5-2019

The Changing Face of Airmanship and Safety Culture Operating Unmanned Aircraft Systems

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Scholarly Commons Citation
Lamb, T. (2019). The Changing Face of Airmanship and Safety Culture Operating Unmanned Aircraft Systems. *Unmanned Aerial Vehicles in Civilian Logistics and Supply Chain Management,* ().
https://doi.org/10.4018/978-1-5225-7900-7.ch009

Chapter 9
The Changing Face of Airmanship and Safety Culture Operating Unmanned Aircraft Systems

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ABSTRACT

The notion of using drones for commercial purposes has evolved in the past 5 years from the initial "boom" of excitement around this, somewhat of a novelty and curiosity, to more calculated and sophisticated use of unmanned aircraft systems (UAS), or drones. In the hands of true professionals, drones can offer highly efficient and profitable solutions for industrial, and commercial inspections and other data capturing tasks. The appetite for safe and efficient collection of data is a changing face of safety cultures and how teams and individuals apply airmanship principles, and how inspection crew and UAS crew interact. UAS are no longer viewed as novelty or useful addition to the inspectors' "toolbox," but as an integrated part of safety critical system. While there is much to be learned from tradition manned aviation, UAS pilots are confronted with different task priorities in order to effectively "aviate," and therefore, like the changing face of airmanship and safety culture, to "aviate" emerges has having different attributes when compared to manned aviation.

DOI: 10.4018/978-1-5225-7900-7.ch009

THE COMMERCIAL DRONE BOOM OF 2013-2018: ITS VICTORIES AND CHALLENGES

Much of the small commercial Unmanned Aerial System (UAS) industry emerged out of the industrial inspection, information technology, photogrammetric survey, 'big data', and technical industry. However, some had their origins in the hobby and 'modellers' area. The emerging applications of small commercial UAS started to increase in prevalence in the public media following Federal Aviation Administration (FAA)'s approval of first commercial UAS flights over land in 2014 (FAA, 2014). The novel use of UAS has rapidly advanced to a variety of industry sectors around the world, and today, in 2018, the FAA has just recorded over 600,000 commercial UAS operators licensed under Code of Federal Regulations (CFR) Part 107, in the United States alone (Elwell, 2017).

Back in 2013, as awareness increased about the innovative uses, and benefits of using small UAS in practical applications, the commercial organizations became highly motivated to focus their attention on learning and capturing this novel and cost-effective way to bring value to their customers, to capture images of their assets, and more importantly, not to miss out on what appeared to be a competitive edge. The Association for Unmanned Vehicle Systems International (AUVSI)'s economic report of 2013 predicted that the small commercial UAS industry would be cumulatively worth USD 1.8 billion, between 2015-2015 (Jenkins & Vasigh, 2013). Today, in 2018, we recognize that those predictions were not conservative, considering the latest studies (e.g., Grand View Research, 2016) indicate that the small commercial UAS industry is expected to reach USD 2.07 billion by 2022.

In many cases prior to 2017, the procurement of small commercial UAS or 'drone' was not formal management or organisational decision, the *C-suite* was generally not informed of the acquisition of the 'drone', as it was viewed as another relatively low cost '*tool*' or solution for day-to-day operations.

Specialised inspection personnel who recognized the value in the data collection ability viewed the UAS as something that would add value a capability to their tool box, usually after learning and reading about the latest technological advancements through blogs, social media, technical papers, and other industry peers to achieve efficient and effective completion of allocated tasks (Lamb, 2017).

The rapid advancement of UAS technology, including supportive platforms, software, First Person View (FPV), and other gadgets to improve performance, quickly became the focus of technical discussions and field stories[1], among the professional community of inspectors. For these professionals, working in industries that rely on data monitoring and imagery to determine the condition of their high-value infrastructure and physical assets such as oil, gas, mining, utilities, rail and road. For these organizations and their stakeholders, the return on investment in utilizing the UAS was obvious. However, the benefits of using this new technology came with follow-on implications and considerations that were yet to be discovered. Some of the questions that needed to be addressed relating to topics include: Standards, certification, training, liability, safety and risk management integration. In the absence of formal processes, protocols, regulations and standards for this new industry, organizations did their best by improvising what was required (Lamb, 2017).

Even today, in 2018, the small commercial drone industry presents a relatively low barrier to entry as UAS platforms are considerably less expensive than a conventional commercial aircraft in terms of initial capital investment and the operating costs. Also, the qualifications and approvals required to pilot a small commercial UAS are easy to obtain. In the United States, there are currently no pilot competency assessments required to gain a small commercial UAS license under Federal Aviation Regulation (FAR) Part 107 (FAA, 2018b).

This low barrier to entry makes it an attractive opportunity for organizations to gain the benefits of UAS. In terms of the diversity in UAS's design, capabilities and their applications, this has led to the dynamic growth in the ubiquitous utilization of UAS (e.g., Palmer & Clothier, 2013; Weibel & Hansman, 2005)

It is not only the United States that is experiencing this tremendous adoption of UAS into the commercial industry. According to Statista (2018), the estimated spending on UAS in US Dollars for financial years between 2017 and 2021 in the top five countries are:

- 17.5 Billion in the United States;
- 4.5 Billion in China;
- 3.9 Billion in Russia;
- 3.5 Billion in the United Kingdom; and,
- 3.1 Billion in Australia

While both the evolution and proliferation of commercial Unmanned Aerial Vehicles (UAVs) is evident there are growing concerns with their use. These concerns include, but not limited to, the combination of lack of training in the operations and technical expertise such as; understanding the control interface complexities, data processing, programming, security issues with transferring and storing and interpretation, and being able to meet the client expectations or requirements from that data. More importantly, having in-depth understandings of the safety and operational requirements of complex environments owned by the client's industry (e.g., mine site, off-shore rig, chemical plant, cell tower, wind turbine, complex power network) are all key considerations for the success of a UAS service provider.

The majority of the small commercial UAS platforms used today have some basic safety mechanisms embedded within their systems to facilitate the operators to use the UAS safely, such a return to land function, or an altitude limiter. However, these safety mechanisms are not required by legislation or standardized by any manufacturer, and frequently not fully understood by the operators (Plioutsias, Karanikas, & Chatzimihildidou, 2018). With the release of the FAA Reauthorization, Bill 302, in October 2018, there are provisions within this that direct small UAS to be equipped with some of the components that support the safety of flight capabilities as part of the certification process (USA Congress, 2018).

With no provision for remote pilot flight competency, training or assessment provided within legislation, a well-balanced and harmonised merger of safety cultures and safety behaviours remain challenges for both the operator and the organisation. Despite this, most small commercial UAS platforms promote the benefits of using '*off the shelf*' equipment, such as an iPad or computer as they are "easy to use". However, the human-induced errors or '*human factors*' remain a major contributor to small UAS mishaps and safety incidents (Lamb, 2018).

The use of an iPad, iPhone or other familiar devices such as a laptop computer should support UAS operations by providing a familiar platform, however; safety incidences involving small drones is increasing (Flatley, 2017). The propensity for human errors increases in complex activities, especially when interacting with new and complex technology such as the interaction required to operate a drone remotely from a computer, iPad or control station (Mouloua, Gilson, Kring, & Hancock, 2001).

This industry challenge is further exacerbated by the fact that there are currently no requirements for flight competency assessments within the regulatory framework. Neil and Griffin (2002) argued that leadership is a critical driver to have a positive impact on safety behaviors in terms of safety compliance and safety participation, at this juncture, there is no leadership in the industry on competency-based training standards or regulatory flight assessment standards. This has a twofold effect where the former refers to individuals performing core activities while maintaining workplace safety while the latter refers to individuals developing an environment that supports safety (Neil & Griffin, 2002). Therefore; safety leadership must be driven and supported by the leaders in the UAS industry and organizations who support the use of UAS in their day-to-day operations, must support, champion and drive a proactive safety culture that integrates drones (Helmerich & Merritt, 2001).

THE CHALLENGES OF INTEGRATING SAFETY CULTURES AND MERGING NEW TECHNOLOGIES

Despite the considerable benefits in utilising UAS, there are significant integration factors that must be considered when using UAS in commercial applications. Research (e.g., Gawron, 1998, as cited in McCarley & Wickens, 2006), has found that having the human separated from machine produces different human performance and risk factors that attract a multitude of potential hazards when compared to conventional aviation. However, there are considerable challenges from the human integration perspective as well as the introduction of small commercial UAS as a cultural shift, both at the organizational level and the personal safety level was postulated (Helmerich & Merritt, 2001; Lamb, 2017).

Another part of the challenge is recognising the falsehood of the inaccurate aggregate risk value, promulgated by the 'probability' factor, that potential hazards associated with small commercial UAS are viewed as '*low risk*', because chances of the UAS causing major damage or loss is low. This perception is largely due to the weakness in the use of the standard Risk Assessment Matrix although the standard risk matrix is widely used and highly promoted and recommended by aviation regulators worldwide (ICAO, 2012).

Two main limitations of the standard risk matrix; the first lies within the human factor realm, this limitation is subjectivity, especially when assessing the 'Low Probability' (LP), and 'High Consequence' (HC), risks (Robinsons & Francis, 2014). The second; the specialized training, or lack thereof, provided to the front-line staff who use this commonly applied tool (Peace, 2017). Most users of the risk matrix estimate the probability factor of a catastrophic event caused by the UAS being extremely rare (*total risk value = probability x consequence).* This is an estimation based on the subjective perspective or frame of reference to the safety representative of the operation.

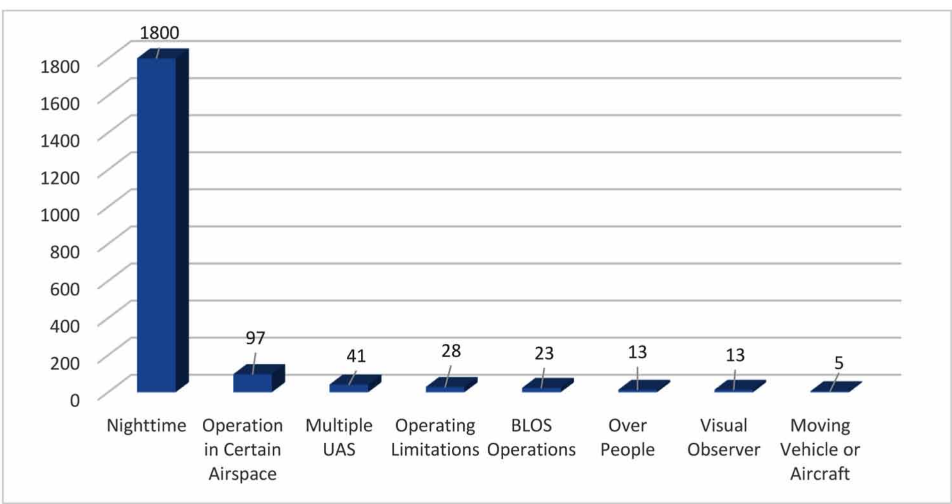
While the aviation regulators direct operators to consider residual risks and support safety assurance (closed loop systems), the risk matrix as a standalone tool does not direct, or remind the operator to report back into their system or consider additional or residual risks, or confirm the accuracy of their initial aggregate risk values. Therefore; the risk matrix itself as a tool "*…when used with front line staff, who are not properly trained, performs like an open loop system*" (Stolzer, Halford, & Goglia, 2013, pp. 156-168). Therefore, small commercial UAS operators often miss this critical function that is implied but not indicated on a standard risk matrix.

Research has shown that mishap rates involving UAS are up to 300 times greater than that of conventionally piloted aircraft fleets in general aviation (Carrigan, Long, Cummings, & Duffner, 2008) and UAS operations in military is no exception (Williams, 2004), which is surprising if you consider the amount of training that military crew receive compared to that of small commercial UAS pilots. Therefore, this trend of ubiquitous mishap rates should be further investigated given the unprecedented growth in the utilisation of UAS across many industries.

It is not only private commercial organizations that have become captivated by this emerging UAS technology, government and public safety agencies began embracing the potential benefits of using drones as early as 2005 when drones were used to search for survivors of Hurricane Katrina (NSF, n.d.). Implementation and coordination of UAS in public safety are now viewed as a matter of paramount urgency given the increases in natural event occurrences such as flooding, fire and severe storms. The national emergencies in the USA associated with hurricanes and floods in 2017 and 2018 increased the use of designated public safety UAS to an all-time high with the FAA issuing over 300 special flight permits called 'waivers', in response to the demand for UAS search and rescue capabilities, and has since issued over 2500 waivers (Figure 1) to commercial UAS operators (FAA, 2018b).

Humans play a vital and centric role in UAS operations. Research has indicated that this role is more complex than conventional aviation and safety critical activities such as commercial infrastructure inspections, testing and data collection. For instance, McCarley and Wickens (2004) identified that an Unmanned Aerial Vehicle (UAV) operator performed duties "in relative sensory isolation" due to the absence of various sensory cues such as vestibular input and ambient noise (p. 1). As the UAS industry is growing exponentially and UAS operators have become more prevalent in commercial aerospace, safety behaviours, safety culture and the concept of being able to 'Aviate' are evolving.

Figure 1. Waiver types granted to operators
Adapted from AUVSI, 2018. (https://www.auvsi.org/our-impact/waivers-under-part-107-interactive-report)



To '*Aviate*': We Used to Know What That Meant

According to Oxford dictionary (2018), 'Aviate', is defined as "*to pilot or fly an aircraft*". Similarly, the FAA defines 'Aviate' as 'maintaining control of the aircraft' (FAA, 2018a; Hobbs & Lyall, 2016). Based on currently accepted aviation and general definitions to a pilot, 'Aviate' refers to pilots' priority to 'fly the aircraft' and this specifically addresses the pilots' performance tasks of maintaining control and keeping the aircraft in a safe state prior to addressing other tasks of navigating or communicating. Many pilots recite this commonly used phrase; *"Aviate, Navigate, Communicate"* (A-N-C), as a reminder of priorities the pilot-in-command follows particularly in an emergency or non-normal situation.

1. **Aviate**: Maintain control of the aircraft
2. **Navigate**: Know where you are and where you intend to go
3. **Communicate**: Let someone know your plans and needs

It may be assumed that the common definition of 'maintaining control of the aircraft' could easily be transferred to the unmanned aircraft system, except that the techniques and modes of how that is achieved are radically different to a conventionally manned aircraft. In a UAS operation, operators are required to consider numerous factors including; command control (C^2 Link)[2] latency, or interruptions, limited ability to "see and avoid", absence of sensory feedback of aircraft state, and control station configuration that may not relate to conventional pilot task actions. All of these factors directly or indirectly affect the task of controlling the aircraft and maintaining it in a stable powered state.

According to a NASA report (Hobbs & Lyall, 2016), most current designs of advanced Remotely Piloted Aircraft System (RPAS) rely entirely on automated systems for basic flight control and they do not provide options for pilot manual control. Instead, the remote pilot is responsible for supervisory control of the automation. Consequently, manual flight control becomes less of an issue for the remote pilot making automation management issues of critical importance. However, unmanned aircraft systems present unique challenges to effective Human System Integration (HIS), and the various levels of automation may affect the pilot of a remotely piloted aircraft's ability to control the aircraft on certain tasks. Some aircraft systems are on the higher level of automation, to the extent that they approach 'autonomous', the level at which the pilot is excluded from determining and actioning the task, effectively removing and/or limiting the pilot from some of the flight process (Parasuraman & Wickens, 2008).

A pilot of a conventional aircraft can lose almost all on board functions (navigation, communication, even flight control and propulsion) and the pilot may still be able to 'Aviate' or control the aircraft to a safe or safer outcome than a crash (examples include 'Captain Sully Sullenberger landing his crippled Airbus on the Hudson River, the Glimi Glider). Not having those human minds on board the aircraft presents challenges. Clearly, there is a barrier, an interface that sometimes does not support the indirect control 'connections' of the system, as witnessed in examples of this in a high percentage of human factors in remotely piloted aircraft incidents (Tvaryanas, Thompson, & Constable, 2006). Remote pilots' ability to continue to perform the traditional tasks designated as 'Aviate' may be completely removed due to the failure of the C^2 link. Depending on the level of automation, this may occur at a much lower threshold in some UAS platforms, compared to others.

For instance, a complete C2 link failure may remove the operators' ability to Aviate, navigate and communicate all at once, even though the aircraft may continue to maintain stable powered flight. This is referred to as the 'lost link flight profile' where the aircraft flies for a pre-determined time on predetermined programmed flight planning inputs. In this situation, operators are expected to organise backup or alternatives systems or 'capture' methods. Alternatively, the operators may orchestrate the emergency procedures. These potential actions do not fit to a conventional definition of 'Aviate'. Therefore, if the term 'Aviate' is to be used in the context of he remote pilot in control, being responsible for controlling the unmanned aircraft, it must be clear on both its definition and contextual elements to ensure that the correct meaning and intent is incorporated appropriately and accurately in ICAO documents, with a particular focus on new proposed Standards And Recommended Practices (SARPs) for RPAS operations. This is a topic that is currently being discussed among industry experts.

From Figure 2, you may notice that when controlling the aircraft sensory and perception differences have an influence, and there are also environmental and network quality and latency that may also affect the pilot's ability to Aviate effectively in the traditional sense. The Pilot's commands and the aircraft messages relayed back to the control station may suffer degraded C^2 influences; variable lengths of time delay (latency); distortion, interference, switching faults or failure. Any one of these faults with the C2 link will affect a pilot's response time and effective control.

There has been research to explore the issues of the pilot's ability to Aviate at differing levels of automation. An illustration of how the different automated tasks affect a pilot's ability to Aviate is presented in Figure 3 (Hobbs & Lyall, 2016). This figure provides a model of the unique pilot performance tasks that are required to maintain or regain control of the UAS. This high-level model of the responsibilities of the remote pilot, consistent with FAA assumptions, adapted from Mutuel, Wargo and DiFelici (2015).

In addition to varying levels of automation, the layout and displays of the control stations can differ greatly that results in the presentation of ergonomic and cognitive

Figure 2. ICAO RPAS Panel Concept of Operations. The blue indicates the remote pilot activity of Aviate
(Diagram reproduced courtesy of ICAO)

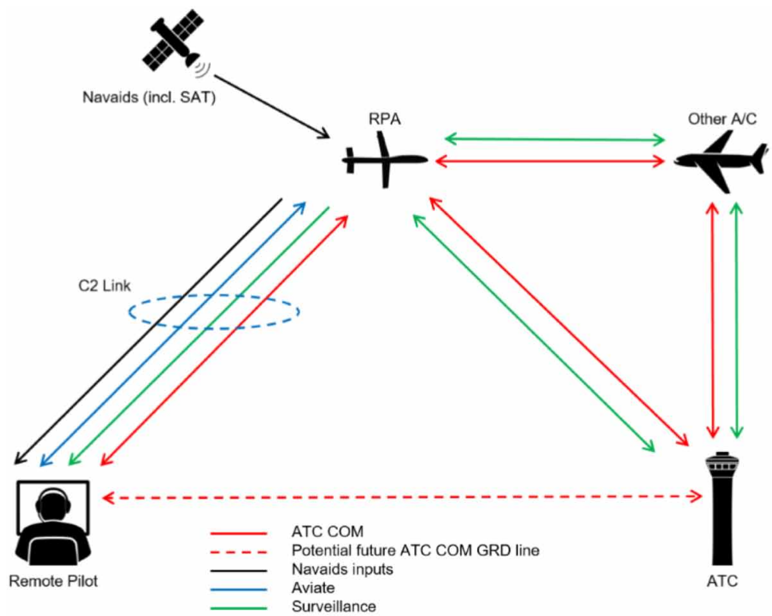
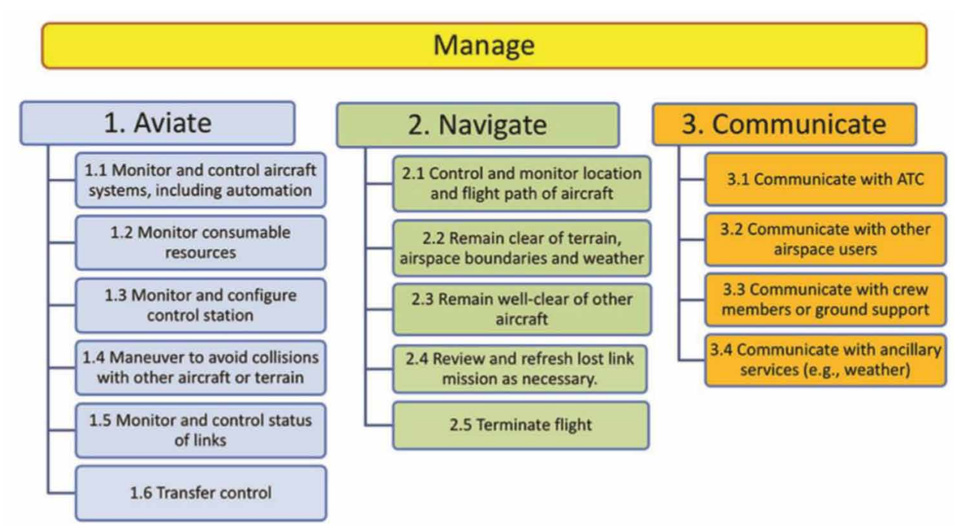


Figure 3. Responsibilities of remote pilots when operating RPAS
Source: adapted from Hobbs and Lyall (2016, p. 18).



challenges for the remote pilot. A pilot of a conventional aircraft can lose almost all on board functions; navigation, communication, even flight control and propulsion, and may still be able to control the aircraft to a safe or safer outcome than a crash. Examples of the human's ability to Aviate include; 'Capt Sully Sullenberger who controlled his Airbus when both engines failed, on the Hudson River New York City.

With UAS becoming increasingly automated and as we move towards some components of the UAS utilizing machine learning algorithms, deterministic and non-deterministic [autonomous] neural networks, one must question, the boundaries that define human's ability to Aviate and the capability for human resilience to be replaced. It is a complex question with deep implications, *who is responsible for what?*

The ability to safely pilot an aircraft remotely is the foundational premise of the ICAO's, Remotely Piloted Aircraft, Concept of Operations document. This document is the operational reference that the RPAS panel follows to develop the SARPs that will evenly be codified into legislation by the 192 contracting states [countries] who are under the 'Chicago Convention'. At present, with regards to piloting the aircraft safely, it is mentioned throughout the document and continually referred to in the current 'draft SARPs' due to be incorporated into state legislation by 2023. The SARPs have been written with the directive assumption (assumption 8), that '*the remote pilot must be competent, licensed and capable to discharge the responsibility for safe flight'*.[3]

There are also implications on the safety assurance processes connected to safety flying the RPAS to mitigate undesirable events such as mid-air collisions or injury to people and damage to property on the ground[4]. Section; 2.6.2 of the ICAO RPAS CONOPS states that all system designs must ensure that the responsibility and liability for safe operation are retained by the operator and their flight crew (ICAO, 2017). Remote pilots must be able to override or modify automated functions, except where such actions cannot be executed safely due to the immediacy of the situation (e.g., an imminent collision avoidance manoeuvre) or where task complexity makes human intervention unreasonable. This guiding principal indicates a clear responsibility of the remote pilot to be able to firstly safety operate the aircraft, the word operates, and fly is used interchangeably in the context of controlling the aircraft. The CONOPS section 4.5.3 mentions in-flight handover between Remote Pilot Stations (RPS) that there are considerations during handovers that need clarifications as to what constitutes the remote pilot in commands ability and obligation to Aviate (ICAO, 2017). The section states; '*In either case, the safe and effective handover of piloting control from one station to another must be assured'*.[5]

Safety Culture and the Challenges for UAS Operators

Turner, Pidgeon, Blockley and Toft (1989) defined safety culture as "the set of beliefs, norms, attitudes, roles, and social and technical practices within an organisation which is concerned with minimising exposure of employees, managers, customers, suppliers and members of the general public to conditions considered to be dangerous or injurious" (p. 4). Simply put, it is a type of relationship that an organisation has with safety (Helmreich, 1998; Helmerich & Merritt, 2001).

The concepts of safety culture highlight a dynamic and multifaceted nature of humans and their behaviour, especially within the workplace or organization framework. Safety-related behaviour includes, but is not limited to, dynamic interfaces between psychological and organisational factors within the organisation, and occurs at different levels, from the individual to the collective, and pervading from top management. It has been described that safety culture as a composite and dynamic term, wherein the two components, safety and culture, can be defined independently depending on individual perspective. In reality, safety culture is a dynamic configuration of factors interacting on multiple levels within an organisation that influence and measurably determine total safety performance (Helmreich, 1998; Reason, 1990) The safety culture of an organization will directly impact safety performance of the organization.

The term safety culture first appeared in a report in the aftermath of the 1986 Chernobyl disaster (Cooper, 2000), where the errors and violations of operating procedures that contributed to the accident were identified by some experts as being evidence of a 'poor safety culture', (Salas & Maurino, 2010, p. 97). Historically, safety culture has been developed as a result of incidents and accidents. This is what is described as a reactive safety culture' (ICAO, 2012) whereby past accidents and mishaps escalated the evolution of safety policy and practices. Research findings (e.g., Stolzer, Halford, & Goglia, 2013; Helmreich & Merritt, 2001; Helmreich, 1988) suggested the importance of having, at the very least, a 'proactive' approach of safety management. From there, drive towards a predictive approach to safety, involving not just studying past statistics but shaping safety behaviours of the people within the system through developing, adopting and improving the safety policies, procedures and values over time.

Bethune and Huler (1998) added to this concept of safety culture stating that it could take organisations up to 10 years to achieve notable positive changes in behaviours. Hudson (2001) expanded that it was necessary to further develop organisational cultures that supported higher processes such as 'thinking the unthinkable' and being intrinsically motivated to be safe even when there seemed no obvious reason to do this. If having a strong positive, predictive safety culture takes a long time to evolve, where does that leave the exponentially growing vulnerable commercial UAS industry?

Safety culture is not an abstract concept. Components of safety culture can be developed, implemented and improved upon and thus, it is often termed a part of a 'living system'. Cooper (2000) added that the establishment and enhancement of a safety culture relied on the deliberate and targeted manipulation of various organisational characteristics potentially impacting safety management practices. Alternatively, safety culture can start, for instance, with one committed individual and filter through the whole organisation as it can and has been used as a motivating tool for the organisation, ultimately leading to achieving its safety goals. It is recognized that the most influential individual to drive an organization's safety culture is the top-level management, an accountable executive, who is usually the Chief Operating Officer (CEO) of the organization (ICAO, 2012).

Organizations that engage in safety critical activities are often called 'High-Reliability Organisations' (HROs) (Helmerich & Merritt, 2001; Reason, 1990). Examples of HROs' are: nuclear power plants, industrial installations, offshore installations, mine sites, rail organisations, wind farms, aviation and aerospace organisations, and medical facilities such as the emergency departments in hospitals.

HROs are acutely aware of and pay particular attention to their safety cultures as safety culture is a lead indication of safety performance (Helmreich & Merritt, 2001). As the benefits of using UAS are becoming widely accepted, commercial UAS operations are integrated with these HRO industries, and therefore; bring 'outside' influences into the established HRO safety culture (Lamb, 2017). Companies that achieve safety and efficiency in HROs share a common practice. Their safety systems and protocols are the critical focus, forming an integral part of '*how they do business',* in order to ensure a safe, efficient, healthy and productive workplace. Generally, HROs are highly dependent and technology centric, including software, data analytics, navigation technology and new composite hardware such as robotics and now, with the increase in small UAS platform, readily available 'Off The Shelf Solutions' (OTSS).

Once an organisation has decided to replace some of their traditional way of performing certain operations such as site inspection with small commercial UAS capability, there are usually enthusiastic discussions around the benefits of capturing data and imagery with UAS capability, and the tremendous financial benefits that are attached to that for stakeholders. Occupational Health and Safety (OH&S) managers are also enthusiastic about utilizing small commercial UAS, realising considerable 'safety savings', by not exposing their personnel to; working on ropes, scaffolding, at heights or in dangerous, potentially toxic or combustible environments.

However, there is a significant truism that must be raised—*people love gadgets*—especially gadgets that are innovative, fun and novel, and especially in industries that are technical in nature such as the HROs. There is a novelty factor with the introduction of a commercial UAS into an operation, and this factor has been an influence in more than one commercial drone mishap[6].

Introducing a small UAS into an inspection operation can entice curiosity, unintentional (and intentional) non-compliance, excitement and distraction. There is also a misconception that safety risks are extremely low or eliminated by using a UAS. However, this potentially introduces new latent risk producing conditions within the operation, particularly in unfamiliar areas. The danger with these latent conditions is twofold. The potential hazards are hidden within the systems, and the UAS crew and other company safety personnel are also in direct contact with the operation. Integration of the roles and responsibilities of UAS crew with the host team and establishment of how they will work together is a key enabler of UAS safety culture. This highlights the importance of practising non-technical skills in UAS operation such as effective communication.

Communication is one of the complex factors that affect safety at the crew level and the organisational level for both the UAS crew and the host organisation in HROs. Communication modes in UAS also utilise many and varied mediums including verbal, digital, and visual modes. Often verbal communication is augmented by digital channels such as Data-link (Ashdown & Cummings, 2007), VHF communication radio, walkie talkies, mobile phones, and Wi-Fi communications via laptop computers.

Effective communication has a significant impact on how safety culture, policy, procedures and checklists are executed. Effective communication is the essential social element on which a positive safety culture is established and sustained. Effective communication not only facilitates an effective team culture but enables the tone of the safety culture within complex systems. Research (e.g., Calhoun, 2006; Foltz, Martin, Cooke, Kiekel & Gorman, 2003) identified that it was fundamental to have a clear understanding of and to subsequently facilitate crew communication across all phases of a UAS flight for a generic safety culture to be established and maintained.

Communication challenges that are unique to UAS include crews that are geographically dispersed rather than co-located. According to Mouloua (2003), these challenges were primarily the results of time delay issues with satellite and data-link relays, lack of real-time feedback of control responses and interference or distortion of images and data. An awareness of the potential for errors in communications is essential when evaluating the potential risks in the UAS operation. A study conducted by Barshi and Farris (2013) based on analysis of more than 12,000 aviation incident reports from NASA's Aviation Safety Reporting System (ASRS) revealed that over 73% contained evidence of a problem in the transfer of information.

The commercial UAS crew and the host organisation will each have their unique method and style of communication, and there may also be differences in acronyms, terminologies and, often, very different phraseologies. What one phrase or acronym means to the host organisation may have a very different meaning to the UAS crew; CRM can mean 'Customer Relationship Management, or 'Crew Resource Management, and these two are very different concepts. In addition, communication methods, contents and styles often vary according to the operational type and environmental considerations. Smaller teams tend to communicate directly with each other which is commonly described as 'horizontal communication', whereas organisations with a number of teams controlled by a hierarchical structure, such as in many HROs tend to follow more 'vertical communication' style. An example includes the hierarchical vertical communication structure of the front lines workers, up to the foreman, the site manager, director of Health, Safety and Environmental (HSE), then Vice President (VP) of HSE, with communication being formal, structured and not in 'real time', whereas UAS crew tend to communicate horizontally and directly, usually in 'real time' with headphones via direct LTG network (phone) connections. Often UAS crews are smaller in numbers and include the higher level operational crew, who operate within a utilitarian corporate structure.

Research has identified that the most effective teams in complex control environments will engage in 'horizontal' communication of their shared mental models of the situation to ensure task affectivity (e.g., Cooke et al., 2007; Waller, Gupta & Giambastista, 2004). Waller et al. (2004) found that the most effective communication was usually between teams operating on the same level, rather than from a higher or lower hierarchical level and this suggested that the commercial UAS crew and the host organisation must work together to achieve the shared mental model and safety values prior to working together in the HRO to achieve effective safety policy, culture and behaviours. Cooke et al. (2007) concurred that although each member might understandably be attuned to different aspects of the same event, particularly an event in a complex team environment, team members were encouraged to share this information in order for the system to be coordinated.

Commercial UAS teams must be supported and integrated within the host organisation's culture, at both the top level (policy and procedures) and the same level of functional teams with which they will directly interact. This integration will facilitate effective communication that may support generative safety behaviours, especially when considering emergency response plans and roles in an emergency and unexpected situation.

The success of the emerging UAS industry will be determined by the willingness and ability of UAS crew and the end users to employ aviation safety philosophies, disciplines and the proven aviation safety culture model. The UAS industry needs more than a compliance philosophy to be successful (Lamb, 2017). A positive commitment to developing a UAS safety culture is paramount, and the core foundation of this is a widely accepted philosophy and framework of behaviours called Airmanship. The application of this type of safety culture to be adopted and integrated into the commercial UAV industry will lead to creating a new generation of Airmanship for a new generation of aviation.

Airmanship: Where Did It Come From and Where Is It Going?

The aviation safety culture is founded on collective principles called *'Airmanship'*. Kern (1997) described airmanship as an uncompromising discipline developed through systematic skill acquisition and continuing proficiency. The International Civil Aviation Organisation defines 'Airmanship' as… "*the consistent use of good judgement and well-developed knowledge, skills and attitudes to accomplish flight objectives*" (ICAO, 2011, P. 1-1). The principles of airmanship are indoctrinated to the potential aviator from the moment they step through the door of their flight training organisation and continues through every step of every day of their career. Implementation of the principles of Airmanship has provided consistent positive safety outcomes for these industries and forms an integral part of their brand of safety culture.

The airmanship model consists of bedrock principles, five pillars of knowledge and capstone outcomes. The five pillars are (Kern, 1997):

- Know yourself;
- Know your aircraft (UAS in this chapter);
- Know your team;
- Know your environment; and,
- Know your risk

The above pillars of knowledge require good aviators to draw on multiple knowledge bases (Kern, 1997). For instance, every commercial aviation organisation has its own '*brand*' of safety culture which defines their unique relationship with safety and what may differentiate them from other organisations. When experienced flight instructors and captains transfer to a new aviation organisation, indoctrinating them into that particular organisation's *'brand'* of safety culture and systems is of paramount importance and one of the essential 'onboarding' elements. This 'onboarding' or induction into an organisation's safety culture is an essential component in the airmanship knowledge pillar of 'knowing your team'.

Airmanship focuses on the conduct and attributes of the individual, their professionalism, skill, discipline, knowledge base and decision-making ability. This is an important concept to consider within the commercial UAS operation. However, while presented in the context of the individual, the principals of Airmanship can and should be applied to the greater team (i.e., all the crew involved in the UAS operation). This is of importance when it is considered that one of the key ingredients to the success of a UAS operation is having clearly defined roles and responsibilities as part of an effective safety management system (ICAO, 2012).

Airmanship is applicable to every team member and the role played by everyone within the UAS team. The performance of each team member contributes to the total system performance at any given part of the operation. For instance, when the UAS team leaders (e.g., remote pilot in command and managers) apply the principles of airmanship at the micro level (e.g., pre-flight task analysis, flight and task planning) right through to product delivery, the collective result achieves higher safety standards, greater efficiency and value in the end products (i.e., deliverables).

The level of professionalism of the UAS operator is often reflected in the deliverables. Deliverables are usually in a form of data such as images, measurements, items, frequency counts, or other detectable and quantifiable objectives. High quality and efficient service delivery include; safe execution of the operation, accurate data acquisition, processing, and storage. In many cases, interpretation and presentation of those data into relevance and 'value' to the end user is all a by-product of the level of professionalism of the UAS operator. The practice of airmanship principals, by each member of a UAS, will yield tangible benefits in customer satisfaction, safety and the long-term sustainability and reliability of UAS enabled services.

Dedicated Roles and the UAS Operation

Wickens (2007) described commercial UAS operations in HROs as a complex system requiring operators to be responsible for multiple tasks. Understandably, a UAS operator involved in a large commercial UAS operation has their role divided between navigation, flight control, communication, system monitoring, target or defect inspection, and mission management. On the other hand, in the case of the smaller commercial UAS operation conducting, for instance, inspection tasks in a complex environment, a UAS team may consist of only one or two crew members, giving a false impression that they are 'self-contained' or 'self-sufficient'. The host organisation may have the impression that providing the UAS team with the 'standard contractor' briefing before leaving them to work is an adequate safety procedure. However, research (e.g., van Breda, 1995) has shown that assigning all tasks to a single operator has been found to substantially degrade the operator's performance. Therefore, it is important to integrate and involve the UAS crew into the organisation's safety and operational team so that all crew have designated roles and a shared mental model of the operation, including what to do in the event of an emergency or 'non- normal' situation. To highlight the dangers of not providing the environment for UAS crew to interact with other onsite crew, consider the following real examples;

Example 1: During an operational safety audit of a commercial UAS HRO, it was found that the flight task had to be abruptly aborted due to an immediate safety issue. The flight activity of the contracted commercial UAS crew had not been communicated, nor had any action been taken to integrate the UAS operation or its crew into the host organisation's site. The incident caused a major distraction to the host organisation's work area and created the potential for several serious accidents. While no injuries or damage occurred, the cost was incurred due to supply interruption, lost productivity, potential OH&S injuries, and delay in data collection and processing all of which represented two weeks of lost revenue for the host organisation.

Example 2: During an operational safety audit of a commercial UAS operation, on behalf of the host organization, it was found that during one of the flight tasks, one of the site workers accidentally 'ran over' part of the UAS equipment. The driver of the vehicle was unaware of the parameters of the operational (launch and recovery) area of the UAS crew and was distracted by the UAS activity. The damage to the equipment was substantial and had to be replaced. This also meant that the UAS surveillance activity had to cease until new equipment was acquired.

There are a number of procedures involved in commercial UAS operations. One of them is a '*hand over*', also known as a '*transfer of control*' which is described as the role and responsibilities of one crew member (the remote pilot(s)or members of the UAS team) are transferred to another remote pilot(s) or UAS crew members. Such a procedure is a deceptively complex task that may occur at the change of shift during the flight or ground operations. These handovers can be a time of increased exposure to risks, especially those risks associated with system mode errors and coordination breakdowns. Hobbs and Lyall (2016) found that there had been cases of inadvertent transfer of control between remote pilot control stations, due to controls set in error. One of the most cited cases that highlight crew co-ordination factors that lead to a mishap is the crash of the United States Department of Defence, Predator B aircraft in Nogales. The causal factors cited in the accident were; human factors, organizational failures, system design and integration (Carrigan, 2008).

Safety in UAS can only be attained if defined and specialised roles are developed with specific training procedures and philosophies, including precision system-based processes for crew changes and shift handovers (AAIF, 2011). Successful UAS crews appear to be evolving to embrace traditional safety procedures and practices that have proven efficient and increased safety in aviation, medicine and other safety-critical operations handovers. The use of precise and appropriate checklists, methodical preparation of both human and material assets is now identified as critical to reduce errors. The power of scenario-based training (simulation) has also proven to reduce handover error in many industries (Flynn, 2008) and UAS operations will yield the same safety benefits if quality scenario-based training is employed.

CONCLUSION

As we drive towards harmonious integration of UAS into both our lower and upper airspace, we face a considerable number of new challenges. Of these challenges, human performance and human systems integration pose the greatest threats to seamless integration. Not surprisingly, the closer to earth (especially below 400ft above ground level), the more challenges arise for UAS integration, the complexities of package delivery, urban mobility and a new Unmanned Traffic Management System (UTM) and these provide not only logistical challenges but safety, certification and training challenges. To achieve this harmonious integration of man, machine, air traffic systems and commercial industry, we must begin at the foundational level, the human operator.

The interaction between human roles and responsibilities, between the technology components, the software, the platforms, and the UTM must be interoperable and harmonised if the system is to be safe and effective. Consider that this is not only at the local area but on a global scale. Achieving this harmonisation will be reliant on the strength of a robust, appropriate safety culture, applied airmanship principles, training, education and certification. Humans will remain the key component to the success of unmanned aviation even as the automation levels continue to increase towards the highest levels of automation, and arguably higher into the levels of non-deterministic system intelligence (autonomy].

Integrating a commercial drone operation into an existing organisation's safety management system and safety culture can provide many challenges on various operational levels. There are human factors challenges, policy and procedural challenges, logistical challenges, possibly financial challenges and the challenge of managing change and expectations. To successfully cope with these challenges and integrate drones into your organisation, the solution may be found by starting at the individual level, educating and cultivating the *Airmanship* principles. This may also have the added benefits of impowering individuals to assist in building the new safety culture.

It is important to understand that safety culture exists in some form or another in any given organisation. For instance, it could be reactive, proactive, punitive, generative, bureaucratic, and predictive. Even the lack of an organised safety culture indicates the organisations' relationship with safety, and usually, it is the key personnel who are responsible for implementing and cultivating the safety behaviours and attitudes of the organization.

Safety cultures can and do evolve unintentionally, usually as a result of drifting away from a disciplined approach to safety, towards the easier, cheaper or faster way of operating. Unintentional safety cultures are usually the by-product of some of the following factors; misalignment of senior management with safety protocols, lack of appropriately qualified safety leader, missing safety oversight and or accountability, deficient regulatory framework, a 'blame culture', lack of education, lack of resources, lack of safety information sharing (and much more).

Many of the aforementioned factors are contributing to the industry culture that is being experienced now, especially in the small commercial UAS industry, operators are protective about disclosing the nature of their mishaps, safety data, contributing factors, and any corrective measures implemented in a highly competitive industry are often viewed as a competitive edge. This is a very different culture to that of manned aviation. Therefore, we must accept this difference and work with these concerns and challenges to unite the industry under common safety interests. With many countries still grappling with UAS legislation, some small commercial UAS operators have little professional industry support or guidance, unlike the traditional aviation community or model aircraft culture. This is a time where regulators and industries in all countries can and must work together to find the solutions to safety challenges.

The success of the emerging commercial UAS industry will be determined by the willingness and ability of organisations to adopt not only conventional aviation safety philosophies and disciplines but work together to develop a specific UAS safety philosophy, supported by Safety Management System (SMS) and Quality Management System (QMS) principals, cultivate UAS safety Culture at the individual level. This UAS safety philosophy will be successful if it embraces and supports the unique challenges of integrating professional UAS crews and their equipment into our national airspace, society and operational environments.

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ENDNOTES

1 Pilots refer to this as '*Hangar talk*'.

2 The C^2 link is defined as the communications, *command and control* link to the remotely piloted aircraft. It is usually the only direct link between the remote pilot's ability to control the aircraft. The C^2 link is able to be provided for via several mediums; satellite, WIFI, telecommunications networks.

3 ICAO RPAS Concept of OperationS (CONOPS) (March 2017), page 5.

4 ICAO RPAS CONOPS (March 2017) page 22.

5 ICAO RPAS CONOPS (March 2017) page 19.

6 During 3 years as an ISO accredited QMS and Safety auditor, 3 separate incident reports indicated that distraction of workers due to 'watching' a UAS conduct its mission, occurred. One incident resulted in a vehicle colliding with the UAS crew launch equipment. 2014-2016 Australia.