AVIATION SAFETY THROUGH FUTURE EYES
Foreword

I would like to take this opportunity to highlight a number of recent changes in the safety world. Firstly, I should introduce myself as the new Director of what was DDAAFS. I have replaced Group Captain John Grime, who heads off to a new and well-deserved appointment as the Officer Commanding 92 Wing. He is currently grappling with the conversion from AP-3C Orion to the new P-8A Poseidon. Grimo, good luck on 92 Wing, and a well-done from all here for your great work in leading DDAAFS.

That leads me to the next change. After more than a decade known as DDAAFS, we must now change our name. Most of you will know that Air Force Safety (AFS) have moved to Air Command, under the command of HQAC A9. Therefore, our name which included Air Force Safety - the ‘AFS’ in ‘DDAAFS’ no longer accurately describes us. We will now be known as the Defence Flight Safety Bureau (DFSB). This name acknowledges the subtle difference between our role in a ‘flight safety’ sense, and the broader remit of the Defence Aviation Safety Authority (DASA, of which we are a part) in the ‘aviation safety’ sense. Finally, our use of the term ‘Bureau’ aligns us with our maritime Safety Authority (DASA, of which we are a part) in the ‘aviation safety’ sense. Finally, our use of the term ‘Bureau’ aligns us with our maritime and civilian colleagues (MSB and ATSB respectively).

The DFSB will continue to provide the support to all areas which you should expect, such as safety investigations, and hazard reporting. We are focused on ensuring the success of ASR in Sentinel, and will continue to work with you on that. We intend to strengthen our focus on areas such as ASMS policy, research, and exploiting new media for use in safety promotion.

Finally, and somewhat unusually, we have dedicated this entire issue of Spotlight to emerging issues in the field of aviation safety, seen through the eyes of our talented students undergoing training at ADFA. I will hand over to COL Peter J Murphy (PhD) to explain further.

Regards,

GPCAPT Nigel Ward
Director DFSB

Introduction

As I write, the next generation of aviation professionals is being readied across Defence training institutions. These trainees are mostly from the millennial generation, which cops a lot of flak about its work expectations (ambitious) and use of social media (heavy).

Yet there is no doubt that millennials are technologically savvy, they learn fast, and they are keen to develop professionally. These characteristics were amply demonstrated by the 43 students who recently completed the semester-long Aviation Safety course at the Australian Defence Force Academy.

The broad aim of the course is to introduce human factors as an applied discipline and explore its role in support of aviation performance and safety across a range of aviation industry occupations.

The course has a balance of the theoretical and the applied. Students began by conversing with concepts such as systems theory, the organisational accident model, and modern precepts of human error. Numerous accident and incident case studies highlighted the importance of learning from the past so that we can better address and integrate human factors in support of aviation safety.

An important learning opportunity on the course was the presentation seminars, mostly in pairs, on topics as diverse as perceptual illusions, motion sickness, display technologies, flight simulation, human factors in airport security, automation philosophy, air traffic management, and unmanned aerial systems.

Students also submitted an essay to demonstrate their ability to critically evaluate the scholarly human-factors literature and to deliver an original and engaging perspective based on their research. This edition of Spotlight – through future eyes – showcases a selection of these essays. I trust they will provide the reader with an appreciation of how the next generation of practitioners are viewing safety and performance issues in aviation.

COL Peter J Murphy (PhD)
ADFA
Is the human dimension the key to successful automation?

A human factors analysis of modern aviation automation

By Ryan Lake

The field of aviation automation is rapidly expanding and has been continually doing so since its earliest introduction in the mid-1950s. When we consider the data presented on the history of aviation accidents, there is clearly a significant reduction in incidents in the late 50s and 60s (ICAO, 1998). Although not the only factor, the introduction of automated systems aimed at eliminating negative factors on human performance has made a clear impact on aviation safety (Chialastri, 2012).

It is worthwhile to note that past the spike in the mid-’70s, the occurrence rate of aviation incidents has not continued to significantly reduce (ICAO, 1998; Both Oster et al. (2010) and the ATSB (1996) in separate studies of aviation accidents concluded that the pilot was the main causal factor in the accident, suggesting that although automation technology has continued to rapidly improve in both sophistication and reliability, it has had an apparently disproportionate net result on aviation safety and improving pilot performance. This initially perplexing observation can nevertheless be explained through the analysis of the human factors component or the human-automation co-ordination. This essay will discuss the reasons for concern in this regard, detailing the effects of poorly adapted automation on human performance and how it can occur. It will then investigate the modern aviation-system designer approach towards the human dimension of automation and how that approach has developed over time.

Finally, we will look at what the consideration of human factors discipline can achieve towards perfecting human-automation co-ordination on the flight deck.

Unintended effects on human performance

The basic problems identified with control of an aircraft using a flight management system can be described by three common questions asked by flight crew: What is it doing?, Why did it do that? and What will it do next? (James et al., 1993). Although there are a number of serious issues that can arise when a system designer neglects to consider the human component of an automated system, these three fundamental questions sum up the crux of the problem. What is often briefly described as: situational awareness.

According to Endsley (1996) achieving situational awareness is one of the most challenging aspects of these operators’ jobs and is central to good decision making and performance. In that context Endsley is writing with regards to all workers in highly complex and dynamic systems but the application to aviation is seamless and in the context of aviation, when we understand and apply the concept of situational awareness to the system design process, we can achieve truly effective human-automation co-ordination.

For the system designer to safeguard against loss of situation awareness they must understand its causation. Humans are naturally poor supervisors of highly automated systems that keep them in a state of mental underload. It has been largely reported that mental underload and overload can negatively influence performance (Xie & Salvendy, 2000). What this means is that in a highly automated system, the user is potentially left too little to do in the system process and falls out of the loop. It is worthwhile to note that past the spike in the mid-’70s, the occurrence rate of aviation incidents has not continued to significantly reduce (ICAO, 1998).
A pilot may believe they are fully engrossed in the system and fully aware of their current situation and suddenly the automated system behaves completely unexpectedly; the pilot detects but does not understand the issue.

Roles in the system and changes in feedback to the operator (Endsley, 1996). The opposite of this can also occur and instances of extreme mental overload can severely detract from pilot performance. An example of this is Qantas Flight 72, in which an automation error resulted in an extreme number of audio and visual warnings sent to the pilot, some of which completely contradicted other warnings. As such, these warnings intended to assist the pilot, created a significant amount of workload and distraction for the flight crew (ATSB, 2008). This clearly demonstrates a lack of consideration for the human observer of the automated system.

Operators of an automated system have a diminished ability both to detect system errors and subsequently to perform tasks manually in the face of automation failures when compared to workers who manually perform the same task of that automated system (Endsley and Kiris, 1995).

Endsley and Kiris are among many who have conducted studies into the effects of automated systems on human supervisors to discover the significant impact in human performance decreases. Casner et al. (2014) conducted a study specifically to address the concerns on pilot-skill degradation caused by reliance on automation. They found that basic skills such as instrument scanning and stick controls were reasonably maintained but higher-level cognitive tasks such as navigation and recognising instrument system failures suffered frequent and significant problems. They hypothesise that the retention of such cognitive skills may depend on the pilot’s level of active engagement while supervising the automation. The findings of Casner et al. are consistent with the three pathways to becoming out of the loop suggested by Endsley, particularly with regards to the necessity of assuming an active role in the automated system.

Automation surprise is another highly vital factor for a modern system designer to be aware of. It is strongly linked to a loss of situation awareness, although subtly and distinctly different. Automation surprise does not necessarily mean the pilot has experienced any of the detractive pathways suggested by Endsley. A pilot may believe they are fully engrossed in the system and fully aware of their current situation, and suddenly the automated system behaves completely unexpectedly; the pilot detects but does not understand the issue (Dehais et al., 2015).

De Boer & Hurts, 2017 conducted a study into automation surprise into Dutch airline pilots and concluded that automation surprise seems to be a manifestation of the system complexity and interface design choices in aviation today, nearing the bounds of what is humanely possible to comprehend. Furthermore, they concluded that lack of knowledge or training were outweighed as factors when compared to the advanced sophistication of the automated systems. This means that the modern designer will need to duly concern themselves with exactly how much complexity a pilot is able to comprehend effectively.

Do aircraft systems designers appreciate the human dimensions of their work?

The safety philosophy behind the adoption of increasing onboard automation is based on the assumption that human error is the main cause of accidents (Chialastri, 2012). If it is
of which applies to the attitude of aviation automation over past decades. Many organisations have made a small step to limit the variability of human action, primarily to minimize error, but it is this same variability – in the form of timely adjustments to unexpected events – that maintains safety in a dynamic and changing world (Reson, 2000).

When applied to the automation of aviation we can see that in many cases the aircraft system designers have fallen short, to at least same degree, into this paradiglic trap. Airbus’ automation design philosophy in particular demonstrates this, with its automated policing of any flight manoeuvre outside of the safe flight envelope. Thus, showing a greater willingness to trust the autopilot over the design pilot in such an emergency situation.

Perfecting human-automation co-ordination on the flight deck

To perfect human-automation co-ordination requires a willingness from aircraft system designers to commit significant research into the human components by which their pilots interact with the automation of their aircraft.

Modern aircraft have come a long way in addressing the majority of the safety issues related to aviation and automation is becoming so advanced that the idea of completely designing the pilot out of commercial cockpits is fueling market feasibility research. Yet even unflown Zumqig is plagued with human-automation co-ordination issues, a report on aviation accidents among IAVs of the US military found that up to 47 per cent of accidents per airframe where human factors related (Williams, 2004).

The answer lies in designing the system around the human crew rather than inserting the human into an ill-fitted system as has been done in the past. System designers must consider the effect a highly automated system can have on the supervisor and adapt to mitigate those effects from the earliest design phase.

Creating a system that is adaptive and actively engages the pilot in periods of low mental workload but is able to intuitively take up tasks in times of high mental workload will likely be the way forward. However, adaptive automation itself is not a solution, key elements must be considered in order not to create its own human-factor problems (Endsley, 1996).

The exact methodology for the implementation of adaptive automation requires significant study and automated system research would make a critical point for further research.

Other points of improvement are easier to approach. This could include creating a system to encourage the pilot to behave in an active manner when monitoring, as shown by Casner et al. (2004), which will likely benefit cognitive skill retention. Furthermore, the drop in situation awareness brought on by changes in feedback to the user is partially made up through a robust user interface designed to feedback that is interactive and easily digestible by the pilot. It should provide the information in such a way as not drastically increase the mental workload on the pilot and thereby reduce his performance.

What this means is that in a highly automated system, the user is essentially left too little too do in the system process and fails out of the loop. This out-of-the-loop performance issue is suggested to occur due to violations and complexity problems, shifting from active to passive roles in the system and changes in feedback to the operator (Endsley, 1996).

Conclusion

It must be noted that little or no systematic attempt has been made to design and implement automatic systems in relation to the needs, capabilities and limitations of human performance (Edwards, 1977). As illustrated by Edwards, concern for mitigating the inadvertently negative impact that automation can have on the human component and by extension, human performance, has existed for decades of high-level automation aviation.

In 1977 Edwards wrote a journal article stating the lack of human factor concern based on the system design in 1993 NASA released Human-centered aircraft automation: A concept and guidelines to direct their organisation, and even in 2018 books are being written on the same topic. As exemplified by this the human-factors approach to automation is one that has been discussed throughout the entire history of its use. It is clear from the analysis of the sources that system designers are aware of the need to appreciate the human dimensions of their work, although translating this knowledge into tangible results has thus far been modest success.

Inarguably, automation has had a significant impact on the reduction of aviation safety incidents and will likely continue this trend far into the future. However, we can see that the application of human factors to the improvement of human-automation co-ordination may succeed in finally closing the gap in gap automation safely.

While we can only see the human system designer and automation co-ordinator, it is considered, analysing and perfecting the human dimensions of the flight deck that is key to successful automation.

ABOUT THE AUTHOR

MiDN Ryan Lake is an undergraduate student in System Design Engineering at the University of Toronto. His undergraduate thesis was titled “Creating a System that is Adaptive and Actively Engages the Pilot in Times of Low Mental Workload but is Able to Intuitively Take Up Tasks in Times of High Mental Workload.” His graduate thesis was titled “Human-automation Co-ordination: A Concept and Guidelines to Direct their Organisation.” His current research is in safety science, with a focus on aviation and machine learning.
A cross the globe, the aviation industry employs about 500,000 commercial pilots. According to recent reports, there is a requirement for more than 600,000 new pilots in the next 20 years. This is accounting for a growing retirement rate of an aging generation of professional pilots, as well as the steady growth of airline travel across the globe (Gabriel, 2017). This means that more than half of the pilots that will be flying by 2027 have not started training yet (CAF Inc, 2017). These new pilots are receiving less training and will have less flight experience than their retiring counterparts.

Previous pilot generations, due to the large draw from military pilot pools and differing training methods, had a reserve of technical aeronautical knowledge, which has led to the safety culture of the aviation industry that can be observed today. The technology that is implemented by these experienced pilots, such as autopilot features, has been done with an underlying assumption that the pilot is able to utilise the capability that the technology provides them in order to make safe decisions about flight operations (Sinnett, 2017).

If new pilots do not have the experience and proficiency of the pilots of today, a technical solution is required in order to maintain the safety standards of the industry. This technical solution may be one where the aircraft has the capacity to make active decisions about flight. This is called autonomy and its rapid development is currently occurring in the automotive industry. How can aviation learn from this development in order to meet the rapidly changing requirements of a growing industry?

Autonomous cars

Autonomous motor vehicles (ATMVs) are set to revolutionise the automotive industry, presenting dramatic economic and safety advantages. According to the World Health Organization (2015), worldwide road traffic deaths sit at about 1.25 million per year.

In a study by the U.S. Department of Transportation (2018), found that human error is the critical reason for 93 per cent of crashes. Thus, the prospect of removing humans from the driver seat is tantalising. Since 2015, autonomous cars have been approved for testing on public roads in several US states. In November 2017, Waymo, the autonomous vehicle division of Google’s parent company – Alphabet – put a fully autonomous minivan on a public road without a safety driver (Hawkins, 2017). In order to understand this progress, ATMVs can be measured on a five-level system designed by the Society of Automotive Engineers (SAE). Level zero is a vehicle with no driving automation. Level 1 is limited driver assistance such as cruise control. Level 2 is partial driving automation such as adaptive cruise control and lane assist. Level 3 is a conditional automation, perhaps automated low-speed freeway driving. Levels 4 and 5 are full automation, with Level 4 being limited to a specific area and Level 5 being unlimited to where it can drive (Society of Automotive Engineers, 2014).

Currently, the leading edge of ATMVs are somewhere around Level 4. If Level 5 ATMVs can become commercially available and well-integrated into all facets of transport, from legislation to cultural acceptance, it is very possible that safety incidents on the road could essentially be eradicated (Stadler, Brenner, & Hermann, 2018).

State of autonomy in aviation

When it comes to autonomy in aircraft, the most modern of passenger airliners has a complex autopilot system that is able to control taxi, take-off, climb, cruise, descent, approach and landing.

There are no operational aircraft, civilian or military, with the capacity to make decisions while flying (Austin, 2010). Most autopilot systems mean aircraft are equivalent to Level 2 or 3 of vehicle autonomy.

While ATMVs utilise camera and sensor systems to build a picture of the road for the vehicle to process and make appropriate decisions about driving, most autopilot systems that are currently in operation utilise internal sensors and cannot assess surroundings. For example, if an aircraft is on approach for an instrument-aided landing, it can divert from the auto-land procedure because of a technical malfunction. However, if another aircraft crosses the runway, the aircraft landing has no perception of the event and the auto-land must be diverted by the pilot (Sinnett, 2017).

An ATMV is more advanced in its capacity to make a similar decision as its outward facing camera and sensor technology can detect a threat and make changes to its operation in order to avoid it (Kichun, Junsoo, Dongchul, Chuhoon, & Myoungho, 2016). Thus, as autonomy becomes more advanced and commonly implemented, the aviation industry could see similar safety and economical advantages that are being seen in ATMVs. Hopefully, the aviation industry can learn from the challenges being faced by ATMV introduction and utilise lessons learnt for a smoother introduction of the technology into aviation.

Driver becomes the driven

Just as the role of drivers is changing with the introduction of ATMV technology, making them into safety monitors of that technology, the role of pilots is likely to change with the introduction of autonomy. There are several ways that the aviation industry could make the journey from A – today – to B – a world where all aircraft are fully autonomous. Stepping stones that may allow this journey could be through augmenting crews of aircraft or changing the decision-making roles within the aircraft (Sinnett, 2017).

If crews were to be augmented, it is conceivable that cargo operations could be done by a single pilot, who would monitor the autonomous technology. In a similar way, long-haul passenger flights could be completed by far fewer pilots, cutting down both the need for pilot volume and experience. No longer would pilots be required to fly the aircraft. Instead, they would act to monitor the safe operation of the autonomous system while being a back up for active decision making.
There are challenges in the field of human factors that need to be addressed in the transition to autonomous aviation. These must be overcome while maintaining the safety, integrity and economic stability of the industry.

The human-factors considerations of the aviation industry are comparable to those being made by teams introducing ATMVs into the market. One significant challenge lies in the differing approaches to a human-machine interface, particularly in relation to take-over requests and alerts.

At lower levels of automation, drivers can hand over driving tasks to the ATM but must be ready to resume at all times. At higher levels, the system must be alert and able to recognize its own limits and hand over to the driver. When this happens, the driver must be ready to take control in a timely manner. Manufacturers are working on the safest way to alert a driver in an emergency with a combination of aural and visual methods (Stadler, Brenner, & Hermann, 2018).

When designing this take-over request, the Chair of Ergonomics at the Technical University of Munich, Germany conducted an empirical study measuring the ideal take-over alert timing (Gold, Dambroeck, Lorenz, & Bengler, 2013). They found that with alert timings of five and seven seconds, those with five seconds responded with imprecise and unsure driver actions. However, those with seven seconds had a longer reaction time to respond to the threat. In another study, different alert timings were analyzed (Rodmay, Gold, Lorenz, Farid, & Bengler, 2014). It was found that those visually distracted with activities such as emailing caused more collisions than those who were cognitively distracted with activities such as conversation with other passengers. These considerations will need to be applied to autonomous aviation. In the transition period, before Level-5 automation can be achieved by aircraft, pilots will still need to respond to take-over requests. Thus, the stimulation of the pilot will need to be managed by aircraft systems in order to maintain a safe take-over response.

**Alert! Alert!**

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**Not just anti-virus**

Since the 11 Sept 2001, the security of aviation has been of significant concern to legislators and the public. The introduction of automated aircraft, the connectivity of the system creates vulnerabilities to cyber-attacks. As the technologies advance, the vehicle-to-vehicle and vehicle-to-infrastructure connectivity will complicate the cyber environment and create vulnerabilities in the system (Ilgen-Noon, 2018). ATMVs are currently overcoming cyber security threats with high-security systems that are regulated by the United States National Highway Traffic Safety Administration. Of particular note, reducing the components of the vehicle that communicate with the outside world reduces the cyber-attack surface of the vehicle, reducing the risk of a breach in security (Stadler, Brenner, & Hermann, 2018).

Automotive manufacturers are developing ATMVs with cyber-security as a fundamental cornerstone of their philosophy and it is a way of thinking that must be adopted by the aviation industry prior to the introduction of vulnerable automation technology.

**Trolley problem in the sky**

Consider for a moment the hypothetical situation (Lin, 2015): A large autonomous vehicle is going to crash and hit a minivan with five people inside. If it hits the minivan, it will kill all five passengers. However, the autonomous vehicle recognizes that it may be able to collide with a sports car in such a way that it reduces the impact on the minivan, sparing minivan’s five passengers. Unfortunately, it would kill the one person in the sports car. Should the autonomous vehicle be programmed to first crash into the roadster? This problem closely resembles the trolley problem (Thomson, 1976).

Thus, for it to be logically consistent, it must be accepted that the ATMV has all empirical data required to make a certain decision about the outcomes of the two choices.

While there is vast amounts of literature and understood norms around decision making under empirical uncertainty seen in De Groot’s Optimal Statistical Decisions (2004), there is no agreed upon framework for moral decision making with empirical certainty. Some ethical researchers suggest that two ethical theories be applied – deontology and utilitarianism (Meyer & Beiker, 2014).

Because of these competing moral decision-making frameworks, a programmer working on the case above cannot program a vehicle based on one particular framework. The competing decision-making values mean that a programmer would need to assign moral weighting to each outcome and come to an ethical conclusion based upon their own moral assumptions and understanding of analogous ethical questioning. This process is called Problem Intertheoretic Value Comparison (PIVC) (Lockhart, 2000; see also Sepielli, 2006, 2009, 2013; MacAskill, 2016).

ATM programmers are overcoming ethical competition with averaged PIVC across a team of specially recruited ethical specialists. Since there is no objective trought by...
which ethical decision making can be made; the autonomous car ethical debate has led to an embrace of ethical complexity where complexity is required (Millar, 2017). This way of thinking about ethical questioning needs to be transferred when autonomous aviation is developed in the near future.

Without a method of overcoming ethical questioning, programmers cannot progress autonomous technology. Thus, the challenges that have been overcome by ATMV development can be subverted by using PVC in autonomous aviation programming. This will lead to faster development and implementation of autonomous aviation in comparison to ATMVs.

Who is to blame?

Having overcome most ethical, human factors and safety concerns, the major challenge faced by ATMV development today is a regulatory one. One concern of legislators is that the regulatory authorities that govern safety concerns of motor vehicles do not have the capacity to certify whether an ATMV is safe for operation (Wood, Chang, Healy, & Wood, 2012).

Most current safety statistics for ATMVs come from manufacturers, but regulatory bodies have lost faith in their ability to self-regulate in the wake of the emissions scandals in recent years (Ganser & Wegener, 2017). Another legislative challenge lies in the liability of an ATMV’s actions. In general, those who are at fault for harm, particularly which that could have been avoided, are punished by the law. By this principle, legal liability is necessary as it is crucial in “advancing the general welfare of society” (White & Baum, 2017). In the automotive industry, engineers and designers are likely to be most liable for harm caused by ATMVs. ATMV liability has posed significant legal challenges to the introduction of the technology and it is a challenge that autonomous aviation is likely to face.

Hopefully a legal precedence has been set by the automotive industry prior to autonomous aviation being fully introduced so that the precedence can be transferred across to the realm of aviation.

What now?

With a growing pilot shortage, the aviation industry needs to make a change. In the next 10 years, there will not be enough pilots to facilitate rapidly growing industry. So, manufacturers are turning to ATMVs – the future of the automotive industry – for inspiration. While there are ethical, human factors and safety challenges that are still to be overcome by developers of ATMVs, autonomous vehicles will surely be common place in the near future.

The technology and lessons learnt from the automotive industry will help aviation to follow down a similar path. Aviation is about to change. Ironically, with or without autonomous systems, the way people think about flying and flight safety will dramatically shift over the coming years. However, without autonomy, the less experienced pilots of the future are likely to degrade the safety culture that facilitates the highly safe operation of aviation that exists today.

References


By Brax Hayes

Over the past few decades, the aviation industry has witnessed a movement of de-cowering, with increased on-board autonomous assistance and even proposals to reduce short-range crews to pilot-only (Harris, 2011, p. 222).

Concurrently, research and development into land-based autonomous vehicle (AV) technology has significantly progressed, with companies such as Google promising to improve road safety in which 94% of accidents are caused by human error (Francesca et al., 2017, p. 8). So much so, AVs are listed in the top 10 disruptive technologies of the future (Bagdooe et al., 2016, p. 285).

It is, therefore, both reasonable and sensible for aviation stakeholders to learn from the introduction of autonomous cars. This paper, after briefly defining autonomous in relation to vehicles, will investigate the current safety of today’s autonomous cars, including issues surrounding sensors and the security of data, and how they can apply to aircraft.

Human factors, and the effect it has on vehicle design in order to mitigate conspicuity while trusting the introduction of autonomous vehicles in the autonomous system, will also be analysed.

Finally, ethical concerns such as the use of forced-choice algorithms, legal matters and job loss will be looked into, and how the aviation industry can learn from such issues.
Automation can be defined as a device or system that is capable of performing tasks that are carried out by a human operator. The Society of Automotive Engineers (SAE) have defined six levels of automation (Lindman, 2018, p. 4). Levels zero, one and two include no automation, driver assistance, and partial automation respectively (Fleetwood, 2017, p. 532).

Levels 3 and 4 are deemed high automation and full automation respectively and involve the system performing all driving tasks in all scenarios (Francesca et al., 2017). However, the only current level-4 vehicle in operation is the ParkShuttle system (Lohmann & van der Zwan, 2017, p. 6). Companies such as Tesla and Uber are in the process of researching level-5 vehicles (Wade, 2018).

Current safety

The current use of AVs is limited, and statistics show that conventional vehicles are still safer than AVs. In the United States, conventional vehicles cover an average of 500,000 miles before encountering a crash, while AVs cover only 42,017 miles before a crash (Francesca et al., 2017, p. 18). However, it is important to note the reasons for this discrepancy. Out of the 26 accidents between September 2014 and March 2017, the AV was at fault for all but one of these. Two of these four accidents occurred while the AV was in manual mode in which the human was driving (Francesca et al., 2017, p. 15). Therefore, we are to account for just the two accidents in which the AV was both at fault and in autonomous mode the accident rate is 1,008.408 miles per accident, thereby corroborating with manufacturer claims that AVs can indeed potentially improve road safety. However, AVs may increase particular types of accidents if the driver relies too heavily on them (Anderson et al., 2014, p. 16). The main current automatic mode for AVs is that which is hard to detect, predominantly being rear-end collisions that the AV didn’t detect in time (Francesca et al., 2017, p. 16). Therefore, as AVs will continue to share roads with human-driven ones in the immediate future, the crash rate will never be zero (Bagiope et al., 2016, p. 296). This fact needs to be noted by the airline industry, in which autonomous technologies are fundamental to preventing most accidents. For example, autonomous systems can respond to imminent collisions in which another vehicle is at fault.

There are many reasons why automation strategies would, therefore, have to be researched and improved, especially if autonomous aircraft (of levels 3 and above) share an environment with human operated aircraft. Another problem of AVs is that of road infrastructure. In a system that relies highly on sensorial data, incomplete data could arise, for example, due to not knowing the geometry of the surrounding lanes (Bertola et al., 2014, p. 287). Illusions that can be picked up easily by the human eye cannot be easily replicated by sensors.

A vehicle leaving a roundabout in the opposite lane may be interpreted by the AV sensor as intersecting its own lane (Bertola et al., 2014, p. 257). Therefore, infrastructure regulations will need to be enforced, and objects such as road signage must be standardised (Infrastructure Partnerships Australia, 2017, p. 15). As road networks are often owned and maintained by all three levels of government, such regulatory discussions may take time (Infrastructure Partnerships Australia, 2017, p. 15). The airline industry needs to make note of this. For example, the International Civil Aviation Organisation (ICAO) may need to amend some regulations to accommodate for more autonomous aircraft, as well as heavily enforce such regulations.

Airport operators will need to ensure that taxiways signs are well maintained to ensure sensors can easily identify correct routes. Another concern that was raised by AVs is the visibility of the vehicles themselves. The main cause of a Tesla AV crash was that the sensor could not differentiate between the sunlight and a large white truck crossing in front of it (Sampali, 2017, p. 3). Aircraft may therefore need to be designed with a specific livery so they can be picked up by sensors.

An often overlooked safety issue that has come about from the introduction of AVs is cybersecurity. In a vehicle that relies on computers and sensors for safe driving, software system security must be addressed, especially as cybercrime technology develops (Bagiope et al., 2016, p. 2). The cyber threat is apparent for both the operation of AVs as ad-hoc vehicles, as well as their communication capabilities as connected automated vehicles (Bagiope et al., 2016, p. 298). It would be disastrous for cybercriminals to introduce fake messages into either one of these two frontiers, as it would prompt inappropriate reactions (Bagiope et al., 2016, p. 298). The airline industry, if it were to progress into more autonomous systems in which both the aircraft and the infrastructure are connected, will need to look at how to mitigate such threats.

Human factors

From a human-factors perspective, an issue raised by AVs is how to design one that allows the driver to understand its limitations and capabilities while maintaining situational awareness of what the vehicle is doing within its environment (Cunningham & Regan, 2015, p. 2). Automatic disengagements are those resulting from a system failure, such as improper sensor readings (Bliss, 2018). Such disengagements require the driver to take control of the vehicle immediately, and therefore pose a risk if the driver is inattentive and distracted (Bliss, 2018). There exists a close link between complacency, attention, and trust (Manzey & Parasuraman, 2013, p. 388).

While there is a need for the driver to remain alert, this is particularly pertinent as pilots have, in the past, “failed to intervene and take manual control” when automation systems failed (Lee, 2004, p. 50).

Some studies have been conducted in the AV industry that investigate how different interfaces communicate automation status and limitations. As mentioned above, these studies are of vital importance as it is paramount for the driver to not fall out-of-the-loop (Cunningham & Regan, 2015, p. 5). Results from the Likert scale exposes a clear benefit that auditory feedback has in comparison to no auditory feedback, with drivers unanimously agreeing that auditory signals enhanced their awareness of the vehicle’s actions (Beatti et al., 2014, p. 7).

Conversely, having no auditory signals significantly reduced the driver’s sense of control over the vehicle (Beati et al., 2014, p. 9). It is important that signals are timed appropriately, early enough to give the driver enough time to react but not too early so that it may be interpreted as a false alarm (Cunningham & Regan, 2015, p. 5).

Driver state monitoring (DSM) technology is one such mitigation strategy being used in the AV industry, in which the driver’s alertness is constantly monitored by inference of the eye-gaze direction and degree of head rotation (Cunningham & Regan, 2015, p. 6).

DSM technology could have prevented a recent crash involving the night of 18 March in Arizona. Investigations into that incident revealed that the operator of the Uber AV was looking down with her hands off the wheel when the car struck a pedestrian (Bliss, 2018). It is therefore practical to implement strategies such as DSM be considered in the airline industry if it were to progress to higher levels of automation.

Regardless of the interfaces used, there still exists a need to teach drivers the limitations of AVs. Currently, only well-trained test drivers monitor AVs for companies such as...
many ethical issues. Like any"},

" distortion and a lack of"},

"industry should note the potential issues"},

"and train people to understand the"},

"the AV is not designed to do just this"},

"the introduction of AVs, such autonomous systems produce many challenges."},

"the introduction of AVs, such autonomous systems are vulnerable."},

"the introduction of AVs has also had deep implications for public health (Bonnefon et al., 2015, p. 1058). Therefore, processes must be put in place (Fleetwood, 2018) so that the aviation industry will be able to adapt and accommodate for such developments.

"This paper presents a framework based on existing theories of the ethical and legal implications of AVs and integrates them with case studies and examples from the aviation industry to provide a comprehensive view of how autonomous technologies can be applied in the aviation sector.

"The aviation industry must be able to adapt and accommodate for such developments.
As modern hardware and software systems become more redundant, rigid and reliable, the frequency of human error becomes more apparent. Studies have found that a 50 per cent increase in safety will bring a 12 per cent increase in productivity (Stewart & Townsend, 2000), and according to Harris (2011) “it is estimated that up to 75 per cent of all aircraft accidents now have a major human factors component” (p.5).

NTS TAILORING, TECHNOLOGY AND TENERIFE

Human safety factors of any organisation is in the interest of all, safety appreciation and subsequent mitigation has been studied extensively for many years. Whether working alone or in a team, Non-Technical Skills (NTS) are exercised routinely when made to manage error. Crichton (2008, p. 1), best defines NTS as “the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance.”

When NTS training has its limitations identified and mitigated, safety will improve in the respective domain. An organisation that enables a dynamic safety evolution process and adapts to changing technology, can promote safe and efficient task performance. The purpose of this essay is to analyse the history of NTS training through analysis of Crew Resource Management (CRM) and Line Operations Safety Audits (LOSA). The current status of CRM will be put into context with examples of adaptation in modern day policy and its parallels in the modern Intensive-Care-Unit environment. Individual adaptability issues and problems with evaluating NTS training outcomes will be explored as potential limitations.

Finally, analysis of its strengths as an exportable product when coupled with a conducive crew-selection program will be undertaken, with future technological challenges considered.

Current status: NTS training and evaluation

To understand the current form and effectiveness of NTS training, context must be given to the changes made throughout its short history. Over time, training has been established and evolved to equip crew with the required social tools to effectively manage themselves, as well as their team.

Research of aviation accidents and incidents (Helmreich, Merritt & Wilhelm, 1999) and airline intrinsic investigations (Burger, Neb & Hoermann, 2002) provided evidence of operational safety breaches due to a lack of non-technical skill, namely: assertiveness, situational awareness and poor decision making. As a result, two leading, non-static, human factor-mitigating initiatives were implemented; namely CRM (Weiner et. Al, 2010) and LOSA (Kinet, 2006).

CRM: history, application and current status

Helmreich (2010) defines CRM as “optimising not only the person-machine interface and the acquisition of timely, appropriate information, but also interpersonal skills including leadership, effective team formation and maintenance, problem-solving, decision-making, and maintaining situational awareness” which coincides with and extends on John K. Lauber’s original (1984) definition of “the application of human factors in the aviation system. (p. 20)

At the NASA-led Resource Management on the Flight Deck Workshop in 1980, the CRM concept was founded after an investigation of the Tenerife airport disaster in 1977, advised that human factor training should be compulsory for all aviation personnel (White & Lauber, 1980). It was concluded that the disaster between the KLM and Pan Am aircraft, claiming 583 lives, was due to poor ATC-pilot communication and a steep authority-gradient in the KLM cockpit (CIAIAC, 1977).

The first CRM program, implemented by United Airlines in 1981, was the first of an eventual five generations. When NTS training has its limitations identified and mitigated, safety will improve in the respective domain. An organisation that enables a dynamic safety evolution process and adapts to changing technology, can promote safe and efficient task performance. The purpose of this essay is to analyse the history of NTS training through analysis of Crew Resource Management (CRM) and Line Operations Safety Audits (LOSA). The current status of CRM will be put into context with examples of adaptation in modern day policy and its parallels in the modern Intensive-Care-Unit environment. Individual adaptability issues and problems with evaluating NTS training outcomes will be explored as potential limitations.

Finally, analysis of its strengths as an exportable product when coupled with a conducive crew-selection program will be undertaken, with future technological challenges considered.
With large demand, militaries worldwide are adopting Unmanned Aerial Systems (UAS). The pilot selection approaches outlined by Damos is required to remain dynamic, as the description of a modern pilot changes, and a steep demand for UAS operators alter how selection and training will be conducted. Services will be forced to rethink their approach to employing people with an appropriate base-level NTS skillset.

crew's lack of recurrent training of CRM, a second generation of the CRM was implemented by Delta Airlines (Byrnes & Black, 1993). This new modular and team-oriented version of training addressed specific aviation concepts related to flight operations (Heilmreich, 1999). The third and fourth generations focused on expanding the context of CRM, and implementing procedure into how airlines award qualifications of CRM training.

The curriculum was extended to encompass skills that pilots could use to analyse the organisational culture, and make assessments on human-factor issues. CRM should exist as an error countermeasure with three lines of defence. The first being avoidance of error, the second being stopping incipient errors taking effect, and the third being mitigating subsequent consequences of an error that has occurred.

Outline the Civil Aviation Authority (UK) Crew Resource Management (CRM) Training: Guidance for Flight Crew, CRM Instructors (CRMIS) and CRM Instructor-Examiners (CRMIES) (2006) is the CRM requirements for modern-day crew in the aviation industry. It makes two notable points, being that, CRM training for flight deck crew is mandatory based on the operator’s syllabus and, that it is a requirement that recurrent training is undertaken at a minimum of once every three years. However, it is not essential to re-cover the entire syllabus in this period.

Threat-and-error-management (TEM) training was implemented by the Civil Aviation Safety Authority (Australia) from 2009 in response to International Civil Aviation Organisation’s (ICAO) lead in TEM training (ATSB, 2009). In the executive summary of an ATSB report on the attitude towards TEM training, it states that “since both threats and error carry the potential to generate undesired aircraft states, the teaching of non-technical or CRM skills, along with expected behaviour policies within airlines that include them, have somewhat successfully addressed the intent of TEM over the past decade—in particular error management” (p.2).

Sates, Burke, Bowers, and Wilson, (2006) explain that the increasing universality of CRM training has led to its incorporation into other areas, including, oil and railroad industries, general transportation and healthcare. Parallels have been made between intensive care units (ICU) and the aviation industry, despite the apparent procedural differences.

ICUs consist of teams that are responsible for shorter lengths of stay, high-quality of care and a lower nursing turnover. CRM aims at improving cognitive and inter-personnel skills, which are critical to ICU performance. The idea of CRM and its focus on threat and error identification as well as early counteracting of human mistakes, fits the criteria that intensive care unit training programs require (Haerkens, 2012).

LOSA: history, application and current status

Line Operations Safety Audits (LOSA) was developed as means of measuring and reporting on the effectiveness of CRM training and the NTS exhibited in an organisation. (Harris, 2011). The Federal Aviation Administration (FAA) defines LOSA as a “proactive measure used to improve safety and enhance performance through peer observation in a non-judgmental environment” (FAA, 2014, p.5). (LOSA) were introduced to commercial aviation in the late 1990s as a result of poor observed safety during day-to-day operations, subsequently putting flight crew at risk.

The audit process screens for both latent and overt lapse of NTS skills by trained observers (Harris, 2011). Kinect (2006) justifies that the implementation of LOSA was caused by over-reliance on reactive measures, which justified the success of safety practises in the absence of accidents.

Both the Harris and Kinect observed that the organisational safety climates are susceptible to normalisation of deviance. LOSA implementation was at the request of Delta airlines in 1994, during which time the company were developing a new CRM course (Kinect, 2006). In collaboration with Continental Airlines in 1996, the first LOSA was undertaken, which measured TEM and NTS proficiency. As a result, an error-management training course was implemented for every pilot at the airline (Kinect, 2006).

LOSA is currently utilised throughout a number of organisations. The US Air Force is introducing LOSA throughout Air Mobility Command (AMC) and the Mobility Air Force Fleet (MAF) on a four to five year rotational basis (Picha, 2016). Additionally, the concept of LOSA has been adapted to Air Dispatch, namely, Dispatch Line Operation Safety Audit (DOSA). The results of a recent DOSA survey at Iran Air identified underlying safety breaches that occurred, and gave the airline a number of recommendations to improve the conduct and safety of their operations (Khoshkia, 2018).

Adaptability and universality of CRM and LOSA

CRM and LOSA’s greatest strength is its adaptability at the organisational level. Implementation of CRM-related NTS training in healthcare and LOSA influenced rollouts in air dispatch, are just two examples that show on the organisational front, that the current state of NTS training has major strengths. Additional research has been done on how CRM training is conceptualised and evaluated for introduction into air traffic control, nuclear power, maritime and gas industries (Hovenga, 2017).

It’s widely accepted in the aviation industry that pilot candidates in multi-crew airline operations require base-level competency in leadership, co-operation and communication (Hoeemann & Goerke, 2014).

Employing the correct type of personnel that have the aptitude to fully grasp the concept of ideas surrounding safety culture and cockpit soft skills, will pave the way for CRM training to take full effect in mitigating human error. Thus, finding the correct type of applicant would act as a CRM training effectiveness multiplier.

Three differing, widely accepted approaches are taken when assessing these soft skills for pilot selection: interviews, questionnaires on personality traits and behavioural-based assessments (Damos, 2014). With large demand, militaries worldwide are adopting Unmanned Aerial Systems (UAS). The pilot-selection approaches outlined by Damos is required to remain dynamic, as the description of a modern pilot changes, and a steep demand for UAS operators alter how selection and training will be conducted. Services will be forced to rethink their approach to employing people with an appropriate base-level NTS skillset (Wiener, 2011).

Limitations: technology and individual tailoring

Limitations are inevitable when implementing a program, or in the case of NTS training, within an organisational population. The argument can be made that CRM is not tailored for every individual and as...
such, potential risks arise. If CRM does not remain dynamic in nature, it risks becoming obsolete (Wiener, 2010).

This extends responsibility to the evaluation cycle in a program’s evolution process. For example, when considering evaluation, the lack of a systematic approach to assessing CRM training will make apparent the difficulties by ensuring crew receive consistent, and adequate NTS training (Sokal, et al, 2001).

Since 1980, the anus has been on organisations to develop and deliver their own CRM training as per the policy of their respective aviation authority. Conducted studies show that CRM training has not been equally effective among all candidates for a number of reasons. (Helmreich et al., 1999; Helmreich & Wilheim, 1995). As found by Helmreich & Wilhelm (1991) personally and character traits were the factors pinpointed and the reason for ineffective training outcomes. The reports suggested that a more universal package was needed within CRM training courses. Heermann and Goerke (2004), through critical analysis, concluded that quiet attitudes existed towards CRM. To overcome the problem, research of CRM limitations made the conclusion that there are several important reasons to include measures of social competence in addition to cognitive tests in employee selection.

The future of CRM training: UAS

As mentioned previously, “human error is ubiquitous and inevitable” (Helmreich, 1999, p.27). The future of CRM will undoubtedly see it become implemented in other industries and domains. As research on CRM progresses within the issue with technological adaptability will need continual addressing.

Future technologies will create new hurdles for CRM research, notably UAS, automation and small jets (Harris, 2011). Weiner (2010) explains the two problems that arise as a result of UAS. Firstly, a loss of sensory cues will be something that always has, and will need addressing (Harris, 2011). Reason (1999), Helmreich (2010) explained that in the future, research and evaluation should proceed in tandem with the implementation of new CRM methods, and that in a globalised modern world, exchange of information will foster a rapid evolution of NTS training.

Conclusion

CRM, LOSA, or any other form of NTS training or evaluation, will never be the answer to eliminating human performance error in any safety domain. CRM doesn’t exist without limitations; however, with correct mitigation of potential training shortfall, CRMs ability to be adaptable allows it to influence change for other industries approach NTS training. When NTS training results are evaluated by an effective LOSA program, a dynamic safety evaluation process can mitigate human error and contribute to safe and efficient task performance.

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Reference
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FATIGUE
How science is influencing understanding and management

By C Baker-Smith

Though the aviation industry has been operating since the 1914, it is only in the past half century that fatigue has been recognized as contributing factor to many accidents and incidents. The issue of insufficient sleep has become significant and yet as common the issue of non-pilots or employees, both in civilian and military environments has resulted in pilots experiencing unpredictable and long work periods that cause a disruption to the human sleep rhythm. Previously the full effects of fatigue have not been appreciated until recent events and studies have called for changes to fatigue countermeasures employed by the industry.

An Australian master practitioner in fatigue management was quoted stating, “we have done all the research needed to properly manage the risks of fatigue in aviation.” Recent studies have resulted in the development of many fatigue-management models to reduce risk. This paper counts this presentation by stating the issues that were associated with the previous fatigue management and modern current methods have been utilised in developing strategies to overcome these issues. Furthermore, it will outline the limitations of these strategies that must be addressed in order to provide current and relevant fatigue risk management systems that are effective applied in the modern aviation industry.

Previous crew rest and duty guidelines:

In the US crew rest in the commercial aviation realm is stipulated by the Federal Aviation Administration (FAA) in the Code of Federal Regulations (CFRs). In this code, flight crews, both augmented and non-augmented, are entitled to a 10-hour rest period prior to duty with non-augmented requiring an additional 10-hour rest period after duty. There are also restrictions to control the maximum flight and duty time over extended periods of time including a week, month and year which are not to exceed 30,100 and 1400 hours respectively (Cardwell et al. 2009). When compared to Australian flight time limitations as stipulated in Civil Aviation Order section 481(4), a crew member’s flight hours are not to exceed 900 in a year. Since there is such a large difference between Australia and the US it can be implied that these values are arbitrary determined and are not based on human physiology. As the complexity of the aviation industry develops, these flight and duty time limitation frameworks (TFL) have been rendered ineffective in managing personnel in an environment that operates continuously. The values in these prescriptive frameworks were one of the first forms of fatigue management, however, due to their restrictive make up they do not take into account recent developments in work policies, technology and research (Cardwell et al. 2003).

It is important that the full effects of circadian disturbances to sleep quality by transition through time zones is appreciated and applied to risk mitigation strategies. Throughout Fatigue Countermeasures research paper (Cardwell et al. 2009), it was identified that both long-and short-haul pilots associated their fatigue to time pressures of all uncomputed duty schedules over consecutive days and the inability to fully

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Fatigue-Risk-Management Systems

Each operation in the aviation industry has its own value of risk that consists of a variety of physiological factors including but not limited to extended duty hours, sleeping or working during opposing circadian times, and transitioning between multiple time zones (IATA, ICAO, IFALPA, 2015). These factors, coupled with specific company or airport constraints, need to be considered if they are to be proper risk management systems. The purpose of this essay was to present a counter argument to the Australian master practitioner in fatigue management and demonstrate the impact research has had on fatigue management. This paper has outlined the significant changes that have been made to risk management in recent years. Risk management is currently in the process of transitioning from prescriptive schedules to performance-based regulatory frameworks in order to adequately manage fatigue despite the high demands of the modern aviation industry. The reason for this shift is to allow operators to tailor their operations in order to provide optimal crew management systems.

As the aviation industry has expanded into continuous operations, previous prescriptive management methods have been proved to be ineffective in managing risk as they lack the application of scientific research. The scientific concepts of sleep and circadian rhythms that underpin FRMS, are the result of decades of research and studies as well as its integration to risk management processes. FRMS have only recently been introduced to civil aviation. Many of these models have limitations in application since population averages are used for prediction and thus, cannot predict risk using an individual’s immediate fatigue levels or personal physiological fatigue factors (CASA, 2017). These models, however, are juvenile and as stated in many research-paper discussions require the incorporation of subtle cumulative factors of fatigue (Beljavic & Spencer, 2004).

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Technology and the decline of cockpit proficiency

By Lauren Finnerty

The introduction of new technologies in the aviation industry has seen a drastic improvement to safety and efficiency but it also introduces new challenges (Funk et al., 1999).

The changing flight deck has changed the way pilots fly, automate and integrate technology in the cockpit. This has resulted in less manual flying by pilots and increased software monitoring (Moriarty, 2015b). This has resulted in a decline in the manual flying skills of modern pilots, a concerning phenomenon that grows as the industry continues to adopt technology to increasingly complex operations (Childs & Spears, 1986; Ebbatson, Harris, Huddlestone, & Sears, 2010; Funk et al., 1999; Hanusch, 2017; Hasbeck & Hoermann, 2016; Pope, 2016).

This essay will investigate this phenomenon from a human-factors perspective by firstly exploring the modern flight deck. Then, potential human factors at play will be identified and ways to mitigate their impacts will be discussed.

Finally, this issue is borne from exponential innovation within the aviation industry, an occurrence likely to continue well into the future. Therefore, the challenges for the next generation of pilots will also be considered.

Cockpits are becoming more advanced and in being so, make it increasingly difficult for pilots to maintain manual flying skills.

Interestingly, Pope (2016) observes the increase in integrated technology in the cockpit and explains that despite it raising the complexity of the workspace it has in fact made his profession as a pilot much easier. Evidently this raises the concern that “(pilots) are becoming too adept at using and managing all the technology at our disposal that our basic armaments skills can degrade; often without us realising to what degree” (Pope, 2016).

This is translating into serious safety concerns as Hasbeck and Hoermann (2016) state that in 26 per cent of commercial aviation accidents analysed by the International Air Transport Association between 2010 and 2014, there was “tangible evidence that manual-flying flight-crew errors were involved”. Safety is critical in the aviation space, even the slightest incursions beyond the safe operating envelope can have disastrous effects for passengers and the wider industry (Stolzer et al., 2011). The decline in manual-flying skills of modern pilots is a concern of the entire aviation industry, pilots, operators, regulators, manufacturers and researchers alike (Ebbatson et al., 2010). However, the conditions in which this issue is born are effectively explored through the application of human-factors research.

Human factors in aviation

“The physical hazards of aviation are well known, but since the dawn of manned flight, human factors have constituted the greatest areas of risk” – Group Captain Rob Lee (Murphy, 2005)

Humans are integral to the aviation systems. We bring to the system inherent advantages and risks. Understanding how humans perform and interact with systems allows for the designing and mitigation for these benefits or risks and has proven effective given the improved safety and efficiency the industry has seen over the past decades (Moriarty, 2015b).

The more we know about human performance the more effective our efforts to facilitate an ‘optimal performance the more effective the industry has seen over the past decades (Moriarty, 2015b).

Potential Causes

Potential Causes

Manual Flight Skill Decline: Potential Causes

Recent studies attribute the decline in manual flying skills among pilots to automation (“CAA PAPER 2004/10 – Flight Crew Reliance on Automation,” 2004; Childs & Spears, 1986; Funk et al., 1999; Hanusch, 2017; Harris, 2003; Hanusch, 2017; Hasbeck & Hoermann, 2016, Moriarty, 2015a). Automation has advanced to the current point where its reliability is almost perfect, and instances of unexpected automation activity are decreasing as we continue to improve the systems (Harris, 2003). Reliability means aircraft are now designed to be flown almost entirely with automation, leaving the pilot to monitor, ensuring the system doesn’t surprise him.
Complacency leads to poor monitoring and according to Moriarty (2015a), humans are already inherently lacking skill of use or practice. The prevalent use of automation in modern flying operations has resulted in widespread instances of opportunities for pilots to exercise their manual flying of the aircraft (Harris, 2011). Although pilots are required to demonstrate their abilities in order to maintain licencing privileges to be tested this is generally required twice a year and this time frame has been proven to be insufficient for skill decay to have effect on manual flying abilities (Childs & Spears, 1986, Hasluck & Hoermann, 2016, Moriarty, 2015a).

Disengaging the system for manual operation introduces levels of risk to operations now seen as unacceptable. Therefore it is generally not permitted (Harris, 2015), Moriarty (2015a) raises that: “If we are to be software managers, we cannot be criticized when we are called on to use our “skills” only to find them degraded by lack of use. If we are to be pilots in the old-fashioned sense of the word, we need to decide when, how and under what conditions we will be allowed to practice our skills, and the industry has to accept that this, in itself, introduces new risk into the system.”

Discusse of manual skills is not the only implication automation has introduced, reliance on automation components can lead to complacency. According to Civil Aviation Authority Paper 2004/00—Flight Crew Reliance on Automation (2004) “Pilots may become complacent in highly reliable automated environments where the role has become supervisory and lacks practice in direct control.” Compliant pilots disengage from the flying operation and situations arise where it is necessary to take manual control of the aircraft they will take longer to react due to lack of situational awareness (Moriarty 2015a). Even the skills of monitoring are susceptible to lack of use.

“Information from instrument scans and the window-scene is inescapable, constant monitoring requires a proper sense of timing of actions which, in turn, requires a clear cognitive pattern of the requirements of an action relate to each other. Such cognitive patterns can be disrupted significantly over time if they are not practiced and reinforced regularly.” (Childs & Spears, 1986)

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Complacency leads to poor monitoring and according to Moriarty (2015a), humans are already inherently lacking skill of use or practice. The prevalent use of automation in modern flying operations has resulted in widespread instances of opportunities for pilots to exercise their manual flying of the aircraft (Harris, 2011). Although pilots are required to demonstrate their abilities in order to maintain licencing privileges to be tested this is generally required twice a year and this time frame has been proven to be insufficient for skill decay to have effect on manual flying abilities (Childs & Spears, 1986, Hasluck & Hoermann, 2016, Moriarty, 2015a).

Disengaging the system for manual operation introduces levels of risk to operations now seen as unacceptable. Therefore it is generally not permitted (Harris, 2015), Moriarty (2015a) raises that: “If we are to be software managers, we cannot be criticized when we are called on to use our “skills” only to find them degraded by lack of use. If we are to be pilots in the old-fashioned sense of the word, we need to decide when, how and under what conditions we will be allowed to practice our skills, and the industry has to accept that this, in itself, introduces new risk into the system.”

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“Over two thousand years ago, Roman orator Cicero cautioned that it is the nature of every man to err”. Throughout the development of society as we know it, this idea has been continued as it is widely accepted among psychologists and philosophers that errors in both human knowledge and conduct are inevitable (O’Donohue & Ferguson, 2003).

Therefore, it is easy to understand why according to Harris (2011, p. 5) “human error is now the primary risk to flight safety with up to 75 per cent of all aircraft accidents now containing a major human-factors component.” Clearly, these findings highlight the requirement for human factors to be considered in all aspects of aviation in order to improve the safety of the industry. One critical aspect of the industry is aviation maintenance, where findings concluded that “aviation maintenance errors account for between 12 and 15 per cent of the global aviation accidents initiators, which rises to 23 per cent when serious incidents are included” (Rashid, Place & Braithwaite, 2012, p. 171). This paper will argue that the integration of human-factors research and interventions into the aviation maintenance domain have improved the safety of aviation. This will be achieved through an analysis of three subjects: human error and risk controls, organisational influences and risk management.

**Context**

Before discussing how human-factors research and interventions have impacted aviation maintenance, it is important to define a number of key terms that will be frequently used throughout the paper. Human factors is defined as the “multidisciplinary field devoted to optimising human performance and reducing human error” (Federal Aviation Administration, 2004, p. 2). Found predominantly in socio-technical systems, human factors incorporates elements such as human physiology, psychology, ergonomics, engineering, medicine and many more. Now that human factors has been defined, a background on aviation maintenance must be established.

Aviation maintenance is defined by the European Aviation Safety Agency (EASA) as “any one or combination of overhaul, repair, inspection, replacement, modification or defect rectification of an aircraft or aircraft component” (European Aviation Safety Agency, 2013, p. 72).

The nature of aviation maintenance results in personnel being subjected to hazardous conditions that are amplified by the mental and psychological pressures that accompany each task (Rashid et al, 2002). These pressures derive from personnel understanding the cost of maintenance errors, which could potentially result in fatal incidents. One clear example is Nigeria Airways Flight 2120 which crashed in 1991 killing 261 people after experiencing an inflight fire (Ranter, 2018).

Subsequent investigations into the crash revealed that before the aircraft was dispatched, aircraft technicians identified a major defect; however, they failed to rectify it (Ranter, 2018). This example highlights the extreme cost of maintenance errors and the essential role aviation maintenance plays in aviation safety. Furthermore, aircraft accidents such as the aforementioned reinforce the requirement of human-factors research and interventions into aviation maintenance in order to improve the safety of aviation.

**Human error and risk controls**

Consequently, there has been significant research conducted by a number of organisations and individuals into identifying and analysing human error within aviation.
Despite this, no comprehensive human error framework existed in the aviation maintenance domain until the Human Factors Analysis and Classification – Maintenance Extension (HFACS-ME) model was developed (Weigmann & Shappell, 2000). HFACS-ME captures latent conditions, active failures and places them into four categories (Weigmann & Shappell, 2000). Located in Figure 1, it can be seen that the HFACS-ME framework is able to "capture human factors induced error causes and facilitate the recognition of absent or defective associated defences" (Rashid et al., 2012, p. 177).

To demonstrate the effectiveness of the HFACS-ME model, a case study will be presented. The US Navy selected 15 NTSB accident investigation reports and used the HFACS-ME model to determine the maintenance errors that caused the incident (Schmidt et al., n.d.). The result was that 55 unsafe acts were identified – 37 per case compared to the average of 2.4 identified in the original reports (Schmidt et al., n.d.). Clearly this demonstrates the effectiveness of the model in identifying potential maintenance errors. Therefore, upon identification of absent defences, risk controls can be implemented to address errors and improve safety.

Risk controls, which fall into two categories, are a human-factors intervention aimed at reducing human error within an organisation (Hobbs, 2008). Preventative risk controls aim to deter the chance of human error occurring from the outset and include training, physical components and engineered solutions (Hobbs, 2008).

Recovery risk controls are designed to reverse the effects of a human error that has been made and include secondary checks, inspections, and procedures (Hobbs, 2008). One key criticism of risk controls is that they differ in their effectiveness, with engineered solutions being the most effective control and self-checking of work being the least effective (Hobbs, 2008). Despite the controls differing in effectiveness, well implemented controls contribute to improving the overall safety of aviation.

With this in mind, it is clear that human-error frameworks and risk analysis tools are contributions of human factors research that have improved the safety of aviation. Organisational influences

Importantly, the aviation maintenance domain now widely accepts that maintenance errors are caused by more than just individual failures at the lowest level. "While acknowledging that maintenance personnel are responsible for their actions, it must be recognised that in many cases, the errors of maintenance technicians are the visible manifestation of problems with roots deep in the organisation" (Hobbs, 2008, p. 7). Evidence of this can be viewed in the Reason Model, as included in Figure 2. The model illustrates that the unsafe acts that result in maintenance errors are often caused because of organisational conditions (ATSB, 2007).

A common criticism of the Reason Model is that, because of its simplistic nature, it fails to provide a comprehensive guide of a maintenance error causation (ATSB, 2007). However, the model wasn’t designed to perform this function and there is still an absence of a subsequent model that meets this description (ATSB, 2007).

Despite this criticism, the model identified the requirement for research to consider the organisational factors of aviation maintenance.

Perhaps the most pertinent organisational factor identified is the requirement for a positive safety culture. Safety culture is defined as "the shared and learned meanings, experiences and interpretations of work and safety...which guides people’s actions towards risk, accidents and prevention" (Atwal & Kingma, 2011, p. 269).

While this definition accurately defines safety culture, it is important to note that a safety culture is generated from the top tiers of an organisation which then filters through the entire workplace (Sumwall, 2011). This is captured in the Ripple Model of safety culture, which was created by Morley and Harris (Harris, 2011).

Located in Figure 3, the Ripple Model identifies "three threads running across people within (and without) an organisation, irrespective of their level and role" (Harris, 2011, p. 284). Concerns, actions and influences make up those three threads with the aim of demonstrating that outside elements vastly influence the safety culture in an aviation maintenance environment (Harris, 2011).

Through utilising the Ripple Model, safety cultures of aviation maintenance organisations and aviation incidents can be analysed. Analysis proves to be a proactive measure that allows for areas of concern to be identified before an incident occurs. Human-factors interventions can then be implemented within an organisation to reduce the risk of an incident, thus improving the safety of aviation.

Risk management

While identification of safety risks and hazards in aviation maintenance is crucial in improving safety, identified risks can still lead to incidents if they are not managed appropriately. Thankfully, human-factors research has revealed tools for effectively managing risk within an organisation. The first tool to be discussed is an error management system that is "based on understanding the nature and extent of error, changing the conditions that induce error, determining behaviours that prevent or mitigate error, and training personnel in their use" (Helmreich, 2000, p. 787).

A number of experts have theorised that one of the key components of error-management systems is generating an environment that can tolerate and contain errors (Reason, 2000).

Without a sufficient error-reporting system in place, aviation maintainers may cover up maintenance errors due to a strong fear of negative consequences that may follow an admission. To illustrate, a 1998 study conducted in Australia focusing on aviation maintenance engineers concluded that "over 60 per cent reported having corrected an error made by another engineer, without documenting their action, to avoid potential disciplinary action against the colleague" (Hobbs, 2008, p. 29). Evidently, there is a significant

Figure 2. The Reason Swiss Cheese Model of Organisational Accidents

Figure 3. The Ripple Model of Safety Culture (Harris, 2011 p. 285)
organisations should ensure they reduce the risk of maintenance error. The result of the course “was delivered to aviation maintenance workers at Continental Airlines (Edkins, 2000). Undoubtedly, the MEDA model is a human-factors intervention tool that enhances error reporting systems, error management and the safety of aviation. This is highlighted by a survey conducted with 237 aviation maintainers in which 58 per cent of respondents indicated that maintenance errors would decrease due to the tool being introduced within the organisation (Rankin, Hibit, Allen & Sargent, 2000).

Additionally, another human-factors intervention that can drastically improve the safety of aviation maintenance is human-factors training. Human-factors training aims to “improve safety in aviation by making states more aware and responsive to the importance of human factors in aviation operations within the provision of practical human factors material” (International Civil Aviation Authority, 1991, p. i). A case study which demonstrates the effectiveness of human factors training is the two-day training course delivered to aviation maintenance workers at Continental Airlines (Edkins, 2002). The result of the course “was a 68 percent reduction in ground damage incidents” over the annual period (Edkins, 2002, p. 26).

Ultimately, error-reporting systems and human factors training are interventions that significantly reduce the risk of maintenance error. Therefore, aviation maintenance organisations should ensure they utilise the aforementioned in order to improve the overall safety of aviation.

Conclusion
Human-factors research and interventions in the aviation maintenance domain have undoubtedly increased the safety of both aviation maintenance, as well as aviation as a whole. Firstly, analysis of human error and risk controls identified that through human error frameworks such as HFACS-ME and the implementation of risk controls, maintenance error could be reduced in organisations, thereby increasing the safety of aviation. Secondly, analysis of organisational influences concluded that through analysing the safety culture of an organisation, areas of concern could be identified and addressed before an incident occurs. Lastly, analysis of risk management illustrated that error reporting systems and human factors training are two effective methods in reducing maintenance error. In conclusion, combining the human-factors interventions identified in this paper with further research of human factors, the aviation industry will be well equipped with the tools necessary to deal with future challenges while simultaneously improving the safety of aviation.

References:
DASM ALB introduced a new training framework to replace the CRM and MFH programs
Key changes include:
A change in terminology from Crew Resource Management (CRM) or Maintenance Human Factors (MHF) to NON-TECHNICAL SKILLS (NTS). The term NTS denotes targeted human-factors training designed to promote reliable and effective performance. It promotes the integration of technical and non-technical training and assessment and recognises that not all Defence aviation personnel work in crew-based environments.
Aviation NTs Trainer Course replaces SAFAC and prepares participants to deliver NTS Foundation and Continuation training.
Aviation NTS Foundation course replaces CRM and will be integrated into all initial employment training for aviation-related training.
Aviation Continuation Training replaces refresher training sessions and consists of targeted scenario-based NTS training packages developed by DFSB. It must be conducted every two years for all aircrew, JABC, AAM, UAS pilots and operators, engineers and maintenance personnel.
"The new framework supports a move beyond classroom-based NTS training to the conduct of skills-based training integrated into the broader training system. There are several evidence-based techniques for assessing performance. DFSB recommends using the Method for Assessing Personnel Performance (MAP) contained in the DASM.
For more information on NTS visit the DFSB intranet homepage.
By Sean O’Sullivan

Captain Sullenberger displayed the effectiveness of non-technical skills (NTS) in an extreme situation, when he safely landed flight 1549 in the Hudson River; he credited his crew’s teamwork and communication to making it possible (Morgan, 2017) (CASA, 2016).

NTS training has been used by the aviation industry for almost 40 years, to assist in reducing the human-factors element in aviation accidents (Helmreich et al., 1999, p. 19).

This paper will discuss NTS and crew resource management (CRM) training, analyse the current status of NTS training, explain the strengths and limitations of NTS training and finally explore its future. It is crucial that NTS training continues to deliver increased safety and efficiency to the aviation industry and is ready to adapt to the future changing environment (O’Conner et al., 2008, p. 354).

Non-technical skills and crew resource management

A variety of complex technical professions including industry, medical and the armed forces, focus on equipping people with the appropriate NTS to reduce risks and workload demands (Crichton et al., 2008). NTS can be referred to as the personal, cognitive and social skills that complement an operator’s technical skills, to achieve safe and efficient task performance (Flin et al., 2003; p. 96) (Crichton et al., 2008). The European Joint Aviation Authorities (JAA) used NTS in reference to CRM skills defining it as “the cognitive and social skills of flight crew members in the cockpit, not directly related to aircraft control, system management and standard operating procedures” (Flin et al., 2003) (Kanki et al., 2010).
CASA (2011) states CRM training has been utilised as the primary method to provide NTS in aviation, however, “many safety related occupations within aviation do not work as crews, the label NAS training has been introduced as a more general and inclusive term for this form of training.”

CRM and NTS training can be considered synonymous, furthermore NTS training is a general term for all training programs in high-reliability industries, designed to improve knowledge and performance in the human dimension of work (CASA, 2011).

Generations of crew resource management

CRM states back to a 1979 National Aeronautics and Space Administration (NASA) conference, which identified communication, decision making and leadership as critical factors in the human-error component of most aviation accidents. The conference resulted in the term cockpit resource management (later changed to crew resource management) being applied to the training of flight crews, maximising human resources on the flight deck to minimise pilot error (Helmreich et al., 1999, p. 19). Helmreich et al. (1999) states CRM has evolved through five generations since it was first targeted in the aviation industry (p. 20-29).

First generation cockpit resource management training programs were influenced by corporate training programs that heavily focussed on managerial effectiveness (Helmreich et al., 1999, p. 20). The courses were psychological in nature with a clear focus on correcting individual behaviour and leadership styles (Harms, 2011, p. 258b). Pilot attitudes and communication skills were targeted examples included improving the assertiveness of junior pilots and the authoritarian behaviour of captains (Harms, 2011, p. 258b) (Helmreich et al., 1999, p. 20). Annual CRM training became part of pilot-training programs; however, many programs encountered resistance, being accused of manipulating personalities (Helmreich et al., 1999, p. 21). In 1986, second generation crew resource management focussed on cockpit group dynamics (Helmreich et al., 1999, p. 21). Training programs focused on teamwork, decision making, situational awareness and stress management (Harms, 2011, p. 258).

Although CRM training was still largely unrelated to aviation in its demonstration of concepts, trainee acceptance was significantly improved (Helmreich et al., 1999, p. 21). When crew training correlated with the aviation systems in which they operated in the 1990s, third-generation CRM evolved. A clear focus was made on supplying aircrew with specific skills and behaviours, improving efficiency, while integrating CRM with technical training. While this generation of CRM provided many benefits by extending CRM to encompass all personal within-aviation, such as pilots, flight attendants and maintainers, it lost focus on its original objective to reduce human error (Helmreich et al., 1999, p. 212).

The fourth generation of CRM was initiated by the Federal Aviation Administration (FAA) forcing flight crews to be trained in CRM and making airlines integrate CRM concepts into technical training (Helmreich et al., 1999, p. 22-23). United States airlines added specific behaviours based on CRM concepts to their checklists. Helmreich et al. (1999) stated that this generation of CRM solved “the problems of human error by making CRM an integral part of all flight operations and training” (p. 23).

A culture change throughout the aviation industry where CRM emphasises error management to minimise inevitable human error, is proposed as the fifth generation of CRM (Harms, 2011, p. 258) (Helmreich et al., 1999, p. 28-29).

The current status of non-technical skills training

In the aviation industry, CRM programs are the primary means of training NTS for cockpit, cabin, dispatch and maintenance crews (Kanki et al., 2010, p.182). According to CASA (2011), Jensen (1997, p.265) and Kanki et al. (2010, p.182) CRM training provides flight crews with a variety of NTS as displayed in Table 1.

<table>
<thead>
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<tr>
<td>Aeronautical decision making</td>
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<td>Conflict resolution</td>
<td>Management of:</td>
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<td>Leadership</td>
<td>Automation</td>
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Table 1. Three categories of NTS

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By targeting the operator’s NTS, CRM training becomes significantly improved, while improving their ability to identify issues (Crichton et al., 2008, p. 1). CRM courses are heavily regulated at the international level, allowing aviation to keep the change in NTS training. CASA has provided CAAP SMS-XTI and the Civil Aviation Authority (CAA)’s has published Civil Aviation Publication 737, mandating course requirements (CASA, 2011) (CAA, 2016).

CRM training is usually taught through a combination of lectures, role playing, case studies and cockpit simulator exercises (O’Connor et al., 2008, p. 354). Initial CRM training has a duration of up to three days, while refresher courses only require half a day (O’Connor et al., 2008, p. 354). Many airlines utilise Line Orientated Flight Training (LOFT) sessions to allow personnel to implement and practice using NTS (Harms, 2011, p. 262). LOFT sessions are usually conducted in flight simulators, allowing the entire crew to train together and respond to various inflight problems. Instructors overview the training exercise, recording information on how the aircraft and the technical aspects were handled, and how the human dimension was employed to address problems (Harms, 2011, p. 262).

The training effectiveness of a LOFT exercise relies on appropriate training-flight scenarios and the debrief; for maximum benefit, it requires discussion on crew performance covering both positive and negative aspects (Harms, 2011, p. 263). To improve the effectiveness of learning, two briefings occur prior to the exercise, the first explaining the objectives and purpose, while the second is the normal brief explaining the operational context (Harms, 2011, p. 263). These factors assist the crew in understanding the operational context of the exercise, adding to in the reality of the simulation. Technical failures have been found to be most commonly associated with NTS problems (Kanki et al., 2010, p.185). The NOTECHS (Non-Technical Skills) framework was developed by the JAA to assess CRM skills across four primary criteria: co-operation, leadership & managerial skills, situational awareness, and decision making (Harms, 2011, p.258). The framework relies heavily on the examiner “detecting and recording behavioural markers, which indicate the presence or absence of particular NTS” (Moirarty, 2015, p. B). An individual cannot fail a simulation or LOFT exercise purely on NTS deficiencies, as it needs to be associated with a technical skill
**Table 1. Popular types of tools and techniques used to identify important non-technical skills**

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tbody>
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**Figure 1. The NOTECHS framework utilises five principles to maintain fairness and reliability**

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<tr>
<td><strong>Event-based analyses</strong> (examining safety reports to identify patterns)</td>
<td>• accident incident analysis in own’s or similar operations&lt;br&gt;• conflicts of information reporting systems</td>
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<td><strong>Questioning techniques</strong> (gathering information directly from workers)</td>
<td>• interviews: structured, unstructured and semi-structured&lt;br&gt;• focus groups&lt;br&gt;• questionnaires and surveys</td>
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- **Principle 2** NTS are associated with technical skills, thus requiring flight safety to be jeopardised for NTS to fail.

- **Principle 3** Repetition of an unacceptable behaviour must be observed in order to conclude it is a significant problem.

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transitional from knowledge-based training programs to skills-based training, ensuring a wide range of NTS behaviors that contribute to effective crew performance are delivered (CASA 2011) (Tofteklef & Kottanpary, 2017, p. 1).

Finally it is recommended CRM training is delivered during the earliest stages of flight training, to ensure NTS and the concepts of crew co-operation are instilled in all aircrew.

Conclusion

It is critical that NTS training continues to deliver increased safety and efficiency to the aviation industry. Various studies have proven that NTS training delivers satisfactory results for participants with large success.

The majority of personnel who undertake current NTS training deem the training as significantly useful. Future NTS training will need to overcome its limitations, particularly cultural and research limitations and adapt training to the increased modernisation of the industry; specifically human factor problems caused by automation:

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<tr>
<td>• communications processes and decision behaviour</td>
<td>• human behaviour</td>
<td>• human error and reliability error, chain error, chain prevention and detection</td>
</tr>
<tr>
<td>• briefings</td>
<td>• human performance limitations</td>
<td>• company safety culture, standard operating procedures, organisational factors</td>
</tr>
<tr>
<td>• safety, security</td>
<td>• communication</td>
<td>• stress, stress management, fatigue and vigilance</td>
</tr>
<tr>
<td>• inquiry/advisory/assertion</td>
<td>• threat and error management</td>
<td>• information acquisition and processing, situation awareness, work load management</td>
</tr>
<tr>
<td>• crew self-critique (decisions and actions)</td>
<td>• leadership/fellowship</td>
<td>• decision-making</td>
</tr>
<tr>
<td>• conflict resolution</td>
<td>• team co-ordination</td>
<td>• communication and co-ordination inside and outside the cockpit</td>
</tr>
<tr>
<td>• communication and decision-making</td>
<td>• situation awareness</td>
<td>• leadership and team behaviour synergy</td>
</tr>
<tr>
<td>• team-building and maintenance</td>
<td>• judgement and decision making</td>
<td>• automation (for type of aircraft)</td>
</tr>
<tr>
<td>• leadership/fellowship/concern for task</td>
<td>• stress management and fatigue management</td>
<td>• case-based studies</td>
</tr>
<tr>
<td>• interpersonal relationship/group climate</td>
<td>• workload management and automation</td>
<td></td>
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<tr>
<td>• workload management and situation awareness</td>
<td>• mission analysis and planning</td>
<td></td>
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<tr>
<td>• individual factors/reduction</td>
<td>• mission briefing and debriefing</td>
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<tr>
<td>• organisational and safety culture</td>
<td>• organisational and safety culture</td>
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</table>

Table 2. Recommended non-technical skills training topics for three aviation agencies

**About the Author**

Sean O’Sullivan is studying a Bachelor of Science at UNSW ADFA, majoring in aviation and geography. Sean has a passion for aviation and aspire for a career in rotary-wing aircraft. Sean enjoys surfing, four wheel driving and travelling.

Reference


**Course Description:** The course provides theoretical background of aviation non-technical skills and trains students in the skills and knowledge for delivering non-technical skills training. The course also introduces students to scenario-based training and assessment techniques.

**Course Aim:** To graduate students with the knowledge and skills to deliver non-technical skills training.

**Prerequisites:** A solid background in Crew/Maintenance Resource Management and/or Human Factors.

**Course Description:** The course provides the theoretical background of aviation non-technical skills and trains students in the skills and knowledge for delivering non-technical skills training. The course also introduces students to scenario-based training and assessment techniques.

**Course Aim:** To graduate students with the knowledge and skills to deliver non-technical skills training.

**Prerequisites:** Person who are required to perform the duties of an ASO.

**Course Description:** The course provides theory and practical exercises in the broad topics of the Defence Aviation Safety Management System, human factors, risk management, and baseline emergency response. Includes participation in a practical emergency response component.

**Course Aim:** To develop members with the skills to conduct aviation incident (level) investigations in support of their ASOs.

**Prerequisites:** Any personnel who are involved with Defence aviation. There is no restriction on rank, defence civilians and contractor staff are also welcome to attend.

**Course Description:** This one-day course provides theory (taken from the ASO course) on the topics of the Defence Aviation Safety Management System, generative safety culture, error and violation, the Defence Aviation Safety Analysis Model, aviation safety event investigation and reporting. Interested personnel should contact their ASO.

**Course Aim:** To graduate Unit ASOs, Flight Crew and Flight Sensor Maintainance Sailors.

**Prerequisites:** Person who are required to perform the duties of an ASO.

**Course Description:** The course provides theory and practical exercises in the broad topics of the Defence Aviation Safety Management System, human factors, risk management, and baseline emergency response. Includes participation in a practical emergency response component.

**Course Aim:** To develop members with the skills to conduct aviation incident (level) investigations in support of their ASOs.

**Prerequisites:** Any personnel who are involved with Defence aviation. There is no restriction on rank, defence civilians and contractor staff are also welcome to attend.

**Course Description:** The course provides the theoretical background of aviation non-technical skills and trains students in the skills and knowledge for delivering non-technical skills training. The course also introduces students to scenario-based training and assessment techniques.
Dangerous goods are a risk to health, safety, property or the environment. These include obvious things, such as: explosives, radioactive materials, flammable liquids, dangerous or volatile chemicals, strong acids, compressed gases, poisons and aerosols. Everyday items that can cause problems include toiletries, aerosols, tools and lithium batteries. **REMEMBER – IF IN DOUBT, ASK!**