappropriate or insufficient engagement of end-users is recognised as one of the influencing features in the failure of major IT projects which seek to change how users deliver the service and/or interact with the systems and facilities used. The developments currently being observed in the fields of AI and ML will increase the capabilities and use of intelligent autonomous systems, thereby disturbing hitherto established equilibriums, relationships and boundaries between end-users and the systems they are required to operate. Professional roles are not immune to the changes that this technical disruptor is bringing, nor how it will challenge the existing paradigms that only humans can undertake certain key tasks and perform specialist roles, primarily within the knowledge-based economy. More specifically and from the perspective of myself as a professional within the air transport industry, such developments will start to have a significant influence on how ATC is provided, thereby changing the role, power and influence of the Controller community within the service delivery chain. The use of such types of technical innovations will result in the boundaries between the human (e.g. the Controller) and the machine (the intelligent autonomous ATC systems) becoming increasingly blurred, boundaries which have traditionally been intentionally separated by design to reflect differences in capability. The current demarcation of accountability and cognitive skills between the Controller and the ATC systems they use to provide the service will undoubtedly change, such that the current clear distinction between human decisions and system-supported advice will start to dilute and decision making will become shared between Controllers and the systems they use.

Understanding the importance of engaging the Controller community to facilitate and support the development and widespread use of intelligent autonomous systems within the ATC domain will increase the likelihood of achieving successful outcomes. More so if some of the capabilities being developed are, or could be perceived by Controllers to be, a threat to the level of competence currently required to successfully perform the role, and provide a sense of security, reward and job satisfaction by those who hold such skills. The technical innovation selected in this research allowed me to develop two key themes that could suggest why the capability selected was a success in terms of its acceptance and continued use: i) *effective user-engagement;* and, ii) *trust* in both the capabilities of the system and in the motives for its deployment. However, it also identified what appeared to be an overall rather limited awareness within the Controller community of longer-term possibilities and more significant

implications in terms of their future role. Some of the information I developed in the thematic analysis supported the attributes identified in recognised technology acceptance models, with both 'ease of use' and 'perceived usefulness' being identified by participants as key characteristics which supported its ultimate acceptance. Specific examples and anecdotes were identified from the thematic analysis which aligned with the dimensions proposed by the UTAUT (Venkatesh et al, 2012). The logical flow of emotions and feeling that supported acceptance can be traced back to trust: Controllers understood and trusted both the motives of the change (i.e. to maintain service delivery in a safe and resilient manner during adverse operating conditions) and trusted the robust and independent safety assurance processes which underpinned to development, integration and ongoing use of the new capability.

A distinction can also be made between the need for Controllers to understand the assistance provided by intelligent autonomous systems as an enabling antecedent to developing trust (i.e. the concept of 'explainable' AI discussed in section 1.2) and being willing to accept an advanced tool that is certified as being safe to use by an external accrediting body (such as the UK CAA). Should such a distinction be valid, it may be that Controllers may be willing to tolerate a lower level of trust in intelligent autonomous systems provided they have been approved by a recognised and credible certifying body. No breach of psychological contract was inferred from the analysis of the interviews, rather there appeared to be an understanding that changes in how the operation is provided over time come as part of the role.

The outcomes and consideration of the thematic analysis and the subsequent views raised by the Senior Managers confirmed the importance of understanding and empathising with the possible emotional consequences and outcomes that techno-change could have on Controllers when it could be seen as a threat or disruptor to the established equilibrium. Change management models that recognise the value of understanding emotions, such as the Change Curve (Kubler-Ross, 1969) and the Transition Model (Bridges, 1991), may be able to offer a framework for the constructive engagement of those who will be affected by the increased use in technology to supplement their role.

A limitation of the research was that the innovation used within the example selected was a success in terms of delivery to specification, timescale and budget, thereby not providing an opportunity to infer or induce possible reasons for failure. Given that the deployment and use of the types of innovation considered in this research are quite recent in the timeframe of developments within the ATC domain, examples of failures of introducing the types of change

considered in the recent example considered do not exit. Investigating a project that is accepted as being an 'IT failure' within the ATC sector would have provided an opportunity to explore any potential outcomes or consequences that ineffective engagement of the Controller community might have had on the success of the change. Given the complexity of the types of changes being envisaged and how these can be expected to change the Controllers' role, future innovations may not be as successful, thereby providing opportunities to try to understand any underlying or systemic reasons. Thus, whilst it is possible to suggest that the type and level of Controller engagement provided by the particular innovation considered in the example selected contributed to its success, it is not valid to assert that a lack of such engagement would in itself have resulted in failure. It is however valid to suggest that the type and level of Controller engagement seen (in terms of the participating of valid Controllers on the Core Team; the use of UCD; and strong Human Factors input) all contributed to an outcome that was trusted and accepted by Controllers, which are themselves recognised activities undertaken on successful projects.

From a methodological perspective, the research philosophy (inductive/interpretive) and the method use (semi-structured, face-to-face interviews) worked within the context of the specific change investigated. No limitations or restrictions on access to the interviewees were detected. Nor were there any suspicions that the Controllers interviews were being anything other than being open and willing to discuss all aspects of the project, with their interactions with the development and delivery process, and their wider feelings about the potential outcomes that AI and ML could have on their future role. The corresponding conversations with the Senior Managers identified a similar perspective, although went deeper by raising the importance that understanding the potential influences future changes may have on Controllers' emotions and acceptance or rejection of developments which they may consider as leading to result in more fundamental changes to their role.

The opportunity to undertake research within my sponsoring organisation provided unique access to a group of employees (Controllers and Senior Managers) which would not usually be available to an external researcher, nor would they be permitted to discuss the types of matters covered in this research. It also provided me with a wide-ranging remit to explore any unexpected issues or concerns that the Controllers may have had, and in a manner where they were assured of the anonymous nature of the conversations being held. The depth of the issues discussed may not have been possible if this research has been undertaken by an external party.

The research elicited valuable insights into how the ATC profession engaged with, reacted to, and accepted a specific instance of intelligent autonomous support within a safety-related environment. Access to those affected is ordinarily difficult and restricted due to the nature of the services provided and security constraints. The type of support and access provided by the sponsoring organisation demonstrated a willingness to understand the various aspects that made the development a success whilst also being open and receptive to accepting that the research may have found some aspects that could have been more critical.

8. Recommendations

Based upon an awareness of the culture and prevailing power discourses within NATS, knowledge of the type of research currently being undertaken within the industry to increase the use of intelligent automated systems within ATC, and the outcomes of my own research, the following recommendations are made:

- Recommendation 1: That the potential influences which intelligent automated systems could have on the Controllers' role is specifically considered by NATS during the Research and Innovation phase of any such developments, and in a manner that engages by all affected stakeholders, including trusted representatives from the Controller workforce, akin to the existing concept of the 'core team' but established at the earliest stage of the technical development.
- Recommendation 2: That NATS considers the value of proactively raising the level of awareness and understanding within the Controller community to start to dispel some myths that may exist, with a view to seeking thoughts and ideas from 'the shop floor' about how such advances can be developed within the specific context on ATC. Such a recommendation could be progressed through 'focus groups' or potential 'technology champions' from within the Controller community. Adopting this recommendation may help Controllers and 'live through' the types of technological changes envisaged.
- Recommendation 3: That NATS starts to reflect on the potential emotional aspects that automation may have on the Controllers' role and how any potential concerns or fears that may exist could start to be understood and aired in a safe and constructive environment.
- Recommendation 4: That NATS shares the findings and recommendations made with other ATC services providers via established and respected industry groups (such as CANSO[5]) to increase the value of the contribution that can be made within the wider ATC and aviation community.

My thesis found that relatively little research has been undertaken on the influence of autonomous intelligent systems within the field of Air Traffic Control as compared to other professions which appear more within the eyes of the public, such as the medical, education

[55] Civil Air Navigation Services Organisation, the global body that represents the views and positions of ATC service providers.

and legal professions. To address this potential opportunity, and considering the types of changes being envisaged (e.g. as being progressed by the European Commission Horizon 2020 Research and Innovation initiative), future research could be undertaken within the academic community to consider the influences and potential outcomes of future advances in technology. One possible avenue would be to explore the changing dynamic that technology will deliver between the future role of Air Traffic Controllers and pilots/aircrew, themselves experiencing changes to their role from technical advances.

Contributions to both theory and practice could be further strengthened by disseminating the research through journal articles, with T*he Journal of Change Management, The Human Resource Management Journal*, *Human Factors* and *The Journal of Air Traffic Control* all being potential publications to share and encourage debate on the outcomes of this research. Similar, professional associations and bodies such as the Institution of Engineering and Technology and the Royal Aeronautical Society could provide a credible platform to publicise the outcomes and stimulate further interest and research.

9. Contribution

Contribution to Practice

Understanding how and why individuals can react to change helps to inform effective change management programmes. Whilst much of the literature and evidence provides models and instances applicable to organisational change, the same types of outcomes can occur from functional changes which affect peoples' roles. The type of functional change investigated in this research considered the Controllers' roles being supplemented and potentially replaced with intelligence autonomous systems that use AI and ML characteristics and capabilities. Professions, roles and organisations which understand the influences that such technological advances can have on employees, and in NATS case on its Controllers, will be better placed to plan and prepare to realise the benefits of such opportunities. Being aware of the workforce's attitudes to change will help develop change programmes that have the potential to secure user engagement in a manner that realises unexpected benefits from unforeseen and innovative use, and which can only be achieved when users are prepared to immerse themselves in the full capabilities of the system. This will only happen when the users can fully trust the new system/s that they are using and are aware of the motives that drive the change. From my perspective as a sponsored researcher and being aware of the scale and cost of the investments within the ATC field and the potential outcomes these could have on Controllers' roles, the findings of this research will contribute to the development of an awareness and need to develop engagement initiatives which recognise and address potential outcomes that future technology will have on its workforce. The contribution to practice will be most visible through addressing the recommendations made in a manner that seeks to maximise the value of the outcomes of effective user engagement. The main contribution to practice that my research offers is to raise the awareness within my organisation of how a sub-set of its Controller workforce experienced a significant change to their role and what particular aspects of the change were successfully managed. The research provides a basis for NATS to consider the influences that automation could have within the organisation and reflect on whether it is now timely to better engage its Controllers to raise the overall awareness of the possibilities and possible outcomes.

My employer has responded positively to the conclusions and recommendations, recognising that there is an opportunity to engage those whose roles will be most affected by new technology, whilst being aware that the prevailing employee relations climate may make initial

inroads more challenging. One of the challenges my sponsor raised regarding the deployment of automated tools related to the mindset of Controllers, which as a group are selected and trained to conform to rules and rulesets to operate in a highly processual and systemised environment. Going forward, careful thought will need to be given to engaging a workforce that has been trained to conform and assume full accountability for decisions, as emerging technologies will start to blur cognitive boundaries which have become embedded within the culture of their role. This is different to the intentional manifestation of resistance to change and the actions of a workforce which sees functional change as a threat. Rather, it goes to the root of their views and beliefs of conforming to rules, concepts and operating in a culture of trust, where Controllers not only have their embedded views on their actions and behaviours but expect the same from others.

Contribution the Theory

The findings of the example selected aligned with the constructs and dimensions set out in the UTAUT (Venkatesh et al, 2012). The two key factors of *usefulness* and *perceived ease of use* were specifically identified by those Controllers who were interviewed. The outcomes of the analysis contribute by providing a unique insight into how Controllers experienced and engaged with the deployment of an intelligent autonomous system which changed the way they interacted with a system to provide a safety-related service. The extent of the insights in this research and the candidness of the participants has provided a valuable contribution to the theories of technology acceptance in a workplace setting, informed by trained professionals working within a highly regulated and safety-related field. The research supported the existing body of literature that identifies the importance and value of understanding the emotions when reflecting upon the possible outcomes and consequences that could result from the types of changes expected to be delivered by future advances in technology. Promulgating the key findings of this research will provide anecdotal support to the theories and models which support: technology acceptance models (Davis, 1989; Venkatesh and Davis, 2000; Venkatesh and Bala 2008); constructs that support the importance and the value of emotional engagement in change management initiatives to maximise the user experiences and outcomes (Huy, 1999); and, the value of the theories that underpin the concept of UCD (Norman and Draper, 1986; Winter, Rönkkö and Rissanen, 2014).

The research also supports theories that assert the value and importance of emotions when individuals experience change and how these need to be considered as part of user engagement and enrolment to different situations and outcomes, especially when the outcome could be perceived as a threat. The importance of the ability to recognise and empathise with Controllers as they traverse the spectrum of emotions through the changes observed in this research supports the concepts and theories of empathetic design when implementing new technical facilities where their use is non-discretionary. The use of both cognitive and emotional perspectives developed in the themes supported the concept of 'Design and Designerly Thinking' as a reflexive (Gasparini, 2015). More broadly, the importance of understanding emotions and empathy align with previous analysis undertaken in the field of the development and delivery of advanced technology and intelligent autonomous systems (e.g. Klein, Jiang and Tesch, 2002).

10. Personal Reflexive Statement

As well as contributing to both theory and practice, my decision to undertake DBA studies was motivated by the desire to make a 'contribution to myself', where I sought to develop a better understanding of my ability to undertake research within the robustness of an academic framework at doctoral level. The research required me to make, understand and justify material decisions regarding the research philosophy and methods for data collection and analysis. Such considerations helped me to better understand the value and appropriateness of the variety of research philosophies and methods and to be critical of, and reflect upon, the decisions that I made and the path I followed. Looking back at my learning, I feel that the taught part of the course provided a valuable opportunity to understand the theory and structure underpinning doctoral research, as well as allowing me to become aware of the importance of my ontological and epistemological positions and reflecting on how these may have influenced my professional development and interactions with others within a vocational context.

My research also provided me with greater visibility within my sponsoring organisation and provided a platform to identify where further contributions can be made within the specific field addressed. Furthermore, it provided me with the opportunity to offer support and encouragement to others who may be considering embarking on similar research. I have developed an understanding of the importance of Critical Reflection, and how it can provide insightful and valuable perspectives when considering the outcomes of my actions and behaviours, how others could perceive these, and how they could have shaped and influenced the outcomes.

One aspect that I feel I could have approached more productively was the synthesis between the taught and the research phases. Despite valid advice not to consider these as distinct entities, in retrospect, I now see that I considered these as separate aspects of the journey, almost as if the taught part was a self-contained entity to get through, and the subsequent research phase was the next step. Looking back, given that I knew the topic that I was planning to explore and knew I would have access to the workforce that would be affected by the driver change I was exploring, I could have developed my thinking and summative assignments during the taught phase in a manner that better aligned to the research phase. This would also have strengthened my learning as it would have enabled my summative assignments to be set in a more relevant context.

From a personal learning and development perspective, the outcomes of my viva voce forced me to reflect on my research strategy and reconsider how I had approached some aspects in a far deeper way. In particular, it became clear upon reflection after the viva that I had not provided and justified a clear path for the research strategy that I adopted and as a result my analysis was not developed within a sufficiently robust and understandable framework. The viva helped me see and understand this, and the remedial action required has, I feel, resulted in a thesis that is more robust and thus stands a greater chance of making the contribution I seek. I have also reflected on my feelings and reactions just after the viva, concluding that the comments made were valid and valuable, and rather than seeking to challenge these in my own mind, it was clear that the most productive and constructive approach would be to develop the thesis in a way that addressed the suggestions, and in a way that could add the most value to the objectives of the research. In this respect, I am grateful to my examiners, whose responses and feedback has enabled me to strengthen my research and further develop me as the researcher.

One of my most valuable learning experiences was experiencing how difficult the interviews with the Controllers were in terms of maximising the amount of information that I had initially expected to gather. As well as the answers provided and being aware of the general direction of the conversation, I had expected that I would be able to observe and use non-verbal communications and cues in my analysis. In reality, this was far harder than I had expected. Upon reflection, I am not sure whether this is because, as professional communications, they were able to emotionally detach from the interview, or whether I was (and remain) insufficiently skilled and experienced in observing such cues. Going forward, if I was to undertake any further research, I would be able to reflect on myself as an interviewer and either be more aware of my limitations or consider whether an alternative data collection method may secure the type of information I sought.

I intend to support the progression and further development of the recommendations coming from my research and help develop these further if requested by my sponsoring organisation. From an academic perspective, I am willing and able to support other DBA students in later cohorts to share with them my experiences of the research phase and offer insights into what I felt I did well and what I would do differently in hindsight.

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Appendix 1: Summary of Meetings with Relevant Thought Leaders

Who	Establishment, Date	(Relevant) Field	Key Takeaways / Linkages
Dr Jun Chen	Queen Mary, University of London, 17th October 2019.	Intelligent decision support for airport operations, human factors & brain-computer interface and future flight deck automation systems.	A focus on ground-based automation to increase runway throughout and stand utilisation. An interest in exploring the impact on aircrew of automation – intending to engage with Cranfield University of workload and cognitive impacts.
Professor Neville Stanton	University of Southampton, 18th October 2019.	Research into improving and optimising human performance in systems, especially with the introduction of new technology and automation.	The influence of the HMI on user engagement and trust. Considering what work is and how it will evolve.
Dr Paul Cairns	University of York, 3rd December 2019.	Research methods for interactive technologies, measurement of user experience and player experience in digital games.	Potential linkages between digital gaming theory, task-oriented user experiences and levels of interest/engagement. Research into whether a sweet spot exists between user interest across the ease/difficulty continuum. The use of Federated Systems with Human-in-the-Loop. Relationships between explainability and trust. The concept of the sense of felt uncertainty – with trade-offs between predictability and maintaining engagement. Understanding the influence of feeling external/unexpected uncertainty with training.
Professor John McDermid	University of York, 3rd December 2019	Safety-critical systems, safety engineering, safety of autonomy and robotics. Influences on and importance of certifying regulating / approving bodies.	Leading the Assuring Autonomy programme, citing real like examples / trials of autonomous systems (including trails of automated drug infusions). Applications of autonomous systems within safety related and safety critical

			applications. The value of automating activities that humans are not good at (e.g. monitoring) to provide time to allow them to remain engaged in those things that cannot be provided to autonomous systems.
Dr Mark Nicolson	University of York, 3rd December 2019.	Safety and certification of modular systems including configuration of complex systems. Application of System Safety Engineering into the civil aerospace, automotive, railway, Medical and civil maritime domains.	The importance of engaging with regulators and approving bodies to ensure the development of autonomous systems is set within a recognised framework. The use of robots to provide physiotherapy to stroke victims. The application of Sociotechnical design (structure; people; process' tools' conceptual) – a view that the interview could be developed onto these phases.
Dr Jeremy Goslin	Plymouth University, 4th December 2019.	Behaviour and cognitive neuroscience related to topics in language, economics, and trust, through research into neurocognitive investigation of reinforcement learning, electrophysiological study of tool use in Virtual Reality and implicit cues to trust in humans and robots.	The relationship between user trust and human like behaviours. Trust in subservient systems. The impacts of physical size (of robot) and tone of voice and human trust. Linkages to anthropomorphism and human like physical characteristics. The influence of agency. Relationship between reliability and explainability – do humans relay more on outcomes that are explainable. Electrophysiological Imaging (brain waves/patterns) and linkages with trust. Development of a sweet-spot for trust in autonomous systems – not too little but not too much.

Appendix 2: Participant Information Sheet

Background

The fourth industrial revolution is having a dramatic effect in the workplace, with industries and organisations seeking to exploit the improving capabilities of Artificial Intelligence (AI), digitalisation, automation and robotics. However, such advances are having a significant impact on the way people work – in part redefining what work actually is – and resulting in capabilities that are now challenging the premise that only people can undertake tasks that require greater cognitive capabilities, intellectual capability, experience and reasoning.

Such developments could be seen as a threat to those who have previously enjoyed a monopoly in certain professions (e.g. aviation, medicine, aviation, legal, academia) and it can be expected that such developments would be resisted, as it could be seen as deskilling or dilution of highly capable & specialist roles, with potential consequences on status and terms & conditions.

Engaging future users in the drivers for change and securing their constructive engagement in the change process will be vital to ensure the desired outcomes are fully realised: excessive resistance may frustrate or prevent the change, whereas unchallenged acceptance may result in sub-optimal outcomes. Is there an optimal balance between these two extremes? The successful integration of such capabilities within the workplace is underpinned by the engagement and 'buy-in' of those affected. Change that could affect peoples' roles and effects how they perform their activities can be particularly difficult to manage and requires particular types of engagement and delivery strategies which are different to those used to deliver organisational restructuring where the same general role is performed by fewer people.

My research will focus of the 'people aspects' of such change – how those directly affected become enrolled in the underlying business strategies to understand the commercial drivers and how they can be engaged in the change delivery programme to enable successful outcomes (e.g. how change can be embraced as opposed to resisted).

Context

My research is motivated by exploring the most effective strategies for the change management processes required to support the introduction of intelligent systems and automation within the 'Ops Room', whereby air traffic control services that are (generally) hitherto delivered through the cognitive powers and capabilities of people will the supplemented (and possibly replaced) by automation systems, eXplainable Artificial Intelligence (XAI) and Machine Learning.

Such a development could change the manner in which the Controllers and support staff discharge their roles: they will have to trust, accept and interact with facilities that are depicting a safety-related real-time situation, potentially moving from a 'controlling' roles to a 'monitoring' role. There are thus human and cultural issues that can be explored here, using a small and straightforward airport as a case study example (e.g. the development and Deployment of Times-Based Separation within the TC Ops Room).

Proposed Research

My research will start with a review of the academic and theoretical frameworks that underpin organisational Change Management activities, leading to a more focused review of: i) the capabilities of current and emerging technologies to scope the scale of this professional disruptor; ii) which professions are effected; and, iii) what specific type of Change Management / Business Transformation strategies and methodologies have been used to implement the changes and the perceived level of success.

The initial phase of the research will answer the question "Is there <u>really</u> an issue here?" It may be reasonable to expect there to be HR/IR challenges when deploying systems that support, augment or replace people, but can it be <u>evidenced</u>, and if so, what are/were the challenges and to what extent have they been addressed in the past?

The research will then consider a recent example of innovation in the Operations Room: the transition to the use of Time Based Separation within the TC Ops Room (which has been in operation, and iterated to provide greater capabilities, since 2017/18). The outcomes are expected to enable the development of a user-engagement structure or process to inform

subsequent (and more complex) deployments of such systems as we roll-out the D/SESAR IT Programme and introduce the new concept of Digital Towers.

An interpretivist/inductive methodology will be adopted, with face-to-face, semi-structured, interviews conducted with those directly affected by the transformation activity. The interviews will be recorded and transcribed to enable a Thematic Analysis to be undertaken to identify and explore in detail emergent key themes. Academic contribution at Level 8 (Doctorate) is intended to be made through the identification, documentation and application of Best Practice, enabling the key issues and lessons learned to become embedded within analogous Change Management Programmes within my sponsoring organisation.

The value of my research may be able to be measured in terms of how it could support the successful delivery of this type of large scale, safety-related and expensive investments, where effective user-engagement and buy-in is required to achieve overall success.

Participation

Your participation will be voluntary and anonymous. Any excepts used from the transcribed interviewed will not be attributed to any individual. If you chose to participate, you will be provided with an Ethics Statement to sign and retain to provide evidence of the activities being undertaken to ensure that this research accords with appropriate ethical standards.

Stephen Pybus, DBA Student & Researcher.

26th November 2019.

Appendix 3: Participant Research Ethics.

1. *I am willing to participate in the research being undertaken by Mr Stephen Pybus as part of his DBA studies being undertaken at the University of Winchester.*
2. *I have received the Participant Information Sheet.*
3. *I understand that my participation is and will remain anonymous throughout this research.*
4. *I understand that I can withdraw at any time and for any reason and no reason will be sought from the researcher for such a withdrawal.*
5. *I am providing information from an individual and personal perspective and that any views I may express are my personal views and not those of my current or any previous employer.*
6. *I have not been coerced or pressurised into participating in this research.*
7. *I am receiving no reward for participating in this research.*
8. *I consent to my interview with the researcher being recorded for the sole purpose of the research being undertaken.*
9. *The researcher, Mr Stephen Pybus, has discussed the above points with me and has satisfactorily addressed any points I may have raised.*
10. *I will receive a copy of this Form which will be signed by both myself and the researcher before the interview commences.*

Name of Participant: _____

Signature: _____

Date: _____

Name of Researcher: Mr Stephen Pybus

Signature: _____

Date: _____

Appendix 4 Framework Used to Guide the Semi-Structured interviews

Explaining the Background

- About me and the research
- This meeting is for research purposes only
- Anonymity is assured and no statements will be attributable to any individual
- Ethical consent – run through form and jointly sign if acceptable
- Ask permission to record and transcribe; state that the transcription will be offer to the participant and that any redactions they require will be made. **CHECK THE RECORDER IS RECORDING!**

Opening Aspects – Getting Related - Thoughts / Feelings on AI & Automation in general

- Do you consider yourself to have much knowledge about the advances in AI? *Test the answer as appropriate?*
- Is there any particular aspect or development that you are aware of? *Explore what is said to understand what and why.*
- Do you have any views or feeling about this? *Develop this line as appropriate and steered by the responses.*
- Do you see any possibilities for Air Traffic Control in general? *Explore whether they make any linked between what they have said relating to the outside world and whether they feel it could affect them.*

Potential Outcomes on their Role as an Air Traffic Controller

- How do you see ATC evolving in the next 10 years? *See if they have any views on if or how their role could evolve – do they show any interest in this?*
- Do you think your particular role will be supported by advances in technology?
- Do you have any thoughts or feelings on how AI & Automation may change your role as a controller? *To what extent have they considered such possibilities?*
- Do you feel that your role as a professional will change as the result of future technology? *Develop the thread depending on outcome.*
- Do you feel that there is a channel for your views on technologically driven change to be expressed and listened to? *An opportunity for them to reflect and report on how they feel they were able to influence – test understanding as appropriate.*

The Example Being Used - TBS

- Can you explain how TBS has changed what you do and how you do it? *Reflect on the level of detail provided – help or hindrance, threat or opportunity.*

- Was it difficult to transition from Distance Based to Time Based separation? *Points to training and transition and the possibility that some found it harder / easier than others.*

- Do you feel TBS has made your role easier or harder? *A focus on the role, not just that person.*

- Do you feel it has changed your capabilities and skills? *Pointing to whether they feel this may be a threat, lead to deskilling, challenge observed capabilities.*

- Did you find it hard to trust the new information that TBS was providing you? *Pointing to trusting the system, leading to trusting the motives and whether there are any concerns that this may be being used for undeclared purposes.*

Move to the Cards Sort

- Can you select 3 cards whose words you would recognise on this? *Are these coherent with each other; do they support the preceding conversations; are reasons offered or do I need to probe or challenge?*

- What word/s would you write on the blanks? *Are any alternatives offered?*

Close Out

- Thank you - I will transcribe and show only you this transcript

- You can make changes if you feel that you would like to clarify anything

- Once the thesis is complete, the transcript will be destroyed and the recording erased

- Is there anything further you'd like to add or say?

Switch off the recorder – document any immediate thoughts for subsequent consideration if there was anything in the interview that was out of the ordinary or unexpected.

Appendix 5 Transcript of Example Interview

Interview Transcript: NAME REDACTED

Controller Identity Code: ID4

Date of Interview: 9 January 2020, 15:15hrs to 16:00hrs

Steve Pybus, Researcher & Interviewer	**NAME REDACTED**
Thank you for participating in my research. Can I start by asking if you consider yourself as someone who has much knowledge of artificial intelligence, do you follow the developments and those things being built?	I have some idea of artificial intelligence but I'm sure it would be the sort of thing that if someone sat me down and talked to me about the differences and how big it is I'd probably realise that my knowledge is actually very small – but compared to some people it's probably a lot more, but compared to the entire things it's probably quite narrow.
Have any recent developments or newsworthy items caught your eye over the past couple of months?	The only thing that's happened in the past 48 hours is that I've been potentially looking at getting a new car, and Tesla has come across my radar in terms of wanting to get one, and there's a lot of artificial intelligence in terms of how the Tesla are made in terms of the automotive industry, I believe Elon Musk has brought in quite a lot of interesting ways of putting cars together speedily and well in his factory that allows that to happen. Things such as SpaceX comes across my thing but how that feeds into artificial intelligence I don't really know, but certainly in terms of stuff like that recently, that's probably about it, but you might say something and I might say, yeah…
Over Christmas there was a Sky News article where artificial intelligence has been used to detect breast cancer cells, against some consultants, and the machine came out better.	I actually saw that on the news and to be fair I probably wasn't watching the news properly at the time, it's sometimes on and I did see that bit I didn't really take it in to be fair.
And when you look at your Tesla and the automation in it, do you see analogies between	I think it would take somebody with the financial capital that is changing in the way the motor industry is working with the things like the Tesla is coming through and its only in recent years that its becoming a mass-market car thing for the general population – it's going to take that

that and air traffic control, do you think "*well if the motor industry is doing all these things…*"	sort of input from somebody to do the same thing to the aviation industry. I think the aviation industry is probably already a long way towards it – and to make the leap probably won't be quite as significant as making the leap for the automotive industry. This is purely, and you've caught me at a good time reading about the Tesla in the past 48 hours, it has a self-drive capability. Now we've all heard about self-driving cars, you can buy an upgrade for this car that has a self-drive capability, but they're talking about in the UK not allowing it because of the safety aspects that go with it and it's not just other cars that you need to miss, it's pedestrians, it's bikes, it's motor bikes and all those sorts of things, so how do you make that work? In the aviation industry we've got controlled airspace that have planes coming though that have equipment on board that talk to each other – we already have TCAS in place that can take over from us if two planes are getting relatively close together to be that last chance to get out of a situation. To me that doesn't seem too great a leap to have those planes talking to each other, sort of next generation, to almost take us out of the loop.
So how do you feel about that – in terms of your training, experience, terms and conditions, salary, but then '*out of the loop'*?	I hope it doesn't happen before my retirement, obviously. There's a programme I watched about 15 years ago called something like *"Air Traffic Control – Too Difficult For Humans"* - it was a Discovery Channel Program, I think that was the title of it, and it talked a lot about automation and they finished it by saying you can probably have planes that fly themselves now, you could probably do the job without air traffic controller, but what would that do to the market of aviation? Would you get on a plane that has no pilot and would you get on a plane that has pilot who is not being spoken to by somebody on the ground? People weren't too sure about that – so that is the leap. For me in aviation, it's not the technology, the leap is the trust in the technology to ensure that it will work.
Trust?	Yeap.
And talking of trust, I suppose with all the tools and technology presented before you in the TC Ops Room, you must trust that?	We trust that technology, to a degree. There are certain parts of the technology that we trust more than other. Parts of those are borne out of experience – parts of the distrust are borne out of experience as well. If a new piece of equipment comes in it will take you a long time to trust it, but once you've used that new piece of equipment for a long period of time, it will just become part of the ordinary.

	If it got taken away, you'd find the job a lot harder – but that's obviously a backward step in a way. These new things that are coming in, you go to CTC I'm sure you've got people walking around and they've got no idea what half these people do, but they're the analysts behind how we can bring through new technology, and TBS wasn't brought up an idea from my understanding about controllers, it was brought up by somebody with a bigger brain than any of us, who say well why don't we try and reduce down the gaps between the aircraft landing to a time as opposed to a distance and the let's get the controller's input to that to see how it would work. Most controllers couldn't see how it was going to work when it first came in, most controllers probably distrusted it when they did their simulations – I think when it first came in I certainly remember people saying, we're probably never going to get within half a mile of the marker and nowadays if you took TBS out, people would struggle, so you have these leaps forward that allow you to make our job easier as well as making us better at doing the job but in terms of the full automation, where you don't have any of us sat there on the Heathrow position, we're off in an office marking time to retirement doing something, that's a much bigger leap that would require much more than something new, something new, something new.
So just thinking of TBS, did you use the previous system, before TBS came in, the distance-based system?	Yeah.
Roughly how may years' experience do you have as an operational controller?	So for me, I was, 2004 I started at the College, so on radar, I started training on Heathrow, for just over a year, failed my training, went onto something called Thames radar, where I qualified 2006, started retaining in 2010 on Heathrow, qualified in 2011, so I've been a valid controller nigh on 14 years now, but for Heathrow it's probably been around 7 of these.
And when this TBS thing came in, all of a sudden there was the marker on the screen, how did you feel about such a concept, because previously you had used you skill, experience, capabilities, professionalism, to achieve the distance and you got it right time after time,	Personally, I did not have any problems with it whatsoever and I know that wasn't the experience of a lot of people in the Ops Room had. A lot of our debriefs and personal ones you have with your colleagues happen over a coffee, and a number of people I heard were unhappy about it, they felt it was going to be a performance-based review towards the work we were doing, are they going to be monitoring how far behind the marker you are on average as a controller, are they going to be monitoring

then all of a sudden 'Ronnie the Robot' appears and he puts a marker on the screen for you.	it as a Watch, morning shifts versus afternoon shifts, and I think there was a big concern about whether it was going to be used as more than just a tool to help the controller but a tool almost to punish the controller. In a way it has, because if you go the wrong side of the marker, it's a lot more noticeable, so you're ahead of where you should be. But actually we're a professional organisation that's required to provide a certain amount of distance between the aircraft and in the old days and old school and the way I was initially taught, *"You're a quarter of a mile underneath that, that's fine"*, whereas nowadays, it's not fine, and it's not fine for a reason because we are legally contracted to provide a specific distance between the planes. So it's actually made us do the job better in terms of we're doing it properly, I'm not saying that we didn't do it properly in the past, but the old school way of doing it when it was distance based markers, you know, if it was a 5 mile gap and you got 4.9, I think the phrase I heard a lot when I was training back then was *"Well, that's close enough for government work"*, but now if you're after a 5 mile gap, it actually tells you you're after a 5 mile gap your distance from the marker is minus 0.1 miles and it's written down that we need to do something about that. So it's made our job better in terms of what we're providing to the Tower, better in terms of safety for the planes, I think the concern initially was that it would also be used to say "W*ell why are you 0.1 miles behind the marker every single plane, let's take you off for some remedial training to work that one out*" but it's never happened, and that, when you go back to trust, it's not just trust in the system, it's trust in the powers that be, the management, we call it Level 4, it's where the management sit, what are they going to be looking at from us using this new piece of equipment some in? Several years have passed since it's been in now, and that hasn't happened and because that hasn't happened I think everyone embraces the tool to use it the way it's meant to be used and I think that's probably borne out by the fact that other countries are now looking to pick up similar schemes to use it, which you can understand, NATS make a bit on money out of it and other companies reduce down their delays and its more money for them, so you can understand it.

	Those sorts of changes, brilliant. The distrust and concerns come in because it sits a change for us that different - why is it coming it, is it coming in purely to help, or is there something else involved?
Is there a potential trust issue where you have to accept and trust the technology and at the same time trust the motives of the leadership that are introducing that technology?	Absolutely. I'm presuming, we're going back several years now, that that's not the reason why it's coming in. But you don't really know and it's the case, and there's some amazing computer software that's going on to let the marker come up in the way in which it is, so it's not too much of a stretch in the imagination to put in a piece of code that then, that the General Manager gets a little message that pings up on his desk each morning saying *"Average distant behind the marker yesterday was 0.4, average distance in this hour was 0.3, that was NAME REDACTED, and that's the fifth time that's happened…"*
Do you think it's [TBS] made your job easier?	Yeah, hugely.
And do you think that's effected your skill level?	No, no, because I still think we provide the job in exactly the same way, we just provide it slightly differently. There are occasions when TBS gets turned off, either through design or the thing not working properly and thus breaking and we're all set in the procedures we need to fall back to working a slightly different manner and going back to using distance based markers. For myself, holding two validations, it means that on a different sector – I work on a sector that doesn't have TBS and I work on a sector that does have TBS – so having the two doesn't really deskill me, by having it or not having it.
Do you sometimes get confused?	Well I'm not allowed to work on the Final Director position on Heathrow on a day and work on another FIN positional on the same day, because they've got different rules and regulations – it's actually the spacing requirement because Heathrow use something called RECAT EU spacing whereas the other FIN sectors don't, so to stop you providing RECAT EU spacing and getting it wrong, it's simply a case of if you're doing FIN one day you can't do FIN anywhere else that day. So, you don't have that confusion because there's been a layer of protection build in.

Do you think as an organisation there are communications channels to you as a controller, where your thoughts and input, concerns or constructive comments could be made available and listened to?	I think there is, but I think there is a certain barrier within the system. So we do have something in the Ops Rooms called SORD which allows us to make a note about something, what position you're working, what went wrong, when a new piece of equipment or a new tool or a new way of working, so Thames changed standard vectoring to something called Point Merge, and for a good 8 weeks when it first came in, ExCDS[6] is another great example, for the first 6 weeks of ExCDS coming in, there were floor-walkers behind us – they were not only there to assist, they were more experts in, I suppose ExCDS is a better example, so the floor-walkers behind were all absolute experts in the ExCDS system, so the person sitting down working could very simply turn around and ask a question and that person would have a better understanding of the question. If there was something that didn't quite work right, or they found a better way of working it in the system, either the floor walker or the controller could come out and put it into the SORD and then it would filter down the line, all of these things would be branched out but then collated into a *"Well this is a strip display, this is a strip input, this is a transfer of communication"* the different columns of how it all operates, and then that was fed back to us. So when the tools first came in, I think it was the same for TBS going back a few more years, but there was a lot more with ExCDS for those questions to be filtered, and I certainly remember several months later a great big package came out, 4 or 5 pages long, *"This has been highlighted, this needs changing"* and it was changes quite a lot, it was a much bigger thing than TBS, so much more changes – still now there are software drops to make it better. The way I think about these things is, you can make as many changes in the Ops Room in simulation, we've got the Farnborough sims going on at the moment, on the Special VFR sector which is one that I do, there's been a couple of changes, but enough to get people in the Sim prior to change happening, so we're going through the sim at the moment, I'm one of the trainers, and because I was sick, I was helping out with the whole design process to the airspace change. We brought these changes in and every single step along the way I was saying to the people *"We may be doing this airspace change proposal, we might be changing the procedures, 6 months after O' date it won't be working the same way as the day we brought it in",* because suddenly you've got 40 people, using it day in, day out, and each of

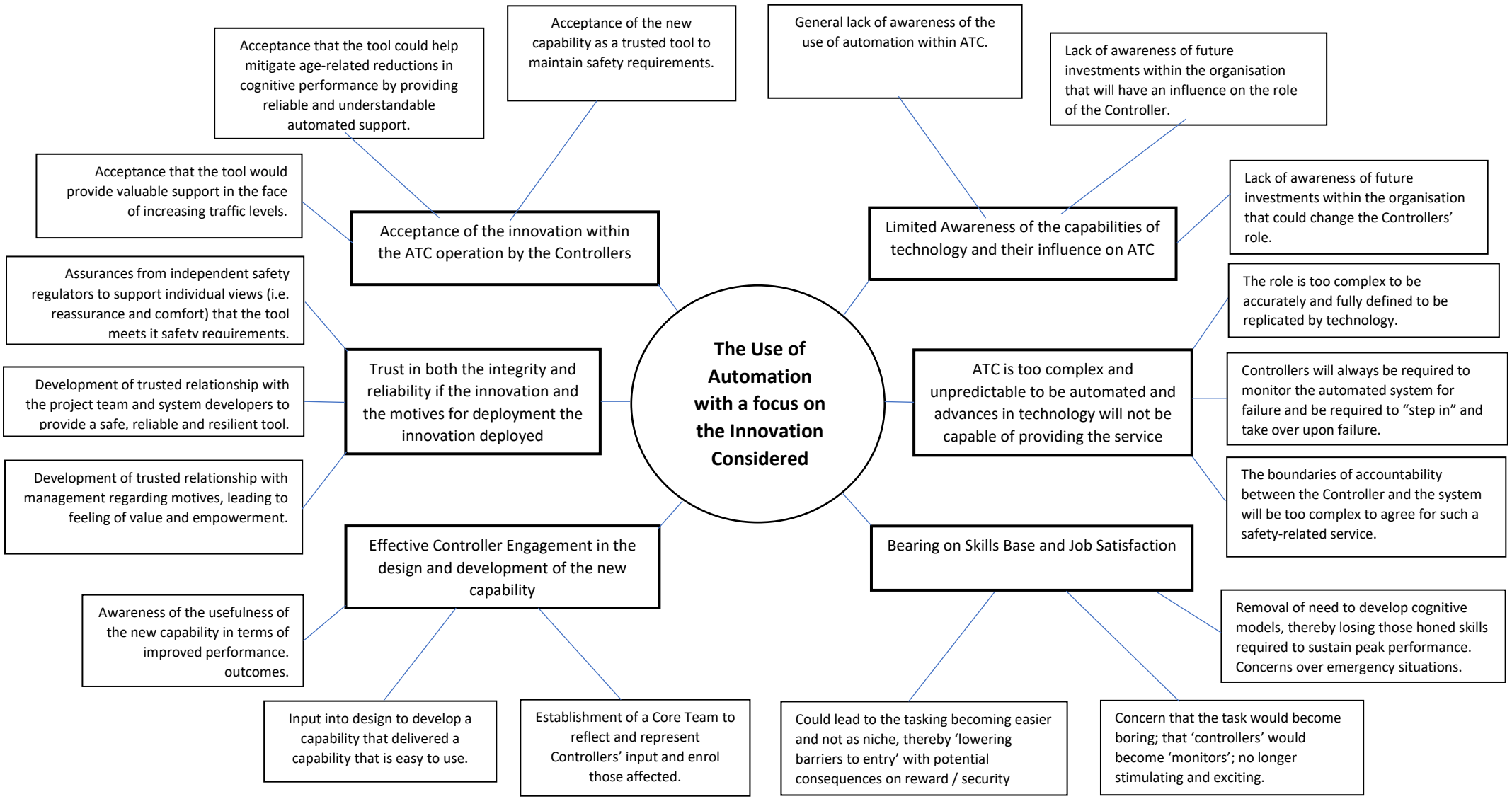
[6] ExCDS is a system that replaced paper flight progress strips with an electronic equivalent to enable rapid dissemination of flight data across the Operations Room and allow direct entry into the ATC system. It was a major technical development but did not automate any of the Controllers functions or activities.

	them will find a slightly better way, until 6 months later, it's being done entirely different but a lot, lot, better. And it's the same with the way TBS and eTBS[7] have come in, everyone was panicking about it and worrying about being a mile behind or half a mile behind and never getting close to the marker, and then we had the whole change that came in when eTBS came in and the markers appeared at different times and that was a bit of an issue for people, but after a bit of experience and after getting some hints and tip from other people along the way, suddenly your experience with using that equipment grows with using that equipment, your experience grows, your confidence level in the tool becomes more assured and therefore you rely on that tool a lot more and by relying a little more you can then find a lot harder to do without it. As is said, we can do without it but its, suddenly you're, it's like Secondary radar – 40 years ago they didn't have secondary radar, and everything was just done on Primary radar.
Do you feel your skill level has changed with TBS, maybe the cognitive abilities to deliver to a distance in changing conditions and the skill you needed for that, now's the tool's there to help you?	If anything, it's probably improved. Because I'm chasing a marker, if I turn on to a base leg and a marker appears at a certain place, I'll be turning on to Final Approach at a slightly different time than I would have done if that marker wasn't there. Because the marker's there it gives me a little more assured confidence as to turning on, whether that turn on is ahead or slightly behind, and if I'm going to be slightly ahead, I won't turn on I'll go another sweep or two and then I'll turn on. So, if anything it's improved my ability to do FIN to a slightly better standard, but it's one of those thing's, it's a tool to help us and I believe that it does.
Okay. Now thinking about air traffic control in the future and thinking about artificial intelligence, maybe automation, I'm going to show you some card. On each card is a word that may or may not resonate with how you feel about that.	So, air traffic control without controllers?

[7] Enhanced TBS was a later development of TBS, used to better accommodate aircraft wake vortex categorisation. The basic concept provided by TBS remained the same.

Supported by, still controllers, still people in the loop, but the activities may be supplemented by artificial intelligence, maybe making string recommendations, and the person either accepting or not. Could you pick no more than three?	[CARDS ARE SELECTED]. **Enthused**, **Apprehensive** and **Inspired**.
There might be some words that you expected to see. If there are, and you would like to reflect what they are, then you can have your own word.	No, I don't think are there, I probably couldn't come up with anything better than those, this company other than companies I've worked for in the past is quite inspiring, by that I'm enthused by it, but with that there is apprehension about my job but also the jobs of people I am bringing on now as new trainees and bringing them though. I worked yesterday in the Sim with some guys who are Heathrow trainees, they're half-way through their training, these are youngsters in their early twenties, they're going to be doing this job for the next 35 years, I don't believe this will affect me, I might be entirely wrong, I've probably got no more than 20 years left in this job, I don't believe that the changes that would affect us in terms of an employment role will entirely happen within that time. It will potentially happen for these guys I was training yesterday, that's where the apprehension comes in, but with lots of these things, they're going to need experts, and in the work we call them SMEs, subject matter experts, we are the people that they need to, you know, it's almost like turkeys voting for Christmas, but there we are, they'll want us and, I was part of the Runway 3 team, and one of the first things I said to them when it was coming in was, how future-proofed are they making the airport, and they said they were doing three runways, so nothing for vertical take-offs, and the guy laughed at me, but this is going to be built in 8 years' time and they're going to want it there for another 40 years, so by that time, things like vertical take-offs will probably be the norm. If vertical take-offs and landings are the norm for planes, do you need a controller, and its technology like that that will advance, that will mean that automation in air traffic will be slightly easier, whereas the way planes fly at the moment, that's where the difficulty comes I think.
Thank you for your time.	

Appendix 6 Thematic Map Induced from the Analysis



Appendix 7 Answers, explanations and positions heard during the interviews that helped inform the Thematic Analysis

ID	Theme 1 – A limited awareness of the capabilities of advancements in technology and how these could influence ATC
1	"Self-driving cars, yeah, it's been on the news, but the finer detail on it, not really".
2	"I wouldn't know unless you said or gave me examples then I might have some knowledge but nothing springs to mind. Maybe my fingerprint on my phone?"
3	"I've seen stuff like that but not paid that much attention".
5	"I know there's many issues for artificial intelligence, it can be used in all manner of industries, I suppose day-to-day we see Alexa, Google, and up to, I suppose, don't know, you've caught me on the hop here, and then you see the high-end stuff I suppose with the talking faces and all that kind of stuff. I know it's used in Trading Floors, that's pretty much it".
6	"I'd say not a lot of detailed knowledge, but quite a lot of interest in what's happening and how it's interacting with us, I guess one of the examples might be when you're on a web site and you get a chat-box come and you think, is this a person or is this a computer? And I've noticed now that lots of companies are making it clear that what you're interacting with is just potentially artificial intelligence kind of programme, so interested, definitely, and from a professional point of view as well".
7	"Fairly limited, only so much as you read in the papers, see on TV and in films. Nothing I can think of, nothing in particular."
8	"To a degree, I guess as much as the next person, not any specific knowledge of it but I realise it has its place and it's coming in more and more".
10	"Not a great deal, only what you see in the movies". "Yeah, I mean I guess it's inevitable it would. The job's going to become more automated as time goes on, most professions, well a lot of professions, appear to be going that way. Aviation particularly, cockpits, flight decks, they're are going a lot more automated, towards monitoring and stuff, so yeah, I guess it's inevitable ours will at some point".

11	“Only like an interest. I saw that Google thing where they built a system to beat the top Go player in South Korea, that was quite incredible, they used Machine Learning and things like that, so yeah only through watching documentaries. Not so much how it works but I know it’s coming. Still can’t quite see it personally”.
12	“I know a bit because when I did my MSc in Electrical Engineering back in the 90s, I worked on neural networks so I did so a bit on artificial intelligence which makes me wonder whether we can have artificial intelligence here yet, or whether it’s just automation. It’s probably not unique but it’s in the minority”. “It’s not going to be the be all and end all and we shouldn’t forget that automation is not given to us, so automation is developed by humans and the same human error that we are trying to prevent by having automation and not the human operator, we embed it in those automated systems, so you just have to be mindful of that”.
13	“I’ve read a couple of articles about that type of thing but nothing particularly in depth. There’s a passing interest but nothing more than that I think”.
14	“No really, no, I hear little bits and pieces and just on the news but it’s not something I really follow, no. Interested in it though”

ID	Theme 2 – A prevailing view that ATC is too complex and variable to be automated, and that the advances in technology will not be sufficiently innovative to deliver the performance of service required
1	"I find that some of the stuff that is automated, although it's helpful, it needs a lot of help, it doesn't work on its own – there's still a lot of human input for it to be used". "If it makes it easier, it's fine. I can't see there ever being a complete replacement". "The problem with that is when it stops working – it's then going back to "is it still possible to do it without them" or has it become so automated and help by our computers that when they stop working, the whole system stops, whereas whether there is less automation its quite easy just to keep it going".
2	"I think we'll get more tools, whether they aid us or not I don't know, whether they're there to take over or not, I don't know, but for the reason I said before, I don't see it evolving that rapidly". "I think it's too dynamic, I think the planes are too close together, the impact of things outside controlled airspace and weather situations just to name a couple, without going into emergency situations etc, etc. I think there's too many variables for what a computer could do".
3	"I'm sure there's plans in the pipeline – I'm sure there are - it will hopefully be a long time after I retire and hopefully after I stop flying". "I think it probably will become more automated, that just seems to be the natural progression of everything at the moment – how much more automated that can be I don't know". "I don't know, I don't know because, well it depends what kind of things come through, the last couple of years there's been a lot of change, a lot of change together, so how much more of that can change in the next ten years I'm not entirely sure. What else they could do to support what we do I'm not entirely sure either. I suppose I'm sceptical in a way, maybe because I've been doing the job for longer".
4	"Would you get on a plane that has no pilot and would you get on a plane that has pilot who is not being spoken to by somebody on the ground? People weren't too sure about that – so that is the leap. For me in aviation, it's not the technology, the leap is the trust in technology to ensure that it will work".

	"It's almost like turkeys voting for Christmas".
5	"If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job". "I thought about this years ago. I thought at some stage we'd be made redundant basically by artificial intelligence. Having seen the pace that NATS moves at bringing new projects and stuff in I think I'm definitely getting a career out of it. Beyond that I don't know, we'll see".
6	"I think it's inevitable that there will be more automation of tasks, but with that comes the usual caveat that comes with aircrew as well, you know, if you just become a monitor of automated systems, when that automated system comes across a situation it can't deal with or doesn't like, then it hands over to the human element, and the human element is then left with perhaps less of an idea of what's going on than they might have had, had they had more involvement". "From that point of view I think you need to be careful in this profession of just going gung-ho, automated everything and then have the controller, yes they can work ten times more traffic, but actually more often than not there is something unusual going on, whether it's weather or it's an emergency or whatever to deal with, so you know artificial intelligence is always going to struggle at the moment with the surprise element".
7	"It's always struck me that there are so many variables all the time for the job that we do, it's always very difficult to put that into a computer, and to have a learning computer and to learn and make its own decisions would I guess be a massive step forward, but I can't imagine we are even close to that at the moment".
9	"I think long term it's a threat, I don't necessarily think it's a threat for me because I've got less than 20 years left, I'm 43, so the reality of something that significant happening between now and the time I retire is pretty slim".

	"I think we're almost a special case in that it takes so long to train us, and it is a difficult job so not everyone who wants to do it can do it, even after training. I think there are lots of factors here at play, I think there could be things brought in with a view to getting rid of us eventually".
10	"I think it will definitely support it – I don't think it will replace it. They've tried a lot of different methods of, like telling us when we need to turn the planes, letting planes do it on their own, and not one of them yet has managed to come in, it can't understand the intricacies of what it is we do and the fine margins to which we work, so, it's quite difficult for something to come in that can cover all eventualities, so yeah I'm sure there'll be stuff that comes in that will support us in that, but in terms of replacing our job, for the next, well as far as I can see, I'm going to be safe until I retire".
11	"I think the difficulties will be the liability and where that lies, so if the system is for example deciding a descent, if the system decides there's a confliction, to resolve it if it needs a descend but it's not going to work for any reason, then where does the liability lay? Is it with the engineers, the software developers, the air traffic controller? Who's responsible for that monitoring?" "You can't have a system that is not safe but a controller whose job it is to make it safe, it just wouldn't be acceptable. Not just for my employment or my job, probably for the airlines themselves have to bear that risk as well"
12	"I think artificial intelligence is used as a buzz word, but it's not really artificial intelligence that we're going to see in the Ops room or in Control Towers or even in the cockpit. Definitely not yet, we're a long way away, because we were already working on neural networks in the 90s and we don't even see that in some of the areas of wireless communications I used to work on".
13	"I think that's the main stumbling block of any form of project that we do of that nature, just trying to systemise and standardise things, the need for flexibility but also predictability, there's a conflict there that's difficult to manage" "Yes, it does currently, it's a difficult one because, especially new technology, trying to introduce it is always the difficult bit, sometimes they help, but more often we work around them, we make them work by getting used to then rather than being supported by them, depends what it is, depends how robust the training is, depends how robust the systems are, there's a lot of variables".

ID	Theme 3 – Bearing on Skill Base and Job Satisfaction
1	"It can make you feel deskilled". "To me that doesn't seem too great a leap to have those planes talking to each other, sort of next generation, to almost take us out of the loop". "Well I think it would deskill, mainly because you'd no longer need to remember the distance the aircraft are required to be apart – because it tells you on the radar". "Well it's now on the screen in front of me so I don't need to learn it – it's fine as it works, but having less knowledge I don't think is a good thing - I feel I should know it".
3	"I guess it would take away some of the decision making that I have, but with that I think it would also deskill controllers, I think that's what I've noticed already". "When I look at trainees coming through now, I think well, how are they going to do it if its broken, will they know how to do it, what will happen to the landing rate if it breaks and we can't use it?". "What does concerns me is if we are being deskilled, that's what concerns me, not how people think about it or how people perceive air traffic controllers".
4	"For myself, holding two validations, it means that on a different sector – I work on a sector that doesn't have TBS and I work on a sector that does have TBS – so having the two doesn't really deskill me, by having it or not having it". "If anything, it's probably improved. Because I'm chasing a marker, if I turn on to a base leg and a marker appears at a certain place, I'll be turning on to Final Approach at a slightly different time than I would have done if that marker wasn't there. Because the marker's there it gives me a little more assured confidence as to turning on, whether that turn on is ahead or slightly behind, and if I'm going to be slightly ahead, I won't turn on I'll go another sweep or two and then I'll turn on. So, if anything it's improved my ability to do FIN to a slightly better standard, but it's one of those thing's, it's a tool to help us and I believe that it does".

5	"If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job"
6	"I think there's a danger of it decreasing situational awareness, certainly with TBS one of the points that I noted fairly early on is a loss of awareness sometimes of the wake vortex categories of the aircraft, well not a loss of awareness, a loss of the awareness of the usual space you might be applying behind a particular aircraft and slavishly sticking to the TBS marker might you know, "*is the marker correct?*"."
7	"I think that like most tools we have, for 85, 90% of our time, it's made our job easier, but for those sometimes when it's not working or there are some other aggravating factors it's made it much harder, because maybe we have lost those skills a little bit, so yeah there's a lot of tools in air traffic like that, but when these tools fail, we're very good at cutting the flow rates right down until they're back in place". "Yeah. One, we'd be slightly less accurate just naturally as we might now have the skills, and you're talking about a small margin, and two, we wouldn't want to push ourselves too far until we'd built up that skill and experience. I mean, if you go, if I was on leave for two weeks, I came back and I was doing the Final Director, I wouldn't expect myself to hit the same spacing as I did if I'd been in for the past 3 weeks, there's an automatic, you're more defensive, it's a skill level that you build up to, so yeah".
8	"Judgement wise, it's probably not too dissimilar to what we were doing it's just that element of the unknown of what actual gap we're going for, so certain skills have been degraded, but are they critical skills? Probably not, and you can get away with it anyway, so it's not a huge degradation of skills". "Me personally, it will definitely deskill me, but to the extent of a person who comes is who hasn't experienced controlling the way I have in the past, for them, when the system does break, which it would, it will be catastrophic, compared to, because they'll have no experience or knowledge to fall back on as to how to do it".

	"I see more and more, now, people doing things they would never have done on paper because it's electronic so they take it more as a written and that is correct as opposed to the system having any fallibility in that somebody's just written something incorrectly on the strip, so technology leads you to cut corners in a way because you're more reliant on it and you believe its technology so it can't be wrong but its misleading you". "You still have to think a little bit, you don't think as much, I don't personally as much as I did with distance based. Judgement wise, it's probably not too dissimilar to what we were doing it's just that element of the unknown of what actual gap we're going for, so certain skills have been degraded, but are they critical skills, probably not, and you can get away with it anyway, so it's not a huge degradation of skills".
9	"You are effectively deskilling a controller who then has to pick up the pieces when it all goes wrong and then he'll be the one to carry the can at the end of the day because he's been unable to". "No really, you've still got to use your experience and judgement to stay on or behind the marker, all you need to know are a basic set of rules that you have different markers for different scenarios and you have certain rules attached to these markers, so to begin with you'd be a little bit more cautious, because you're not quite sure how the aircraft is going to be against the marker, once you get a feel for it, you let it get closer and closer until you've reached that finite point where you're not happy anymore. So it's no different really, we're just providing a set distance or a calculated distance of compression to touch down whereas before we did it to 4 miles, so there's not a massive difference in the way we operate and in very strong wind conditions it can actually help us a lot".
10	"I think it would both necessarily be more or less, just differently skilled about understanding how they work and knowing whether they are working according to how they're designed and what is right and what is wrong and how to deal with it if they suddenly stopped working, so not more or less skilled, just different more of an understanding I guess".
11	"No, I don't think so. I think you still need the skill to get the aircraft on the marker, you still need to make a judgement call as to how close"
13	"I think there's an element of that already, whenever there are certain aspects of the job where automation comes into it, then you do get deskilled, as a natural consequence of that, I don't worry to the extent that we're not going to be required".

	“I don’t think I’m a better controller from using it, but at the same time it’s definitely not deskilled us, because it’s more difficult, so it hasn’t made it easier and it hasn’t taken skills of us, because we’re still using those same skills and it’s harder to put those skills into practice as we get less information”.
14	“It would certainly change the job and it’s hard to say how my view of it may change but certainly you may not get the same satisfaction, you may not get the same enjoyment, you may not get the same salary, if you’re in just a monitoring-type role. There may be a lot less of us required”.

ID	Theme 4 – The users had been engaged in the design and development of the new capability
5	"Whenever I've been involved in a few projects, TBS being one of them, and yeah, your views are taken into account". "I think because I was involved with the project, I had no issues with it, because I was chatting to the engineers, several times a week, I totally trust it and that was it. I was thinking that, and maybe it's a bit of naivety, that if I'm told that this works, and it's approved by the CAA, right I can do it, and that's it and I take that as read, I just worked it and that's it". "It obviously takes different people different amounts of time to learn to trust the tool or whatever, I personally, I was like, the tools been built, I trust the engineers, I trust the fact that it's been approved, I'm just going to work with it and that's it and I get it on the indicator and just let it go".
6	"Yeah, through experience and having some involvement in the initial development and the human interface basically".
10	"You can go to the project leaders if it's a project and they'll listen to your concerns and they'll try and allay any fears if you've got any, they're always encouraging ATCOs to get involved in the development of the project so if there was something that I was particularly interested in then I could get involved that that I'm sure, but no, for me, you know, for me, these tools come in and I'll deal with them and if they don't then I won't have to, so I'm really quite indifferent about them".
13	"I was quite heavily involved in the project itself, so from quite an early stage I was involved, had quite a lot of input".

ID	**Theme 5 – There was a trust in both the integrity and reliability of the innovation and un the motives for its deployment.**
2	…no, I think I rationalised that stuff fairly well and my rational for that is that there are people far more intelligent that I that have designed these things, looked at thousands and thousands and thousands of pieces of data that are the same – that's why computers are so good at that task – so I had no problems with it – I knew the rules, I still know them, and I was happy that I'd been told that as long as I'm doing that, that's my role fulfilled, ultimately I suppose you could say "*Well you'd have to stand up in a court of law*" I'd be happy to stand up and say that, that's what was signed off, like I said at high level people that kind of responsibility on, so at my level I'm quite happy".
3	"No, no I don't not trust it". "But every time we questioned it we we're told "*Trust the marker, you have to trust the marker, you have to work to the marker*".That's quite a jump, but you think that's what the marker says, and you're told you have to trust it – all the algorithms have been done, it's had thousands of hours, so you trust it".
4	"For me in aviation, it's not the technology, the leap is the trust in the technology to ensure that it will work" "We trust that technology, to a degree. There are certain parts of the technology that we trust more than other. Parts of those are borne out of experience – parts of the distrust are borne out of experience as well. If a new piece of equipment comes in it will take you a long time to trust it, but once you've used that new piece of equipment for a long period of time, it will just become part of the ordinary. If it got taken away, you'd find the job a lot harder – but that's obviously a backward step in a way". "A lot of our debriefs and personal ones you have with your colleagues happen over a coffee, and a number of people I heard were unhappy about it, they felt it was going to be a performance-based review towards the work we were doing, are they going to be monitoring how far behind the marker you are on average as a controller, are they going to be monitoring it as a Watch, morning shifts versus afternoon shifts, and I think there was a big concern about whether it was going to be used as more than just a tool to help the controller but a tool almost to punish the controller". "Those sorts of changes, brilliant. The distrust and concerns come in because it sits a change for us that different - why is it coming it, is it coming in purely to help, or is there something else involved?"

5	"It obviously takes different people different amounts of time to learn to trust the tool or whatever, I personally, I was like, the tool's been built, I trust the engineers, I trust the fact that it's been approved, I'm just going to work with it and that's it and I get it on the indicator and just let it go".
6	"Occasionally, particularly in certain wind conditions, in strong wind conditions, the markers for heavy gaps in particular can seem really quite close which is quite different to how it used to be – you know, we'd go for a distance based of maybe 4 miles or whatever and it can be down to 3 miles which seems really quite bizarre, even now, however so many years since TBS came in but I think I've learned to trust it."
7	"Again, it's building up the trust, I think everyone was allowing point 7 of a mile, and now most people are point 3, point 4, I would do, so, I'd say, yeah, there is a little bit of trust, but it's not just trust in the system, it's not just trust in the marker, it's trust in yourself, it's trust in how the aircraft are responding to your feedback regime, the way you're looking at it and the information you're receiving is different and you have to build up some experience level with that".
8	"Yeah, through experience and having some involvement in the initial development and the human interface basically". "It sound quite petulant in a way, but the marker is there because of a system that is designed by NATS, now if it's wrong, it's NATS' problem, not mine, they've trained me to be next to that marker and trained me what to do if I'm inside the marker, so if the marker is in the wrong place and causes vortex issues, I cannot be held responsible for that because I'm doing what I've been trained to do, so trust issues? No." "I don't even think about trust to be honest".
10	"For me there's a lot of people more knowledgeable that me that have done a lot of research than I have and you've just got to trust these people. They've put the research in and it's going to be safe" "We've been told it won't be used to gauge performance because it's purely a safety tool, there was the initial concern that people were going to be looking at it and saying, *"well this guy, he's not performing to the required standard because he's always this far behind, and it's all there"*, we've been assured that that's not going to happen".

	"There was concern amongst my peers, but I've never been concerned, I've always been of the view that if you're doing your job properly then there's nothing to worry about anyway".
11	"There were some discussions at the beginning, that the management were going to monitor the spacing for their own purposes to ensure that the landing rates were as expected, to monitor the performance, so the controllers were a bit worried about their personal monitoring and assessment". "Yeah – huge trust, there has to be, because you couldn't work without that trust".
12	"The system has been certified and is safe to be in operation, then we just follow the rules and go by the system, otherwise nobody knows what rules we're applying so maybe at the beginning yeah there was a bit more of maybe being cautions, looking at the marker a bit more and trying to get a feeling for what the values were, because, as you said, the marker might look too close because you have a heavy and a medium and its now 4 miles as opposed to the 5 that we used to do with distance".
13	"And I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it". "That hasn't been the case and I think we trust the management above us enough for it not to be an issue for me, with regards for bringing it in, a Heathrow there's always motivations to land more aircraft, it's just the way it is, I don't have trust issues over that, no one is pretending it's any different" "Not so much, I was involved in the project in the early days and also, before it came in, I've got the years of experience to fall back on, so I know what the new requirements are, the big reductions were just a reclassification, rather than a systemised reduction, so you can always fall back on what you knew previously to make a judgement call as to whether it's roughly correct or not, so I don't have trust issues in that regard, I would realise if it was badly wrong, and I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it".
14	"And even now in a day of strong winds, when TBS is saying you can really squeeze them up, it does look odd, it does feel strange, but we've been told, we've been assured that, you know, to trust the technology".

	“Yeah, absolutely, those questions did come up in training and in the Ops Room, when it was introduced, there were those questions and queries, but I think we’ve all just learnt to trust it”.

ID	Theme 6 – Acceptance of the innovation within the operation by the controllers
3	"I can see the benefits of it".
5	"I know there was a lot of fear around when TBS was coming in from a lot of the controllers, I actually, for the most part, I'll take things as face value, I wouldn't say I embraced the change but I didn't fight back against it either, so whenever TBS came in, you're still doing the majority of the role in what the FIN controller used to do". "I don't think the job has changed massively although in the fact that we're landing more aircraft now, which is fun, you know, because actually it's a little bit harder, you're a little bit busier, and so, my opinion, it's more fun now". "If anything, it's probably made it a little bit easier by the fact it's calculating the winds for you".
7	"It's been a huge benefit, for the resilience of the landing rate. We used to land, if there was a tail wind, we could land 48, 49 and hour, if there was a strong headwind the landing rate would be down to 32, so you have a 17 per hour range which is, you know, you can't schedule for that, it's ridiculous. Now we land sort of 39, 40 every hour of every day, which is great" "You've got a much more resilient landing rate because the spacing's going to be accurate, much more accurate that we could do at the moment".
11	"I think it has made it easier, there's definitely an element of it's not as difficult, you don't have to visualise a gap without a marker, you can see it with one glance".

Appendix 8: Outcome of Card Sort and Interview Extracts

ID	Cards Chosen / [Added]	Extracts from Interview
1	Dubious Cautious Apprehensive Worried Nervous Sceptical	"Self-driving cars, yeah, it's been on the news, but the finer detail on it, not really". "To me that doesn't seem too great a leap to have those planes talking to each other, sort of next generation, to almost take us out of the loop". "I find that some of the stuff that is automated, although it's helpful, it needs a lot of help, it doesn't work on its own – there's still a lot of human input for it to be used". "If it makes it easier, it's fine. I can't see there ever being a complete replacement". "The problem with that is when it stops working – it's then going back to "is it still possible to do it without them" or has it become so automated and help by our computers that when they stop working, the whole system stops, whereas whether there is less automation its quite easy just to keep it going". "It can make you feel deskilled". "Well I think it would deskill, mainly because you'd no longer need to remember the distance the aircraft are required to be apart – because it tells you on the radar". "Well it's now on the screen in front of me so I don't need to learn it – it's fine as it works, but having less knowledge I don't think is a good thing - I feel I should know it".
2	Relaxed Comfortable [Interested]	"I wouldn't know unless you said or gave me examples then I might have some knowledge but nothing springs to mind. Maybe my fingerprint on my phone?"

		"I think we'll get more tools, whether they aid us or not I don't know, whether they're there to take over or not, I don't know, but for the reason I said before, I don't see it evolving that rapidly". "I think it's too dynamic, I think the planes are too close together, the impact of things outside controlled airspace and weather situations just to name a couple, without going into emergency situations etc, etc. I think there's too many variables for what a computer could do". "No, I think I rationalised that stuff fairly well and my rational for that is that there are people far more intelligent that I that have designed these things, looked at thousands and thousands and thousands of pieces of data that are the same – that's why computers are so good at that task – so I had no problems with it – I knew the rules, I still know them, and I was happy that I'd been told that as long as I'm doing that, that's my role fulfilled, ultimately I suppose you could say "*Well you'd have to stand up in a court of law*" I'd be happy to stand up and say that, that's what was signed off, like I said at high level people that kind of responsibility on, so at my level I'm quite happy".
3	Sceptical Dubious Apprehensive	"I've seen stuff like that but not paid that much attention". "I'm sure there's plans in the pipeline – I'm sure there are - it will hopefully be a long time after I retire and hopefully after I stop flying". "I think it probably will become more automated, that just seems to be the natural progression of everything at the moment – how much more automated that can be I don't know". "I don't know, I don't know because, well it depends what kind of things come through, the last couple of years there's been a lot of change, a lot of change together, so how much more of that can change in the next ten years I'm not entirely sure. What else they could do to support what we do I'm not entirely sure either. I suppose I'm sceptical in a way, maybe because I've been doing the job for longer" "I guess it would take away some of the decision making that I have, but with that I think it would also deskill controllers, I think that's what I've noticed already". "When I look at trainees coming through now, I think well, how are they going to do it if its broken, will they know how to do it, what will happen to the landing rate if it breaks and we can't use it?".

		"What does concerns me is if we are being deskilled, that's what concerns me, not how people think about it or how people perceive air traffic controllers". No, no I don't not trust it". "But every time we questioned it we we're told "*Trust the marker, you have to trust the marker, you have to work to the marker*". That's quite a jump, but you think that's what the marker says, and you're told you have to trust it – all the algorithms have been done, it's had thousands of hours, so you trust it" "I can see the benefits of it".
4	Enthused Apprehensive Inspired	"Would you get on a plane that has no pilot and would you get on a plane that has pilot who is not being spoken to by somebody on the ground? People weren't too sure about that – so that is the leap. For me in aviation, it's not the technology, the leap is the trust in technology to ensure that it will work". "It's almost like turkeys voting for Christmas". "For myself, holding two validations, it means that on a different sector – I work on a sector that doesn't have TBS and I work on a sector that does have TBS – so having the two doesn't really deskill me, by having it or not having it". "If anything, it's probably improved. Because I'm chasing a marker, if I turn on to a base leg and a marker appears at a certain place, I'll be turning on to Final Approach at a slightly different time than I would have done if that marker wasn't there. Because the marker's there it gives me a little more assured confidence as to turning on, whether that turn on is ahead or slightly behind, and if I'm going to be slightly ahead, I won't turn on I'll go another sweep or two and then I'll turn on. So, if anything it's improved my ability to do FIN to a slightly better standard, but it's one of those thing's, it's a tool to help us and I believe that it does". "For me in aviation, it's not the technology, the leap is the trust in the technology to ensure that it will work"

		"We trust that technology, to a degree. There are certain parts of the technology that we trust more than other. Parts of those are borne out of experience – parts of the distrust are borne out of experience as well. If a new piece of equipment comes in it will take you a long time to trust it, but once you've used that new piece of equipment for a long period of time, it will just become part of the ordinary. If it got taken away, you'd find the job a lot harder – but that's obviously a backward step in a way". "A lot of our debriefs and personal ones you have with your colleagues happen over a coffee, and a number of people I heard were unhappy about it, they felt it was going to be a performance-based review towards the work we were doing, are they going to be monitoring how far behind the marker you are on average as a controller, are they going to be monitoring it as a Watch, morning shifts versus afternoon shifts, and I think there was a big concern about whether it was going to be used as more than just a tool to help the controller but a tool almost to punish the controller". Those sorts of changes, brilliant. The distrust and concerns come in because it sits a change for us that different - why is it coming it, is it coming in purely to help, or is there something else involved?"
5	Worried Sceptical Nervous	"I know there's many issues for artificial intelligence, it can be used in all manner of industries, I suppose day-to-day we see Alexa, Google, and up to, I suppose, don't know, you've caught me on the hop here, and then you see the high-end stuff I suppose with the talking faces and all that kind of stuff. I know it's used in Trading Floors, that's pretty much it" "If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job". "I thought about this years ago. I thought at some stage we'd be made redundant basically by artificial intelligence. Having seen the pace that NATS moves at bringing new projects and stuff in I think I'm definitely getting a career out of it. Beyond that I don't know, we'll see"

		"If we end up doing the monitoring role, it will not give me much job satisfaction, that's for sure, just to sit there, even sitting on a quiet sector, I find the job satisfaction is low, you want to be taken along, well I certainly want to be taken along, I know there're guys in the later stage of their career, I'd probably say I'm mid-career, but later stage in the career they're probably grateful of that, but just now I much prefer to be busy, get busy, keeps the mind ticking along, keeps you from drifting off thinking about other things, so yeah there's like a sweet spot in the middle where you want to be busy but not uncomfortably so, and I think we got to stage where we were literally doing a monitoring role, it would just be a boring job" "Whenever I've been involved in a few projects, TBS being one of them, and yeah, your views are taken into account". "I think because I was involved with the project, I had no issues with it, because I was chatting to the engineers, several times a week, I totally trust it and that was it. I was thinking that, and maybe it's a bit of naivety, that if I'm told that this works, and it's approved by the CAA, right I can do it, and that's it and I take that as read, I just worked it and that's it". "It obviously takes different people different amounts of time to learn to trust the tool or whatever, I personally, I was like, the tools been built, I trust the engineers, I trust the fact that it's been approved, I'm just going to work with it and that's it and I get it on the indicator and just let it go" "I know there was a lot of fear around when TBS was coming in from a lot of the controllers, I actually, for the most part, I'll take things as face value, I wouldn't say I embraced the change but I didn't fight back against it either, so whenever TBS came in, you're still doing the majority of the role in what the FIN controller used to do". "I don't think the job has changed massively although in the fact that we're landing more aircraft now, which is fun, you know, because actually it's a little bit harder, you're a little bit busier, and so, my opinion, it's more fun now". "If anything, it's probably made it a little bit easier by the fact it's calculating the winds for you".
6	Cautious Apprehensive Dubious	"I'd say not a lot of detailed knowledge, but quite a lot of interest in what's happening and how it's interacting with us, I guess one of the examples might be when you're on a web site and you get a chat-box come and you think, is this a person or is this a computer? And I've noticed now that lots of companies are making it clear that what you're

		interacting with is just potentially artificial intelligence kind of programme, so interested, definitely, and from a professional point of view as well". "I think it's inevitable that there will be more automation of tasks, but with that comes the usual caveat that comes with aircrew as well, you know, if you just become a monitor of automated systems, when that automated system comes across a situation it can't deal with or doesn't like, then it hands over to the human element, and the human element is then left with perhaps less of an idea of what's going on than they might have had, had they had more involvement". "From that point of view I think you need to be careful in this profession of just going gung-ho, automated everything and then have the controller, yes they can work ten times more traffic, but actually more often than not there is something unusual going on, whether it's weather or it's an emergency or whatever to deal with, so you know artificial intelligence is always going to struggle at the moment with the surprise element". "I think there's a danger of it decreasing situational awareness, certainly with TBS one of the points that I noted fairly early on is a loss of awareness sometimes of the wake vortex categories of the aircraft, well not a loss of awareness, a loss of the awareness of the usual space you might be applying behind a particular aircraft and slavishly sticking to the TBS marker might you know, "*is the marker correct?*". "Yeah, through experience and having some involvement in the initial development and the human interface basically". "Occasionally, particularly in certain wind conditions, in strong wind conditions, the markers for heavy gaps in particular can seem really quite close which is quite different to how it used to be – you know, we'd go for a distance based of maybe 4 miles or whatever and it can be down to 3 miles which seems really quite bizarre, even now, however so many years since TBS came in but I think I've learned to trust it."
7	Comfortable Excited Cautious Apprehensive	"Fairly limited, only so much as you read in the papers, see on TV and in films. Nothing I can think of, nothing in particular.

		"It's always struck me that there are so many variables all the time for the job that we do, it's always very difficult to put that into a computer, and to have a learning computer and to learn and make its own decisions would I guess be a massive step forward, but I can't imagine we are even close to that at the moment". "I think that like most tools we have, for 85, 90% of our time, it's made our job easier, but for those sometimes when it's not working or there are some other aggravating factors it's made it much harder, because maybe we have lost those skills a little bit, so yeah there's a lot of tools in air traffic like that, but when these tools fail, we're very good at cutting the flow rates right down until they're back in place". "The problems that we had, I mean that we were monitoring, when something went wrong, the work rate was huge, so you have the problem whereby if you put the workforce to monitors rather than say people that are actually proactively working, then the work rate, then the knowledge, the experience goes down, and when you suddenly have to ask them to work in peak periods for example when weather is an issue or there is an emergency when there is something that really focuses you, bad or strong winds that computers can't cope with, you'd then have a huge drop in movement rates because the controller were not sharp, as sharp as they could be, that would be sort of one of the issues". "Yeah. One, we'd be slightly less accurate just naturally as we might now have the skills, and you're talking about a small margin, and two, we wouldn't want to push ourselves too far until we'd built up that skill and experience. I mean, if you go, if I was on leave for two weeks, I came back and I was doing the Final Director, I wouldn't expect myself to hit the same spacing as I did if I'd been in for the past 3 weeks, there's an automatic, you're more defensive, it's a skill level that you build up to, so yeah". "Again, it's building up the trust, I think everyone was allowing point 7 of a mile, and now most people are point 3, point 4, I would do, so, I'd say, yeah, there is a little bit of trust, but it's not just trust in the system, it's not just trust in the marker, it's trust in yourself, it's trust in how the aircraft are responding to your feedback regime, the way you're looking at it and the information you're receiving is different and you have to build up some experience level with that". "It's been a huge benefit, for the resilience of the landing rate. We used to land, if there was a tail wind, we could land 48, 49 and hour, if there was a strong headwind the landing rate would be down to 32, so you have a 17 per hour range

		which is, you know, you can't schedule for that, it's ridiculous. Now we land sort of 39, 40 every hour of every day, which is great" "You've got a much more resilient landing rate because the spacing's going to be accurate, much more accurate that we could do at the moment".
8	Dubious Relaxed	"To a degree, I guess as much as the next person, not any specific knowledge of it but I realise it has its place and it's coming in more and more". "Judgement wise, it's probably not too dissimilar to what we were doing it's just that element of the unknown of what actual gap we're going for, so certain skills have been degraded, but are they critical skills? Probably not, and you can get away with it anyway, so it's not a huge degradation of skills". "Me personally, it will definitely deskill me, but to the extent of a person who comes is who hasn't experienced controlling the way I have in the past, for them, when the system does break, which it would, it will be catastrophic, compared to, because they'll have no experience or knowledge to fall back on as to how to do it". "I see more and more, now, people doing things they would never have done on paper because it's electronic so they take it more as a written and that is correct as opposed to the system having any fallibility in that somebody's just written something incorrectly on the strip, so technology leads you to cut corners in a way because you're more reliant on it and you believe its technology so it can't be wrong but its misleading you". "You still have to think a little bit, you don't think as much, I don't personally as much as I did with distance based. Judgement wise, it's probably not too dissimilar to what we were doing it's just that element of the unknown of what actual gap we're going for, so certain skills have been degraded, but are they critical skills, probably not, and you can get away with it anyway, so it's not a huge degradation of skills". "Yeah, through experience and having some involvement in the initial development and the human interface basically". "It sound quite petulant in a way, but the marker is there because of a system that is designed by NATS, now if it's wrong, it's NATS' problem, not mine, they've trained me to be next to that marker and trained me what to do if I'm

		inside the marker, so if the marker is in the wrong place and causes vortex issues, I cannot be held responsible for that because I'm doing what I've been trained to do, so trust issues? No." "I don't even think about trust to be honest".
9	Apprehensive Excited Cautious [Concerned]	I think long term it's a threat, I don't necessarily think it's a threat for me because I've got less than 20 years left, I'm 43, so the reality of something that significant happening between now and the time I retire is pretty slim". "I think we're almost a special case in that it takes so long to train us, and it is a difficult job so not everyone who wants to do it can do it, even after training. I think there are lots of factors here at play, I think there could be things brought in with a view to getting rid of us eventually". "You are effectively deskilling a controller who then has to pick up the pieces when it all goes wrong and then he'll be the one to carry the can at the end of the day because he's been unable to". "No really, you've still got to use your experience and judgement to stay on or behind the marker, all you need to know are a basic set of rules that you have different markers for different scenarios and you have certain rules attached to these markers, so to begin with you'd be a little bit more cautious, because you're not quite sure how the aircraft is going to be against the marker, once you get a feel for it, you let it get closer and closer until you've reached that finite point where you're not happy anymore. So it's no different really, we're just providing a set distance or a calculated distance of compression to touch down whereas before we did it to 4 miles, so there's not a massive difference in the way we operate and in very strong wind conditions it can actually help us a lot".
10	Relaxed Cautious Comfortable [Apathetic]	"Not a great deal, only what you see in the movies". "Yeah, I mean I guess it's inevitable it would. The job's going to become more automated as time goes on, most professions, well a lot of professions, appear to be going that way. Aviation particularly, cockpits, flight decks, they're are going a lot more automated, towards monitoring and stuff, so yeah, I guess it's inevitable ours will at some point". "I think it will definitely support it – I don't think it will replace it. They've tried a lot of different methods of, like telling us when we need to turn the planes, letting planes do it on their own, and not one of them yet has managed to come

		in, it can't understand the intricacies of what it is we do and the fine margins to which we work, so, it's quite difficult for something to come in that can cover all eventualities, so yeah I'm sure there'll be stuff that comes in that will support us in that, but in terms of replacing our job, for the next, well as far as I can see, I'm going to be safe until I retire". You can go to the project leaders if it's a project and they'll listen to your concerns and they'll try and allay any fears if you've got any, they're always encouraging ATCOs to get involved in the development of the project so if there was something that I was particularly interested in then I could get involved that that I'm sure, but no, for me, you know, for me, these tools come in and I'll deal with them and if they don't then I won't have to, so I'm really quite indifferent about them". "I think it would both necessarily be more or less, just differently skilled about understanding how they work and knowing whether they are working according to how they're designed and what is right and what is wrong and how to deal with it if they suddenly stopped working, so not more or less skilled, just different more of an understanding I guess". "For me there's a lot of people more knowledgeable that me that have done a lot of research than I have and you've just got to trust these people. They've put the research in and it's going to be safe" "We've been told it won't be used to gauge performance because it's purely a safety tool, there was the initial concern that people were going to be looking at it and saying, *"well this guy, he's not performing to the required standard because he's always this far behind, and it's all there"*, we've been assured that that's not going to happen". "There was concern amongst my peers, but I've never been concerned, I've always been of the view that if you're doing your job properly then there's nothing to worry about anyway".
11	Sceptical Dubious Cautious	"Only like an interest. I saw that Google thing where they built a system to beat the top Go player in South Korea, that was quite incredible, they used Machine Learning and things like that, so yeah only through watching documentaries. Not so much how it works but I know it's coming. Still can't quite see it personally".

		"I think the difficulties will be the liability and where that lies, so if the system is for example deciding a descent, if the system decides there's a confliction, to resolve it if it needs a descend but it's not going to work for any reason, then where does the liability lay? Is it with the engineers, the software developers, the air traffic controller? Who's responsible for that monitoring?" "You can't have a system that is not safe but a controller whose job it is to make it safe, it just wouldn't be acceptable. Not just for my employment or my job, probably for the airlines themselves have to bear that risk as well" "No, I don't think so. I think you still need the skill to get the aircraft on the marker, you still need to make a judgement call as to how close". "There were some discussions at the beginning, that the management were going to monitor the spacing for their own purposes to ensure that the landing rates were as expected, to monitor the performance, so the controllers were a bit worried about their personal monitoring and assessment". "Yeah – huge trust, there has to be, because you couldn't work without that trust". "I think it has made it easier, there's definitely an element of it's not as difficult, you don't have to visualise a gap without a marker, you can see it with one glance".
12	Sceptical Comfortable Relaxed Cautious	"I know a bit because when I did my MSc in Electrical Engineering back in the 90s, I worked on neural networks so I did so a bit on artificial intelligence which makes me wonder whether we can have artificial intelligence here yet, or whether it's just automation. It's probably not unique but it's in the minority". "It's not going to be the be all and end all and we shouldn't forget that automation is not given to us, so automation is developed by humans and the same human error that we are trying to prevent by having automation and not the human operator, we embed it in those automated systems, so you just have to be mindful of that". "I think artificial intelligence is used as a buzz word, but it's not really artificial intelligence that we're going to see in the Ops room or in Control Towers or even in the cockpit. Definitely not yet, we're a long way away, because we were

		already working on neural networks in the 90s and we don't even see that in some of the areas of wireless communications I used to work on". "The system has been certified and is safe to be in operation, then we just follow the rules and go by the system, otherwise nobody knows what rules we're applying so maybe at the beginning yeah there was a bit more of maybe being cautions, looking at the marker a bit more and trying to get a feeling for what the values were, because, as you said, the marker might look too close because you have a heavy and a medium and its now 4 miles as opposed to the 5 that we used to do with distance".
13	Cautious Relaxed Encouraged	"I've read a couple of articles about that type of thing but nothing particularly in depth. There's a passing interest but nothing more than that I think". "I think that's the main stumbling block of any form of project that we do of that nature, just trying to systemise and standardise things, the need for flexibility but also predictability, there's a conflict there that's difficult to manage" "Yes, it does currently, it's a difficult one because, especially new technology, trying to introduce it is always the difficult bit, sometimes they help, but more often we work around them, we make them work by getting used to then rather than being supported by them, depends what it is, depends how robust the training is, depends how robust the systems are, there's a lot of variables". "I think there's an element of that already, whenever there are certain aspects of the job where automation comes into it, then you do get deskilled, as a natural consequence of that, I don't worry to the extent that we're not going to be required". "I don't think I'm a better controller from using it, but at the same time it's definitely not deskilled us, because it's more difficult, so it hasn't made it easier and it hasn't taken skills of us, because we're still using those same skills and it's harder to put those skills into practice as we get less information". "I was quite heavily involved in the project itself, so from quite an early stage I was involved, had quite a lot of input".

		"And I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it". "That hasn't been the case and I think we trust the management above us enough for it not to be an issue for me, with regards for bringing it in, a Heathrow there's always motivations to land more aircraft, it's just the way it is, I don't have trust issues over that, no one is pretending it's any different" "Not so much, I was involved in the project in the early days and also, before it came in, I've got the years of experience to fall back on, so I know what the new requirements are, the big reductions were just a reclassification, rather than a systemised reduction, so you can always fall back on what you knew previously to make a judgement call as to whether it's roughly correct or not, so I don't have trust issues in that regard, I would realise if it was badly wrong, and I also trust the people who worked on this project and what they've done and I trust that it's robust, so I don't have trust issues with it".
14	Apprehensive Cautious Relaxed [Positive]	"No really, no, I hear little bits and pieces and just on the news but it's not something I really follow, no. Interested in it though" "It would certainly change the job and it's hard to say how my view of it may change but certainly you may not get the same satisfaction, you may not get the same enjoyment, you may not get the same salary, if you're in just a monitoring-type role. There may be a lot less of us required". "And even now in a day of strong winds, when TBS is saying you can really squeeze them up, it does look odd, it does feel strange, but we've been told, we've been assured that, you know, to trust the technology". "Yeah, absolutely, those questions did come up in training and in the Ops Room, when it was introduced, there were those questions and queries, but I think we've all just learnt to trust it".