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UAS Aviation Safety Rigour - A Comparative Analysis of Triton Vs Shadow-200

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Abstract

Uncrewed Aircraft Systems (UAS) such as the MQ-4C Triton and the RQ-7B Shadow-200 Tactical Uncrewed Aircraft System (TUAS) each utilise unique approaches to aviation safety. This presents new challenges to both regulators and operators. Whilst each UAS is unique and presents different safety challenges, the fundamentals of UAS safety do not vary simply as a function of the complexity or size of the UAS. This paper compares and considers the drivers for aviation safety effort and rigour between a large UAS like Triton versus smaller UAS such as Shadow-200. To that end, the safety case of both Triton and Shadow-200 will be examined. In doing so, it will be shown that the UAS platforms can have similar levels of aviation safety rigour applied to them. As it stands, Triton and Shadow-200 make use of different risk-based approaches. These approaches are explained and analysed with a view to highlight key differences and argue that despite the scale of each system, a common approach is not only possible, but necessary. This paper will leverage UNCLASSIFIED aviation safety material from the Triton and Shadow-200 programs as prime source material and provide broader insight into the activities that support UAS operations in the ADF. The paper will also consider the differences in the configuration, role and environment (CRE) for the platforms and will highlight the main differences and similarities that support the aviation safety activities.

Keywords: UAS, Safety, Triton, Shadow-200, Uncrewed, Aviation, Risk

Disclaimer

The views, opinions and conclusions drawn from this paper are those of the Authors and do not represent the views of the Australian Defence Force or the Defence Aviation Safety Authority. This paper aims to provide a discussion on the way uncrewed aviation safety is conducted.

Introduction

The operation of Uncrewed Aircraft Systems (UAS) has become vital to modern military operations and other civilian sectors, such as mining, farming, media to name a few. These platforms may be seen as human replacement machines; however, they are introducing new and enhanced operational capabilities than previously realised. Such capabilities include; food and package delivery, intelligence gathering and monitoring, maintenance checks on buildings and on aircraft structures and even providing reconnaissance support to emergency services [1]. The recent war in Ukraine has shown the world the importance of using UAS technology in the theatre of war. Both Russian and Ukrainian forces are using this technology to gather intelligence on troops, deliver small and large munitions, guide troops to where to attack the

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opposition [2]. UAS can also reduce the casualties and threats to pilots and combat crews who often would have been used to perform intelligence-gathering activities and would have also been sent out to locations were the enemy may possess more territory. In short, they have become the human on the ground and in the air [1-3].

The reliability and accuracy of UAS technology has greatly increased since their initial use in World War I [3]. There has been an increase in the amount of research and development of these technologies over the past decades. The technological inclusions in these UAS are exceptional. Organisations are developing systems that are fully autonomous, systems that are operated by AI and systems that can be operated on a one-to-many basis [4-5]. Though most UAS can be operated autonomously it is currently considered that there is still need for a human in the loop in their operations to provide a high level of safety assurance.

Designers and operators of these systems need to assure regulators, users, the general population and other airspace users of safety when operating these systems. This is why it is important for the various regulators to set up regulations that are consistent and with set criteria in which these UAS should be operated safely. However, it is to be understood that not all UAS are designed to a specific standard and that most of them have niche characteristics that support their use, which causes challenges for regulators when operators want to bring such systems into service. Most regulatory authorities have adopted risk-based approaches to assist operators in bringing their systems into service. These risk-based approaches ensure safety is at the centre of all operations and that risks to users, general public and other airspace users is reduced So Far As Reasonably Practicable (SFARP).

This paper compares the fundamental level of aviation safety that has been applied to the MQ-4C Triton, coming into Australian service in 2024, and the RQ-7B Shadow-200, a mature system in Australian service for over a decade [5]. These two platforms are military operated UAS, and their mission operations are unique in comparison to other uncrewed systems. Though they have unique operational capability the aviation safety rigour that goes into bringing these UAS into service should not vary in magnitude solely as a result of system complexity. The work presented here will look at the UAS regulations, discuss the configuration, role and environment of the two platforms, and discuss the aviation safety approaches for UAS and any risk methods used to assess them.

UAS Regulations

The two aviation regulators in Australia are the Civil Aviation Safety Authority (CASA) and the Defence Aviation Safety Authority (DASA) [6-7]. They have both developed UAS regulations that guide operators as to how they can operate their RPAS safely without imposing harm to the other airspace and ground users. These regulations at the time of writing this paper are still maturing in the way they regulate and integrate the use of UAS platforms especially those still in development like Triton, MQ-28A Ghost Bat and future platforms that are yet to be developed.

Triton and Shadow-200 operate under the defence aviation safety regulations (DASRs), which has the three categories of Certified, Specific and Open category UAS [6]. Each of these categories aligns with CASA and relevant international and military standards on UAS operations such as STANAG-4671. As they will be military owned and operated UAS, the two platforms are categorised under the Specific category of the DASRs and not under CASA who regulate civilian aircraft. Thus, Triton and Shadow-200 will operate under a DASA

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issued UAS Operating Permit (UASOP). The Specific category applies to platforms that have airworthiness standards that applied from initial, continuing to operational airworthiness [6].

Under the Specific category, the UAS have specific restrictions applied to them in order to minimize the risk SFARP on operations. There is specific compliance criteria set out by DASA that should be implemented by UAS operators who wish to operate under a UASOP [6]. Operations under a UASOP have limitations to the classes of airspace in which users may operate UAS. UASOP users fly predominantly in restricted airspace around military locations and any flights in other classes of and over civil airspace require approval from the airspace regulator or other approving authorities. The UASOP application process is outlined by DASA, and it is a risk-based approach that aligns with the 7-Step Safety Risk Management Process [6].

Configuration, Role and Environment Comparison and UAS Function

Shadow-200 by Textron Systems is a tactical uncrewed aircraft system (TUAS) with the ability to provide intelligence, surveillance, target acquisition and reconnaissance (ISTAR) capabilities [11]. The TUAS is also used as a training platform for RPAS operators, mission crew and combat soldiers who need it in the battlefield [11]. It has the capability to operate up to 125km from the UAS operator. This TUAS is designed to provide users with accurate information on activities occurring on the ground in near real-time [9]. Shadow-200 has high-resolution cameras that operate both day and night and can distinguish between a range of tactical vehicles operating on the ground from an altitude of 8000ft and at 3.5km slant range [12]. For an aircraft of its size, Shadow-200 has an endurance of over 8 hours depending on the flight profile and mission objective [12]. Australian operations of Shadow-200 are mainly on military installations, training areas and other restricted airspaces; though, there are instances where it might be flown over sparsely populated areas. One such area was in Afghanistan where Shadow-200 was deployed to replace the missions that the Scan Eagle conducted on behalf the International Security Assistance Force (ISAF) [13]. For such operations, where Shadow-200 is operated over a civilian population, there is usually an assessment of the risk involved from the surrounding infrastructure and airspace and approval is sought from the relevant approving authority to allow flight or missions over high-risk areas. Shadow-200 has a launch system that utilises a pneumatic catapult and recovery system as part of the ground capability [12]. The launcher allows Shadow-200 to be a mobile system that can be deployed to any environment within its operational limits. This provides the users with enhanced capability on the battlefield and in training environments.

The MQ-4C Triton UAS by Northrop Grumman Corporation is a high-altitude long endurance (HALE) aircraft that will be operated by the RAAF for maritime patrol and surveillance. This UAS is equipped with modern real-time ISR capabilities that will support long endurance missions that are over 24 hours operated by the RAAF [13]. The long endurance capability will provide the ADF with excellent Maritime surveillance coverage and the ability to carry out simultaneous and continuous missions over a period. The main areas of operations will be in the North, Southwest Pacific and down to Antarctica [14]. The aircraft has an operational ceiling of up to 50,000ft and has a sensor suite that operates over 2000 Nautical Miles, which then produces a 360-degree view of the surroundings [15]. In Australia, the Triton RPAS will be flown out of RAAF Base Tindal and operated remotely from RAAF Base Edinburgh in Adelaide [15]. The flights out of Tindal reduce the risk SFARP of the UAS as it will fly over less populous areas of Australia. The mission risk for every operation is calculated based on the risk methods that each UAS platform adopts and the operators informed knowledge of the mission or flight profile.

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Though both these platforms have varied capabilities and complexities they both have the same basic function of being uncrewed, they are operated by remote pilots located at a specific ground station and they both have the ability to conduct ISR missions.

Risk and Safety Methods

Modern aviation works under a set of assumptions, regulations and legislation to assure safety of crewed and uncrewed aircraft operations [6-7]. One of the fundamental requirements in relation to safety for non-type certified Defence UAS is that risks are eliminated or reduced SFARP [6]. As non-type certified UAS (e.g. Triton and Shadow-200) may not undergo the same level of technical design rigour as certified conventionally piloted aircraft, it is critical to utilise robust risk and safety methods to assess uncrewed aircraft operations. These UAS system safety assessments focus on ground, air and critical infrastructure risk. The risk and safety methods can broadly be categorised into two methodologies: quantitative and qualitative. These system safety methods are used to assess the safety risk of UAS operations based on the CRE, which can be communicated to the relevant decision makers.

Quantitative methods will characterise the risk of UAS operations to people (ground and air) and critical infrastructure [18]. To characterise the ground and air risk effectively, the first step is to gain an understanding of the reliability of the platform to inform human and autonomous decision-making [19-20]. The reliability information then feeds into the risk calculations – including (i) the reachability of the air vehicle in a degraded or failed states [21]; (ii) essential personnel, general public and critical infrastructure distributions [22-23]; (iii) and risk quantification [24-25]. A similar approach can be used for air risk by characterising the airspace density [26] and quantifying the risk of mid-air collisions [27-28].

The limitations of the above quantitative methods are the requirement for significant data or utilising complex uncertainty quantification methods when there is low confidence in the data. In situations where the data is not available, qualitative methods can support the safety case for UAS operations [29-30]. In general, a combination of the quantitative and qualitative methods are used to develop a robust safety case for complex UAS operations. Indeed, both Shadow-200 and Triton are complex UAS, which utilise both qualitative and quantitative risk assessment methods to support a robust safety case.

Discussion of UAS Safety Rigour and Approach

When it comes to uncrewed aircraft safety, every national regulator applies different emphasis on the level of safety that is required. However, for commercial aircraft operations there is a need to comply with ICAO’s international policies on safety and to ensure that safe aircraft operations are being carried out worldwide and that they meet a certain standard [32-33]. In the uncrewed environment, safety is still of importance; however, the various regulatory bodies have different approaches to assessing the level of safety and rigour that should be applied to UAS [33-34]. For uncrewed systems very little data has been collected on incident or accident reports, fleet management and other data measures that would be gathered for crewed aircraft to generate mathematical models that can be applied to all uncrewed systems and establish quantitative data for UAS safety [33]. However, it is still worthwhile to note that models have been suggested in literature and some have been used for other platforms. To date, there has not been a consistent quantitative method that meets all the UAS platform requirements. Some of these include tools like the Quantitative Approach and Departure Risk

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Assessment (QUADRA) adopted by USN; and the JARUS SORA which has been adopted by CASA when applying for specific operational use that poses different risks [7, 30].

Due to this varied nature of safety analysis, it forces safety authorities in acquisition and design to ask the question "how far should they go when conducting safety analysis for their systems?" Triton and Shadow-200 are unique in the way of their operation, and they provide unique UAS safety perspectives and challenges. However, for Triton's unique design, and operational procedure it provides authorities with a level of assurance on how safe it will be to operate this UAS once it is in service [35-36]. There have only been a few Triton incidents that have been reported, with the main one being caused by a landing gear failure and an inflight mechanical issue that caused it to crash on a Naval base in California [35]. However, Shadow-200 has experienced more crashes during its use in Afghanistan and when being operated by other nations [36-37]. The mature use of Shadow-200 over the years has enabled a greater body of data to be collected on crash incidents compared to Triton, a UAS which is yet to be introduced into Australian Service.

In Australia Triton and Shadow-200 operate in restricted and controlled airspace away from the general population as per their CRE and UASOP limitation. This alters the amount of aviation safety rigour that must be applied to both platforms and it reduces the risks associated with plat platforms crashing over a higher population density. Since both platforms followed the UASOP approval process, the operators and safety authorities would have identified risks and hazards associated with the platforms for various flight configurations and potential mission profiles. These identified risks and hazards advise and inform the risk management systems that are set up for operators when operating the UAS on various missions. This will ensure any known operational and aircraft related risks are reduced before operation.

According to the defence aviation safety regulations (DASR) both Triton and Shadow-200 do not meet the requirements for military type certification [6]. As such, they both need to apply for a Specific Type A category UAS Operating Permit UASOP to fly and carry out mission essential requirements on behalf of the ADF [6]. The UASOP application process and assessments that accompany them will vary in effort as a result of complexity of the system, but they should follow the same phases of the application set out by DASA. However, it should be noted that they both have unique operational requirements and that the levels of risk that they assume are not similar. This is when the variation in aviation safety rigour is seen to differ. Both platforms adopted different safety strategies to satisfy the UASOP application requirements and these strategies are detailed below.

The Triton safety strategy and the level of rigour applied are based on the risk posed by Triton as a large, long range UAS, its cost and complexity, and the approach taken by the USN in approving its operation. As Triton will operate under a UASOP, the safety strategy is based around risk assessment rather than certification against a defined set of requirements. However, in order to leverage the USN airworthiness program and provide defensible argument for the comprehensiveness of the risk assessment, an Airworthiness Criteria Set (ACS) has been developed. The ACS is analogous to a Type Certification Basis in defining criteria that represent best practice in uncrewed system design, but these are used as references rather than strict requirements. Shortfalls against these requirements result in potential hazards which can then be assessed and mitigated to ensure that all risks have been thoroughly identified and reduced SFARP. The outputs of the USN's comprehensive safety program are considered in conjunction with the ACS assessment to develop a comprehensive risk picture for Triton operations. This risk picture is communicated using the bow tie structure described

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in DASA AC 001/2018, providing a consistent framework for assessment and communication of residual risk [38].

For Shadow-200, the safety strategy utilised various mathematical models to calculate the levels of safety risk imposed by the design of the UAS and the exposed population. When Shadow-200 was introduced to service, Defence was still operating under the Technical Airworthiness regulations (TAREGS) that imposed a Safety Target approach to the technical safety evaluation process for UAS [25]. This allowed Shadow-200 to be evaluated under an aviation safety rigour that had an emphasis on an acceptable safety target that they could work to satisfy the probable risks that would be involved. This target would also encompass the various design and operational consideration needed to carry out a mission from a specific area [25]. This method of having safety targets enables UAS operators to assume a certain level of risk when conducting missions. However, this level of risk needs to be defined to ensure the UAS designs can meet the risk standards in operation.

Conclusion

It is evident that for UAS certification and aviation safety procedures there is still a need for standardisation. The regulators, operators and designers need to continually develop these regulations and UAS standards to ensure there is consistent aviation safety efforts being carried out across the uncrewed industry. In a military context it is understood that most platforms have distinct operational needs and having regulations and standards that are consistent allows the military to secure more platforms that satisfy the needs of many users.

The level of complexity of a UAS affects the risks the systems pose to operators, and this is true for both Triton and Shadow-200. The regulations they operate under also influence the rigour of aviation safety in line with the associated risk posed by the UAS. The two UAS presented here, both follow the same fundamental approach to aviation safety as presented by DASA when they apply for the UASOP. However, the risk methods used to establish UAS safety baselines for platforms will differ in effort, but they ought to provide similar level of rigour in application to assure risks are SFARP.

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